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4. THE CARD EXCHANGE: INTRODUCING THE PHILOSOPHY OF SCIENCE

The nature of science is an important though difficult subject to teach meaningfully and effectively to preservice teachers. To engage the students' minds in this subject that many find obscure and esoteric, a good introduction is a necessity. This chapter presents a learning game called *The Card Exchange* which has been found effective in arousing student interest in the philosophy of science. The chapter presents a brief description of how the game is set up and played and how it relates to the authors' instruction on the philosophy of science. The chapter includes a list of card statements. The statements as well as the text of the chapter have been revised and updated from an earlier publication (Cobern, 1991a).

There are a number of thoughtful articles in the literature stressing the need for philosophically literate teachers of science at all school levels (e.g., Andersen, Harty & Samuel, 1986; Hodson, 1985; Martin, 1979) and for many years the textbooks used in science methods courses have contained at least some material on the philosophy and nature of science. Nevertheless, science educators have been concerned that an acceptable level of philosophical sophistication was not being reached within the ranks of science teachers, and consequently are concerned about views toward the nature of science promoted in the classroom (e.g., Schmansky & Kyle, 1986). DuschI (1988, p. 51) summarizes the classroom situation by saying that "the prevailing view of the nature of science in our classrooms reflects an authoritarian view; a view in which scientific knowledge is presented as absolute truth and as a final form." This view has been called scientism. This is a problem first because as we learn more about the world views that students bring to the classroom we begin to understand how the scientistic view extinguishes students nascent interest in science (Cobern, 1991b; 1996). Secondly, those students who do accept the scientistic view are likely to become disenchanted with science at a later date as science fails to achieve the unrealistic expectations accompanying a scientism orientation. The challenge is how to teach the philosophy of science be taught to teachers with greater effectiveness?

THE CARD EXCHANGE

Sometime early each year in many schools, lessons are taught addressing the nature of science. Often instruction in the process of science is nothing more than a method

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listed on the board and provided as *the* way all scientists work. Or it may be suggested that students will be following various aspects of this method in numerous activities throughout the year. Students are told, therefore, they will be doing real science. We take the view that students' understanding of a) what science is, b) just how human the endeavor really is and --perhaps equally important -- c) what science is not, can be enriched and made more engaging by showing that those who do science, and those who write about it, hold varying views as to just what is authentic science (Martin, Kass, and Brouwer, 1990). If we can find ways to determine what individual students currently think, we at least can acknowledge their varying views--whether they come from ignorance, first impressions, or an extensive knowledge base about science. If necessary, teachers can then try to help them construct meanings more in line with a balanced view of science. Our purpose in this chapter is to present an activity, a learning game, which acts as a powerful set induction for subsequent instruction in the philosophy of science. We have found that this activity engages our students' minds and precipitates enthusiastic discussion on the question, "what is science all about?"

We have used the game successfully in a variety of settings. Elementary and secondary preservice methods classes are one example. Here we found our challenge to be how much time we can spend on the nature of science versus all the pedagogical and content issues one must deal with for a variety of science disciplines and a variety of grades preservice students will teach. We found that if students have only one science methods class, it is difficult to find the necessary time to do a good job with nature of science issues. It is always the struggle between our desire to give them the necessary background and their desire to know "what can I do in my classroom tomorrow." The card game does, however, serve as a highly effective entry into a world many students do not know exists.

Another group with whom we have used the card game are veteran classroom teachers, either during summer workshops or at state science teacher meetings in workshop settings. They love the activity, the engagement and, for many, the discovery that there is a whole area about science for which they have not had much background or experience. "Light bulbs" often go on in these settings and some teachers crave more. We both have had, from time to time, this activity result in teachers later enrolling in our graduate courses which concentrate on the nature of science and science teaching. There is little indication that most teachers who have become familiar with this strategy use the cards immediately with their students, although the high school teachers were more likely to see this as a possibility for their students in tenth to twelfth grade. Instead, it appeared that they were seeing this as a self-enriching experience that might enable them to teach from a different perspective.

When graduate students in science education play the card game, they are potentially the best prepared to get the most out of this activity. These students tend to have good backgrounds in science, have taught for a number of years, and have combined that experience with recent course work and, for some, active research in current issues of science education reform. Not only do they tend to have the most intense and detailed conversations, but their resultant paragraphs about science tend to be what we would consider the most perceptive and balanced. Later in the course, they go back to some of these statements to design exhibitions for their peers about how they would teach this principle about science to students. For example, two graduate students designed five different posters depicting five well-known models of classification systems throughout the history of science from Aristotle to the present. Their peers loved it because it was such a vivid way to teach something all children learn in a developmental way. It so clearly showed these systems to be human constructions that were later replaced with what the scientific community decided were more authentic models. What better way to show that "science builds on what has gone on before and refines its conclusions" or "theory and observation interact" or "theories help scientists interpret their observations."

Finally, interesting results occurred when we used the card game with some university scientists. Scientists are diverse in their views about science -- some holding rather strong empiricist views, others seeming theoretically driven, and others appearingbalanced. The cultural component was minimally referred to by our scientists. The research piece to the card game -- looking more closely at the relationship between composition (race, culture, gender) of our various card-playing groups and our results, what they do with the cards, how they respond to the activity initially and in retrospect, what they propose to do differently when they leave us, and what they end up doing back in their schools -- is richly layered and ongoing.

The activity we are writing about is called a "card exchange," a learning game developed by Bergquist and Phillips (1975) for classes of 20 students or more. We use the game very much as it was originally developed except that we have changed the game content to the philosophy of science. The game works well because at the beginning students are encouraged to move around and talk with each other, things almost all students like to do! The subject of conversation is the content of the cards. This works as a set induction because in the course of their conversation students quite naturally begin considering what they believe about science and how those beliefs may or may not coincide with what others believe. Later in the game students form groups based on the content of the cards they hold and then corporately produce a written summary. Both of these later acts require compromise which forces the students to give a rough rank order to their beliefs about science. The result is that when we begin our part of the instructional process, our students are not only keenly aware that many of them hold quite different views on the nature of science, and many of them now have doubts about the validity of their own views. They are engaged.

PLAYING THE GAME

To prepare for this game the teacher must develop a set of science statements related to what that teacher later wishes to accomplish with his or her philosophy of science instruction. A single statement is placed on each card. The statements should be succinct and easily understood. They should represent a broad range of viewpoints including specific views to be expressed in the course. The set of card statements may be redundant. In fact, redundancy as well as diversity is necessary so that students can avoid being trapped with statements that they cannot affirm. We personally use a set of more than 200 cards containing 40 unique statements representing six categories (See Appendix A for the actual statements):

1. Theoretical Emphasis: Science is primarily a rationalistic, theory-driven endeavor (for example, see California Department of Education, 1990, p. 14-18).

2. Empirical Emphasis: Science is primarily and a datagathering, experimental endeavor in pursuit of physical evidence (for example, see Braithwaite, 1955).

3. Anti-Science View: Science is overrated. One should not give much credence to the aims, methods or results of science (for example, see Appleyard, 1992; Sale, 1995; Skolimowski, 1974).

4. Scientism: Science is the way of knowing; it is the perfect discipline. For a good introduction to this topic see Poole (1995) and Settle (1990).

5. Cultural View: Science is embedded in a social, historical, and psychological context which affects all that goes on in science (for example, see Cobern, 1991b; Fuller, 1991; Harding, 1993; Hodson, 1993).

6. Balanced View: This view point, which reflects our own aversion to extremism, takes science to be a complicated affair that cannot easily be reduced to one or even a few simple descriptions (for example, see Loving 1991; 1992).

The statements (see Appendix) used in the activity reflect the diversity found in current thought. They allow for comparison and contrast with our objective which simply put is, science viewed as both empirical and theoretical; science as a powerful though limited way of knowing; science as a human, not mechanical endeavor; science as a dynamic process. Depending on the instructor's objectives, other statements can be used. Our statements were drawn from a number of different sources. In addition to those listed above, we refer the reader to AAAS (1993), Aicken (1984), Eastman (1969), Kimball (1967), Matthews (1994), and National Research Council (1996).

The game begins with the instructor giving to each student a randomly drawn set of six cards (six to eight cards usually works best). The students evaluate their cards according to what they can most and least affirm. They then have a period of time in which to mill about examining each other's statements and making trades. Sufficient time should be allowed for each student to examine every other student's cards. The goal is to improve one's hand by trading cards one for one, in other words the students' goal is to trade cards they like less for ones they like more. There is no discarding. We typically allow our classes of 30 to 40 students a minimum of ten minutes for this phase of the game. At the end of the period we have everyone sit down while we give the next set of instructions. Instructions for each phase should not be given in advance.

In the second phase students are again to mill about, but this time seeking someone with whom they can pair. The pairing rules are that each pair must hold eight cards on which they have relative agreement. Each member of a pair must contribute at least three cards. This is important if the pairs are to be truly formed by compromise. The pair's remaining four cards are discarded.

Phase three of the game is a repeat of phase two, except now the pairs form quadruplets. Each foursome is to hold eight cards with each pair contributing at least three cards. Once the foursome has been established, the students are asked to rank order their cards. Then if they wish they may discard the two bottomed-ranked cards. Based on this final set of cards the students cooperate to write a statement of paragraph length on the nature of science. At the conclusion of the game we ask the various groups to share their paragraphs and to say why they accepted some statements while rejecting others. Generally this is enough to precipitate vigorous discussion. We facilitate the discussion by writing on the board a few phrases that characterize the views being presented.

We follow up the discussion with a presentation of two case studies from the history of science. Typically we use Ignaz Semmelweiss' work with childbed fever and Newton's exploration of the phenomena of colors (Mannoia, 1980). In these case studies we look for examples of the statements on the nature of science that the students have advocated in their card exchange summaries. The case studies can be presented orally in a recitation format by the professor or in the form of a printed handout. The advantage of using a handout is that the groups working individually at comparing and contrasting their card exchange summaries with the case studies do a more thorough job. The disadvantage is the amount of time required. The discussion of the card exchange summaries vis-a-vis the case studies concludes the set induction. From this point we begin the main body of instruction on the nature of science.

CONCLUSION

We personally have found the card exchange activity to be an effective method of drawing our students into the philosophy of science, a subject they heretofore resisted. It capitalizes on the innate gregariousness of students and the diversity of opinion among students. A set induction is, however, only the beginning of a lesson. The effectiveness of what happens afterwards depends on how well one can hold the attention captured during the set induction. Obviously there is a need for many creative instructional strategies if the philosophical preparation of preservice science teachers is to be effective.

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APPENDIX A
CARD EXCHANGE STATEMENTS

Theoretical Emphasis

1. Science is open-ended, but scientists operate with expectations based on the predictions of theory.

2. A theory is what scientists strive for: a large body of continually refined observations, inferences, and testable hypotheses.

3. Theories help scientists interpret their observations: facts do not speak for themselves.

4. In general, scientists plan investigations by working along the lines suggested by theories, which in turn are based on previous knowledge. Theories serve to give direction to observations, i.e., they tell one where to look.

5. A theory is a logical construct of facts and hypotheses that attempts to explain a range of natural phenomena and that can be tested in the natural world.

6. Good science cannot be done without good theories.

Empirical Emphasis

1. Observation is central to all of science, i.e., seeing is believing.

2. A scientist should not allow preconceived theoretical ideas to influence observation and experimentation.

3. Unless an idea is testable it is of little or no use; thus, scientists attempt to convert possible explanations into testable predictions.

4. Careful, repeatable observation and experiment give the facts about the world around us.

5. Good science always begins with observations.

6. Science is never dogmatic; it is pragmatic—alwayssubject to adjustment in the light of solid, new observations.

7. A phrase such as "Many scientists believe. ." misrepresents scientific inquiry because scientists deal in evidence.

Anti-Science View

1. Science is always changing and therefore is not very reliable.

2. Scientists should be held responsible for harm their discoveries have caused, e.g., pollution, nuclear weapons.

3. Earning recognition from other scientists is really the main motivation of more scientists.

4. Most of what scientists do will never be of much practical value.

5. Money spent on projects such as NASA space flights would be better spent on healthcare for the needy.

6. Science destroys values and morality by disparaging the unique nature of men and women.

7. Science and religion are fundamentally at odds.

Scientism

1. The scientific method should be followed in all fields of study.

2. Scientists and engineers should make the decisions about things like types of energy to use because they know the facts best.

3. Science is the most important way of gaining knowledge open to humanity.

4. Science knowledge is of much greater value than any other type of knowledge.

5. Only science can tell us what is really true about the world.

6. Science knowledge is always objective and self-correcting.

7. Credit for our advanced way of life must go to science and scientific progress.

Cultural View

1. Funding influences the direction of science by virtue of the decisions that are made on which research to support.

2. The scientific enterprise is situated in specific historical, political, cultural, and social settings; thus, scientific questions, methods, and results vary according to time, place, and purpose.

3. The predominance of men in the sciences has led to bias in the choice and definition of the problems scientists have addressed. This male bias is also one factor in the under representation of women in science.

4. Scientific facts are manufactured through social negotiations. Nature has nothing to say on its own behalf.

5. Scientists in one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective.

6. The Early Egyptians, Greeks, Chinese, Hindu and Arabic cultures are responsible for many scientific and mathematical ideas and technological inventions.

7. Until recently, some racial minorities, because of restrictions on their education and employment opportunities, were essentially left out of the formal work of the science establishment. The remarkable few who overcame these obstacles were even then likely to have their work disregarded by the science establishment because of their race.

Balanced View

1. Science is one of several powerful ways of knowing and understanding the natural world, however, some matters cannot be examined usefully in a scientific way.

2. Science leads to generalizations based on observations or theories. Science always aims to be testable, objective and consistent.

3. As with all human endeavors science is subject to many influences both good and bad.

4. Science builds on what has gone on before and refines its conclusions, but scientific work does not result in infallible propositions, such as the word "proof" implies to a nonscientist.

5. Scientific progress has made possible some of the best things in life and some of the worst.

6. Theory and observation interact. Each contributes to the other: If theory without observation is empty, then observation without theory is blind.