

LEAVING ELEMENTARY SCHOOL WITH A SENSE OF ORDER IN NATURE (SLCSP 136)

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Abstract

Ninth graders in Arizona high schools have just left their elementary, general science education and are at the start of more specialized secondary science education. They are beginning a course of study that will form the foundation for tertiary education and employment after high school graduation. The research asked, Who are these kids entering high school science courses? The researchers noted that one of the key objectives of elementary education is to foster in children the concept that nature is inherently orderly and thus amenable to scientific investigation. Since the concept of order or disorder is fundamental in one's perception of reality, the researchers reasoned that the qualitative worldview interviews on nature would be revealing of these concepts. The research led to this assertion: After nine years of schooling, ninth graders show no consistent understanding of the order in nature on which science is predicated. Instead, students often "name drop" school science topics such as the ozone layer, rain forests, or the big bang theory.

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Background

The World Is Understandable. Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study. Scientists believe that through the use of the intellect, and with the aid of instruments that extend the senses, people can discover patterns in all of nature. (Science for all Americans)

The purpose of science education, however, is not just to memorize a few scientific concepts, but to learn something of the nature of scientific thought that leads to a scientific conceptualization of nature. In part that requires some understanding of the critical and foundational attributes of nature. Salient among those is the attribute of order. There is in nature an order manifested by patterns and regularities accessible by scientific investigation. Patterns in nature are what science investigates. Thus one assumes that understanding the basic orderliness of nature is both a goal for elementary science education and a foundation for further study.

It is possible, however, that students learn facts about natural phenomena without thinking very much about the foundation upon which that knowledge rests. Everyone has some knowledge about the natural world. Students will know that it does not rain unless there are clouds in the sky. Or, that it does not snow unless the air temperature drops sufficiently low. For example, a student in biology can learn concepts about growth in plants without much thought given to what it is about nature that allows those concepts to have validity. Without the foundational understanding that there are perceptible patterns and regularities in nature which can be made intelligible with scientific concepts, those science concepts are held by students only on the basis of authority.

By grade nine students have finished their elementary school science curriculum. They have been exposed to earth science, life cycles, astronomy, motion, energy, and conservation. Through all of these topics, science according to typical curricula is taught with an emphasis on the order and patterns of nature. It appears, however, from even a casual examination of elementary science curricula that this emphasis is developed implicitly. Pattern and order are not taught explicitly as content but essentially left for the students to infer. What is the consequence? The research reported here began only indirectly related to this question. The original research project asked:

To what extent do students enjoy scientific knowledge vis-à-vis other domains of knowledge in a discussion about nature, given that science is unarguably relevant to the topic of nature, and yet, nature is a topic that most people do not explicitly associate with science? Moreover, what are the concepts that appear to have scope and force in the students' thinking about this topic? For it is one thing to be able to give correct answers on a science exam. It is quite another thing to appropriately use scientific knowledge in the absence of any kind of science prompt or cue. (Cobern et al, 1996, p. 8)

As noted by Heller and Finley (1992, p. 259), it is "important to understand when and how students apply their knowledge" (also see Heath and McLaughlin, 1994). The researchers noted that the concept of order (or disorder) in nature is fundamental in one's perception of reality. Since to foster in children the concept that nature is inherently orderly, and thus amenable to scientific investigation, is one of the key objectives of elementary education, the researchers reasoned that the qualitative worldview interviews of the original study would potentially be revealing of the more specific concept of order. Thus the research asked, After nine years of elementary school what sense of order in nature do students have?

Students

The students that participated in the interviews are from an upper middle class, semi-rural community in central Arizona, although many of the students do not fit the upper middle class description. The community itself includes many vocal, active people that consider preservation of the desert ecosystem an important issue. There is frequent talk within the community as well as frequent articles in the local paper about the rapid destruction of the surrounding desert due to an explosion of urban development. People in the community are “outdoors” people. They hunt, ride horses, hike, camp, play golf, and ride bicycles. Living in the area and most of the students have participated in one or more of these activities. Students volunteered for the research interviews and were not randomly picked. Since they volunteered for several reasons and none of the volunteers were turned away the final group represented a wide spectrum of the ninth grade class.

Methods

The basic method of this research was a modified naturalistic inquiry (Lincoln & Guba, 1990) approach using a semi-structured interview technique (Kvale, 1983; Spradley, 1979). The interview procedures are described in Cobern (1993a) and Cobern, Gibson, and Underwood (1995c), and involve three devices to elicit conversation on the topic of the natural world (for a similar approach see Bliss and Ogborn, 1987). In brief, each student while thinking aloud, sorts a set of words and sentences according to how accurately they correspond to the student’s personal views. The interviewer, consistent with Spradley (1979) and Kvale (1983), asks probing questions and encourages the student to speak freely and at length. The findings are descriptive categories or codes applied to each interview transcript. These are subsequently used to form concept maps which show the qualitatively different conceptualizations of nature held by the students (see for example Figure 2). The concept maps are then used as a guide for developing first person interpretative narratives on nature for each student interviewed. The narratives capture as much of the student’s actual language as possible. They are interpretive in that the narratives are constructed by the research team. (For a full set of maps and narratives, see Cobern, Gibson, and Underwood, 1995a.) Such conceptualizations are called outcome space by Marton (1988) and belief space by Jones (1972). Through out the process from interviewing to coding to map and narrative production, the research team was alert for possible assertions about the students that stood out in the data or in various ways occurred in the research team’s deliberations and thinking about the data. These tentative assertions were logged for later use.

With maps and narratives in hand, the research team began the process of sorting, comparing, and cross checking cases by major code categories. For the first analysis the cases were divided by sex and examined for internal code consistency and cross group code differences. After this comparison similar comparisons of the cases were conducted by using each of the following codes as the initial point of division: religion, aesthetics, knowable, science, order, and conservation. The gender identification along with the codes knowable, order, and science were used because of their pertinence to the research purpose. Aesthetics, conservation, and religion were added because of their frequent occurrence in the data. This process of comparing cases led to further tentative assertions which were added to the assertions gathered earlier in the research. This process ended with 37 assertions when the research team judged that the possible case comparisons had been exhausted. At this point the research team by consensus reduced the 37 assertions to seven logical groups. Each group then became the basis for a new assertion, most with multiple parts. The penultimate step was to cross check each assertion against each case for confirming and disconfirming data. In the final step of the analysis, two qualitative researchers not involved with this study cross checked the assertions, supporting arguments, and examples against the case concept maps and narratives. This process addressed the questions, How do students understand nature? What concepts have scope and power in their thinking? Where does science fit into their thoughts about nature? How is science interpreted when it has become an integral part of student thinking about nature? The final analysis resulted in seven assertions (Cobern et al, 1996) one of which was about order in nature. This particular assertion is the focus of this report.

Discussion of Assertion

Assertion: *After nine years of schooling, ninth graders show no consistent understanding of the order in nature on which science is predicated. Instead, students often "name drop" school science topics such as the ozone layer, rain forests, or the big bang theory.*

The ninth graders' narratives were examined for use of the word "order" (or "pattern") with respect to nature and whether or not a student offered specific examples of order in nature. The result of this examination supports the assertion that the student have no consistent understanding of the order in nature on which science is predicated. Instead, there is a range of understanding. Of the group, four students spoke specifically about order in nature. These students showed the type of understanding one would expect based on the goals of (say) Project 2061. Howard and Bruce are especially clear.

Howard: I think that nature can be fully known because it is logical. we don't know or understand all of it yet but as time goes on we will understand more and more. Most things about nature are somewhat orderly or have a pattern to them. Because of this the study of science allows us to explain what is going on in nature. The orderliness lets us predict many things that are going to happen, like the weather, for example. Sometimes nature seems chaotic but that is mostly because our knowledge is incomplete and therefore our understanding is limited. (ATG.n3, Narrative)

Bruce: Nature is complex, but it is orderly and knowable within a 20% or so margin of error. Some things are dependable (but not always good) like there will always be earthquakes, rain, volcanoes, etc. Most of the natural world can be known through science and the theories that have been developed by science. Science enables us to predict, to some extent, everything such as weather, volcanoes, earthquakes and earth movement. The things that aren't known will probably be known in the future by using trial and error. Essentially more time is needed to know more. (SAU.n4, Narrative)

Though they agree with Howard and Bruce, Samantha and Alice offer a somewhat more balanced view on what is orderly and what can be known. According to Samantha and Alice, along with order in nature there is also mystery.

Samantha: Nature can be understood although it is very complex and sometimes difficult to understand. There is an order to part of nature. Things like food webs or plant life cycles can be understood and predicted. Much of nature is pretty organized. There are many things in nature that we understand now and we will understand more as we go along. Science often leads to understanding interesting questions. It can be used to help in conservation. Scientists and environmental organizations are concerned about conservation and our resources.... Other things about nature aren't so easy to understand. Earthquakes and volcanoes can't really be predicted and that makes them pretty dangerous. The danger there makes these things mysterious to me. That brings me back to my original feelings when I started to think about nature. It's mysterious, I like to think about it. (ATG.n5, Narrative)

Alice: I see many sides to nature.... I think nature is very dangerous: I think nature is very beautiful. It can be beautiful and peaceful but also dangerous and frightening. A tornado, for example, can be beautiful and mysterious in its power and at the same time ugly in the damage it can do. Nature has a predictable, understandable side to it, but also, an unpredictable, uncontrollable side. I want to be a scientist. Nature is very important to the world of science. Through science we understand many of the patterns in nature; food webs, weather patterns, how the solar system works, etc. We need to know more about nature and we keep studying it to find out how things work and to discover ways that different things affect each other. (ATG.n1, Narrative)

Kevin also speaks of order in nature but his comments are tied to science. He seems to say that where science can make sense of natural phenomena, there is order. Other aspects of nature are too complex to be called orderly.

Kevin: I think nature is very complex. There are unknown parts of nature and they are confusing to me because there are no real laws controlling them. There is no order. These parts of nature can be very powerful, dangerous and unpredictable. Earthquakes are an example, also rattlesnakes. I think that because nature is so important to us we need to work to learn more about it. Knowing about nature makes us feel more at home in it. There are also knowable parts of nature. We can learn about nature through science. There is order to some things and we can base predictions on that. Examples of knowable,

predictable things would be states of matter, life cycles, the earth's plates and sometimes the weather. (ATG.n7, Narrative)

In addition to these four student, Betty and Art also spoke about order in nature. Their thoughts, however, are very different and not quite what a science teacher would want to hear. Betty finds both chaos and order in nature, the sacred and the mundane. She has two views of nature but says that her “understanding of nature is more scientific and logical than spiritual” (ATG.n8, Narrative). Nonetheless, she offers some quite non scientific ideas about nature.

Betty: I think there are a lot of conflicts to be considered when you talk about nature. It is both knowable and mysterious, chaotic and orderly... Nature is knowable. But people know or understand nature in two very different ways. Some understand nature on a religious or spiritual level. They "know" nature as an emotionally uplifting experience. God and nature are intermingled in New Age Spirituality. Nature has aspects that can be considered not only to be living and but to also have consciousness. Other people "know" nature on a scientific or factual basis. Their knowledge is based on facts and can be applied to solving problems as it is logical. There is an order to nature which we can use to predict some things, weather for example. Ideas about evolution, the ice age, extinction's and global warning can be developed and studied with scientific methods and proofs.... My understanding of nature is more scientific and logical than spiritual but there are some aspects of both attitudes in my thinking. Nature is complex and therefore mysterious. We don't understand a lot of things in nature because of its unpredictability. Tornadoes and earthquakes are unpredictable and there are many questions that are still unanswered. Another reason that nature is mysterious is that it is living. Things in nature have a consciousness. Plants, for example, scream when you pick a flower. That is something people don't realize or understand. The consciousness and the beauty of nature are another type of powerful force. They affect the way that people look at things and how they react. (ATG.n8, Narrative)

At first, Art sounds like Howard. “Many things that we perceive to be complex and confusing because we don't understand them are actually quite simple and orderly” (ATG.n4, Narrative). The example he follows with, however, takes the unusual twist of offering an spider's perspective on order. Like Betty, Art values both spiritual and material reasoning but in the end the former is given greater weight.

Art: At the present time our knowledge of the natural world is limited. Many things that we perceive to be complex and confusing because we don't understand them are actually quite simple and orderly. The construction of a spider web, for example, is quite a complicated operation to us but to the spider building the web it is a simple procedure. As we gain in understanding of the diversity and power of nature, we will understand the perfect balance of everything in nature. We will also begin to understand our place within nature. It is more important to have a spiritual understanding of nature than just scientific knowledge. That understanding can't be gained from school. You have to spend time in nature and learn to feel it. Then you will understand it. (ATG.n4, Narrative)

If Art and Betty offer a view of order in nature based on an amalgam of science and spirituality, the next four students find it difficult to see any order in nature at all.

Simon: Although I've thought a little bit about the natural world, I don't really understand a lot of things. I suspect that much of nature isn't meant to be understood because nature lacks order and is often unpredictable. It is often unexplainable. Some things like weather and ocean patterns can be predicted but many dangerous things might not be predicted - earthquakes and natural disasters, for example. Animals also do things that we don't understand and can't explain. (ATG.n2, Narrative)

In this excerpt, one can see that Simon can give an example of knowing about nature but he clearly finds the level of disorder such that he is unsure that much of nature is even meant to be understood. Holly offers little more when she says, “There is some order in nature, but not much. An example would be like some parts of the land, like deserts, forests and oceans” (SAU.n7, Narrative).

Allen and Jackie, like Holly and Simon, find little order in nature. They differ in that they find some prediction in nature possible. It is not prediction of natural events, however, which would be indicative of an implicit understanding of order in nature. The prediction they speak of is the prediction of how nature responds to the actions of people. It is an environmental type of prediction.

Allen: For the most part nature is not orderly and predictable in the sense that nothing stays the same. Rocks move, trees grow, houses are built, but nature's reaction to things are predictable, like recycling.... We can predict that if all people recycle, we can save resources like coal and oil, but we would also make this a cleaner planet. (SAU.n6, Narrative)

Jackie: The natural world is incredibly mysterious. There is really no order to what happens.... There is an aspect of nature that is knowable and that is the cause and effect relationship. For example, we know what happens when man destroys the desert to build homes, or what happens to the earth when we pollute or recycle.... The lack of predictableness can be dangerous, such as hurricanes and earthquakes. Even though we can't know everything about nature, we do know that we will eventually destroy it and that we all will die sometime. But even that is a mystery, because we don't know when. (SAU.n7, Narrative).

One might be tempted to see in Jackie's and Allen's thoughts on prediction a very rudimentary awareness of order as an attribute of nature. As noted, however, their examples come mostly from an environmental protection or conservationist perspective. Thus, the more prudent interpretation is to take these two at their word, i.e., "There is really no order to what happens" (Jackie, SAU.n7, Narrative) and that the predictableness they speak of is not indicative of any implicit understanding of order in nature.

The last five students in this group of sixteen are interesting for several reasons. The first of which is that none of the five chose to use such words as "order" or "patterns" in conjunction with nature. They neither said nature was, nor was not orderly. Another interesting feature of this group is that the students are all women and all express religious convictions in conjunction with nature. Moreover, four of the five clearly indicated that knowledge of nature was possible.

Ann: To me nature is beautiful and pure because it is God's creation.... Nature is knowable but the questions I ask about nature make me think that nature is sometimes very confusing.... I know that we can learn about nature and use that knowledge to change some things that we have done that are bad and to predict and/or control some of the problems that nature causes us. (ATG.n6, Narrative)

Patricia: God created the natural world. It has many characteristics: it's powerful, diverse, changeable, and beautiful (physically & emotionally). Nature of the natural world is anything made by God, all the plants and animals on earth and the entire solar system. The natural world is very mysterious to me, I wonder about many things in nature. Something I wonder about is, "what is way out in the universe, perhaps another earth?" Even though nature is mysterious, everything is knowable but maybe not in the near future. The wonderment of the world increases knowledge through science but is limited due to it's complexity. (SAU.n2, Narrative)

Sally: I think of the natural world as what God gave us to take care of. In the Bible it says we are superior to animals and plants. So we are supposed to take care of them.... The natural world is somewhat knowable through science and religion. It is too big to be entirely explained, for example, how can you be sure that an animal is truly extinct if you can't explore all areas of the world. Science and scientists help us to know some of the natural world because things can be predicted, like animal behavior. The predictableness allows us to answer how things work, but we will never really know why things work: Why is nature here, What is the purpose, or, How did life form? Some things are unpredictable like hurricanes, tornadoes, and volcanoes, which make nature dangerous at times. Science can teach us how to be better conservationists through research and technology so we can avoid pollution which ruins nature. (SAU.n5, Narrative)

Liz: The natural world also consists of ideas, why animals do certain things, their purpose, and what they think. It is the work of God. It's purpose is to help us live and enjoy the things - aesthetics - it provides us. Everything happens for a purpose.... The natural world is knowable by means of education through science and by learning through personal experiences. Eventually we will probably be able to know most things about the natural world. However some things will be kept a mystery because not all things are meant to be known. Science tends to teach the how and what questions about the natural world and religion hints at the why questions somewhat. Before it can be knowable to someone, that person must care about the natural world. (SAU.n8, Narrative)

These four students have grades at the high "B" or "A" level. One cannot know for sure without further investigating these students' religious views. It would appear, however, that their view that nature is God's creation is tantamount to the view that nature has inherent order.

The fifth student who neither said nature was, nor was not orderly, is Paula. As with the other four, Paula shows religious convictions. Her views differ, however, in that she does not see that one can have much knowledge of nature or that knowledge of nature is good. The other distinguishing fact about Paula is that she is failing school.

Paula: Nature is mysterious.... God created the natural which makes it very mysterious and, for the most part, is unexplainable. God intended it to be here for a purpose which is only known by him. Because it is God's, humans have no right to mess with it. Even with the best technology and scientists we will probably not every fully understand nature. When man entered this planet, he destroyed its purity, beauty, and power.... I don't understand the human world and why people feel the need to study nature. Studying nature only causes trouble. It creates more technology and curiosity which leads to the exploitation of the land. (SAU.n1, Narrative)

These five students leave us with several questions. The first four have much more traditional religious views than does Paula. Paula is more of a New Age believer. Does that matter when it comes to learning science? Does the traditional religious view of nature support the concept that nature has order while the non traditional view does not? Or, does the fact that the first four are doing well in school account for their more positive view of knowledge? It is not possible to tell. It is possible to say, however, that though the concept of order in nature is part of science curricula, it is also a concept that one will likely find to be much influenced by non school factors.

Implications

As noted earlier science education policy and curriculum documents typically speak of fostering in students a scientific worldview as part of any program for scientific literacy. The research literature, however, indicates little interest in the subject at least where fundamental concepts are concerned. There are of course very many studies on how well students have learned science concepts and processes, and on how well these are taught. The fundamental presuppositions on which science is grounded are not explicitly addressed. The underlying assumption seems to be that adoption of the presuppositions is part and parcel with learning the concepts and processes. The results of our research, in contrast, show that student understanding of order in nature is inconsistent even among students who get good grades in science. This suggests that if an understanding of the inherent order of nature is to continue as part of the elementary school science curriculum (indeed, the secondary school science curriculum as well) - - we think for reasons stated earlier that it should - - more research interest needs to be focused on how students understand this presuppositional concept and how the concept is learned. On the later point, it is quite possible that out of school factors such as religion are at least as influential as school science factors. In terms of instruction, it seems likely that the concept of order in nature needs to be addressed explicitly.

Summary

Ninth graders in Arizona high schools have just left their elementary, general science education and are at the start of more specialized secondary science education. They are beginning a course of study that will form the foundation for tertiary education and employment after high school graduation. The research asked, Who are these kids entering high school science courses? The researchers noted that one of the key objectives of elementary

education is to foster in children the concept that nature is inherently orderly and thus amenable to scientific investigation. Since the concept of order or disorder is fundamental in one's perception of reality, the researchers reasoned that the qualitative worldview interviews on nature would be revealing of these concepts. The research led to this assertion: After nine years of schooling, ninth graders show no consistent understanding of the order in nature on which science is predicated. Instead, students often "name drop" school science topics such as the ozone layer, rain forests, or the big bang theory.

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