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ABSTRACT

Using case studies in science instruction develops problem solving and enhances listening and cooperative learning skills. Unlike other disciplines such as law and medicine, the case study method is rarely used in science education to enrich the curriculum. This study investigates the use of content-based case studies as a means of developing critical thinking skills and stimulating student interest. (Contains 25 references.) (YDS)

Using Case Studies to Teach Science

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Using Case Studies to Teach Science

Purpose

A science inquiry network links forty-five schools in two states to investigate Lake Victoria endangered cichlids. Content case studies are used to stimulate interest about the inquiry and create a knowledge base to support students in their inquiries. The case studies, along with being content-based, use real-life problems with multiple variables. The case studies are also used to teach critical thinking skills. Students communicate and exchange ideas about the case with each other through an Internet conference in support of this objective. The research reported in this paper centers on the effectiveness of using case studies in this way. Data were collected from field observations notes, video taping, student written materials, computer network communications, and teacher interviews. Three questions guided the research: 1) Does the case study approach stimulate the studentsí interest in learning science? 2) What techniques facilitate the use of case studies? 3) Was there evidence to support that the case technique stimulated critical thinking?

Significance of Study

As pedagogical devices, Silverman and Welty (1997) find that cases create a need to know, raise the level of critical thinking skills, enhance listening and cooperative learning skills, and develop problem-solving skills. The case study method encourages habits of thinking such as analysis, problem-solving, listening, and communicating which Wasserman (1994) deems important. Scenarios or problems which students can visualize and are familiar with are more likely to encourage them to remember and comprehend the underlying concepts (Krow & Kostka, 1998).

Cooperative groups used in case study methods potentially promote higher levels of learning associated with critical thinking. Vygotskyís (1978) research indicates that students perform at higher intellectual levels when they work in groups versus individually; Johnson and Johnsonís (1986) findings that cooperative teams achieve higher thinking skills also support this concept. Gokhale (1995) found that collaborative learning groups performed significantly better on a critical thinking test than students who studied individually, and other research (Totten, Sills, Digby, & Russ, 1991) implies that shared learning gives students the opportunity to become critical thinkers. Recent research by Cornely (1998) indicates that as students solve a case they develop higher order thinking skills of analysis and application. Additionally, collaborative group work provides scaffolding for lower achieving students as sharing and comparing of responses evolves through discussion (Ridgeway & Padilla,

1998). Using the content case studies on the Lake Victoria cichlids is an excellent opportunity to observe the thinking patterns which occur in small and large group settings.

Jonassen (1994) stresses purposeful knowledge construction occurs best in learning environments which provide for a multiple representation of reality, avoid oversimplification of the instruction through a representation of the real worldís natural complexity, and which are case-based, real-world learning environments that support collaborative construction of knowledge. In order for constructivism to work, students need to learn concepts relationally (Glynn, et al., 1991) in a certain manner. That is, students learn the concepts as organized networks of related information. Students perform cognitive processes which construct relations among the parts of the concept. From there, students construct relationships between that concept and other concepts. Students need this framework on which to build their conceptual networks. Initially, the students do not know about cichlids; therefore, the case studies provide a way to study how students construct information.

Regarding scientific problem solving, studies have been done in which novices and experts solve problems, and then their methods are compared (Chi, Feltovich, & Glaser, 1981). Some of the findings are that novices often do not plan ahead in problem solving; nor do the novices have a thorough grasp of the problem to be solved. Also, the depth of understanding used to solve a problem differed greatly: experts classify the problem by the underlying principles, and novices deal with the surface issues of a problem. Since the students are definitely novices on Lake Victoria, the methods of analysis and synthesis can be explored in case studies to see if results similar to Chi are obtained.

National reform movements encourage the use of inquiry in science classrooms. The National Science Education Standards (NRC, 1996) emphasize the importance of inquiry. Teachers are encouraged to use real-life situations and to help students do their own investigations. Science of All Americans (AAAS, 1990) also stresses the importance of inquiry. According to Edwards (1997), curricular materials that provide inquiry as outlined in the National Science Education Standards are difficult to create. Chiapetta (1997) declares that questions are at the heart of the inquiry process for critical thinking and he further elaborates that skilled science teachers are good at asking questions. Much more research needs to be done to discover better methods for introducing inquiry into the classroom. The case study method is one way that studentsí interests can be stimulated for conducting an inquiry.

The Case Study Model

Science instructors rarely use the case study method; but other disciplines such as business, law, psychology, and teacher education have used case studies for some time (Herreid, 1994) to enrich their curriculums. For years medical schools have used case studies for clinical instruction and are now incorporating the case study method into pre-clinical instruction (Cornely, 1998). Additionally, instructors of various science disciplines are beginning to adapt the case study method for instructional purposes (Cornely, 1998; Jones, 1997; Brink, Goodney, Hudak, Silverstein, 1995; Cheng, 1995; Richards, Gorman, Scherer, 1995; Giunta, 1996; Ommundsen, 1996). At the end of 1998, the *Journal of Chemical Education* created a column for teaching with problems and case studies because of a lack of resources in this area for teaching chemistry-based concepts (Krow & Kostka, 1998). A review of the literature indicates that case studies and similar problem-based learning situations in science are predominantly used in college courses to stimulate topic discussions.

This study explores the use of content-based case studies at the elementary level as a means of developing critical thinking skills and stimulating studentsí interest in a science topic. The question: What techniques facilitate the teaching of case studies in science? was unanswered at the elementary level. The case studies used in this research were developed in a collaborative effort between university faculty and elementary teachers.

Design of the Case Studies

One case study about ducks was used to teach students the case study method. Three additional case studies were developed around the dilemma of the cichlids in Lake Victoria, Africa; all are written in a story format to appeal to an elementary student. "Kassunís Lake," the first cichlid case study, is a narrative about Lake Victoria and a ten-year old boy whose father is a marine biologist and is trying to fix the lake. The next cichlid case study, "The American Scientist," depicts the arrival of an American scientist to contribute research support for the problems of Lake Victoria. The last case in the series, "Lake Victoriaís Problem," provides additional scientific details of the lake in a narrative format.

The students use the following steps to learn about each case:

1) Read the case

2) List the problems found in the case.

3) Determine the main problem.

4) Decide how the main problem could be fixed.

Case Study Teaching Method

There are a number of ways that a teacher could introduce the cases to students and have them learn the details provided. The method described herein describes how teachers in this project use the case studies. After initial whole class instruction to explain what the students are to do, students are divided into small groups, and the teacher moves from group to group to answer questions and facilitate the process. Reading the case occurs in small groups; these same small groups generate answers to the following basic questions:

1) What are the problems found in the case?

2) What is the main problem?

3) How could this main problem be fixed?

Other aspects of the cases are discussed with the entire class sitting on the floor near the teacher. The discussion begins by the teacher asking a student from each group to give her a problem found by that small group. She lists these problems on an overhead transparency, chart paper, or on the board. Once each small group has a chance to contribute, she opens the floor to any other problems which are not listed that were found in the small groups. This method values the input from each group and helps ensure that all of the problems found by the class are listed. Next the teacher asks for each small group to indicate the main problem found by that group. Starring the previously listed problems is one way that teachers help students keep track of this information. Discussion continues with suggestions from the groups regarding how their main problem can be fixed.

When students have completed two cichlid case studies, an additional component is utilized as a learning tool. At this point in time, students are familiar with "Kassanís Lake" and "The American Scientist." In their small groups, they find problems which are similar in both "Kassanís Lake" and "The American Scientist" and those which are different. At the end of all three case studies, they find problems which are similar in "Kassanís Lake" or "The American Scientist" to "Lake Victoriaís Problem." Likewise, they also find problems which are different.

Implementing the Case Study

Teaching Techniques

Venn diagrams were found to be an excellent way to teach students to compare and contrast case studies. Two overlapping circles, one representing each case, help students to visually see that problems which are only in Case #1 are written in one circle; and those only found in Case #2 go in the other circle. Students learn that problems which are found in both cases go in the overlapping section.

When three case studies are compared and contrasted, a three-circle Venn diagram is necessary. Each circle represents one case study and the overlapping sections of two circles denote elements which are common to those two cases. The space where all three circles overlap includes elements which are common to all three cases. Although the three-circle Venn diagram was more complicated for students to understand, fifth graders successfully found appropriate problems for sections of this type of Venn diagram. The teacher used prior knowledge from the previous case studies to promote understanding of the three-circle Venn diagram. Also, before having the students compare and contrast the three cases, she asked each student in the class to give her a favorite animal(s) from the choices of dogs, cats, and fish; then she put the studentís initials in the appropriate space on a three-circle Venn diagram that she had drawn and labeled.

Guided questions are another teaching technique used to help students understand content information in a case study. The following dialogue illustrates how a teacher used the guided question method to help students think through the problems listed in a case study:

T: Whatís the big problem?

S1: Sewer water and chemicals causing problems with the Nile perch and other fish and the lake.

S2: They all relate: sewer water, smoking the Nile perch, overcatching, and the Nile perch eating the cichlids.

T: Letís say that if you fix one of the problems, which one would you start to fix?

S2: Thatís a hard one.

T: So, you could probably start with any one of them?

S2: The British should give the Africans nets to catch the Nile perch for the restaurants.

S1: How could the British have done the research?

T: The point that youíre trying to make is the British didnít have the means to do the research. But, there have been ways to do the research in the last ten years. How can we fix one of the problems?

S3: Africans could cut up the Nile perch and dry the strips.

As the discussion continued, the students realized that all of the problems were interconnected.

A table is a technique which helps students to analyze a case study. For example, the problems which the class found in a case study can be assigned numbers and/or abbreviated so that each problem becomes a label for a column in a table. Groups can be the label for the first column and each group can be a different row. Then an X is placed in the space corresponding to the main problem chosen by that group. Such a table helps students to see that different groups decided on various problems as the main problem; therefore, it is now easier for students to understand that the problems are interrelated.

A time line is another technique which helps students to clarify when events happened. Students tend to think that the environmental problems with Lake Victoria are recent occurrences or that the problems started with the British introducing the Nile perch to Lake Victoria. However, a time line of events helps students to see that the problems have actually been developing over time. This revelation gives students a different perspective from which to analyze the problems surrounding Lake Victoria and allows them to better understand that the situation is actually much more complex than the surface depicts. This helps the students move from viewing the situation through the lens of a novice to viewing the situation through the lens of an expert with more of the depth, understanding, and critical thinking that an expert would bring to the case.

Technology

An Internet conference is an excellent way for students to consult with each other to see what problems another class has listed and to see if they agree with each other. Therefore, the problems found by one class were posted so that other classes could see the list and compare to theirs. In our study, this was the weak link because there were technological issues with servers in some of the schools, and the class could not list their problems on the network. Other classes had to wait for schools to list their problems. However, this is a potential way to increase critical thinking among students by having students find the problems listed by one class which are the same as the ones they listed and by having students find different problems than they listed. When the wordings are different but the meanings are the same, students also need to decide if the problem they listed is the same or different than the one listed by another class.

Research Findings

Stimulating Student Interest

Results of this study indicate that student interest was stimulated. Students for example wanted to know about water hyacinths and why they were causing such a problem for the cichlids. Consequently, teachers obtained water hyacinths and grew them in a separate aquarium so that students could see what they looked like. We found that it was difficult for students to access information at their level of understanding about the problems of Lake Victoria; therefore, a library of information was created on our Internet conference for this purpose. Students were also interested in knowing more about the water chemistry such as the effects of lower oxygen levels and contributions to the pollution factors from sewer water and erosion. Their interest stimulated higher levels of thinking as they sought to uncover the source of the pollution and the lower oxygen levels. Some classes have subsequently learned to check oxygen levels using computer probes.

Critical Thinking

Bloomís Taxonomy (1956) was used to help determine higher order thinking skills in this study. The six cognitive levels proposed by Bloom are (Sergiovanni, 1979 p. 242):

ï **Knowledge** which is characterized by recall of information, knowledge of specific facts, definitions, symbols, and steps in a process

- **Comprehension**, that is understanding and the ability to translate, rephrase, and interpret
- **Application** which involves using knowledge and understanding to solve problems
- **Analysis** or breaking the whole into its elements and analysis of relationships and multiple causation
- **Synthesis** or putting together parts to form a whole
- **Evaluation** which involves making judgments using internal evidence or external standards

Observations indicating analysis, synthesis, and evaluation were considered higher order thinking skills in contrast to merely defining words, stating facts, or explaining material which represent levels one and two of Bloomís cognitive skills. Therefore, evidence of thinking which represented analysis, synthesis, and evaluation were categorized as critical thinking in this study. In the first and second cases, students primarily stated facts which came from the case study (knowledge level), defined terms for each other (knowledge level), or explained material (comprehension level); this finding is similar to Chiís (1981) results for novices in that the students merely dealt with surface issues, and only 28% of the student discussion statements in the first case are classified as critical thinking. By the end of the discussion on the second case study, some students thought humans were the problem which involved statements indicating levels of analysis, synthesis, and evaluation, but they did not move beyond that statement.

By the third case study, students began to use higher order thinking skills frequently, and some students saw a need to combine two problems for the main problem; therefore, they began to exhibit skills more similar to that of an expert. One student wrote, "...it is hard to find the main problem...But there is more than one main problem." One small group said that all of the problems were connected, and they did not rank them. Another group gave a #1 ranking to two problems. During the final discussion on the case, one student said regarding the problems listed by the class, "They all relate: sewer water, smoking the Nile perch, overcatching, and the Nile perch eating the cichlids." Class discussion became lively when students began to realize that the problems were somehow connected. Another student asked a question, "If all of these problems are related, where should we start?" Evaluation was in evidence when a student replied regarding the British, "If they made the problem, they need to fix it." The teacher took a vote on the three main problems that the class as a whole found, and more than half of the class voted for all of the problems together as the main problem. One student summarized, "I learned that all of the problems we listed on the overhead is the BIG problem." Therefore, with the third case study, 74% of the student discussion statements are classified as critical thinking.

Teacher Facilitation

Methods which teachers use to facilitate case studies appear to be a big factor. Teacher A, who has the most training regarding the use of case studies in the classroom, used a variety of techniques to help the students construct meaningful learning from the case studies and guided the discussion to help students understand the interrelationships of factors in the case studies. However, Teacher B who has had minimal training was not as effective at assisting the students in constructing meaningful learning and guiding the students to conclusions. Also, Teacher B gave students more information and gave them the conclusion rather than guiding the students to the conclusion through questions and discussion such as that used by Teacher A. Teacher B did not use as many tools for analysis and synthesis to help students better understand the connections between the cases. Teacher C who has had no formal training in the use of case studies had more difficulty facilitating the case study discussion as evidenced by more concentration on statements from the case studies and the lack of tools to help students with analysis and synthesis of information.

Conclusion

Case studies can be used to teach students to think more critically through a process of reading case studies, finding the problems embedded in the case, and trying to find solutions to the problems. The methods which the teacher uses to facilitate the case study process appears to be a factor in the depth of class discussion and the evolution of critical thinking skills as evidenced by student statements regarding analysis, synthesis, and evaluation of the case and questioning by the teacher to guide student thought. Venn diagrams, tables, and time lines are tools that can be successfully used to guide student thought to bring about higher order critical thinking skills. The case study approach appears to stimulate student interest in learning science, but resources need to be available for the student; an Internet conference is one way that this can be accomplished.

Future Research

More research needs to be done to determine the relationship between professional development of teachers in case study facilitation and critical thinking skills exhibited by students; techniques used by the teacher to help students with analysis, synthesis, and evaluation of case studies; the evolution of the case study discussion in the class; and guided questioning techniques employed by the teacher.

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