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THE EFFECTIVENESS OF A MOBILE HANDS-ON SCIENCE PROGRAM IN GRADES FOUR THROUGH SIX

by

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ABSTRACT

THE EFFECTIVENESS OF A MOBILE HANDS-ON SCIENCE PROGRAM IN GRADES FOUR THROUGH SIX

By

Kathleen Sledge Lovgren

The purpose of this study was to evaluate the effectiveness of a mobile hands-on science program, known as The Science Van . The Program's objectives were to motivate elementary and middle school teachers to improve their teaching practices and attitudes in science as well as to improve student conceptual understanding through hands-on science activities. The study compared three methods for science lessons: Textbook based, Video based and Science Van based. The study involved sixty-eight teachers from grades four through six with eighteen hundred students from Mecosta-Osceola Intermediate School District. The statistical analysis of the improvement means from pre-test to post-test scores showed no significant differences between methods. This analysis was based on classroom averages rather than individual student improvement, and on a test that may have been too difficult to detect improvement. The study also showed that although teacher attitudes toward science lessons have improved since their exposure to the Science Van program, the amount of time spent on science activities has not increased. Student interviews revealed a preference towards the hands-on approach .

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Two interconnected questions are addressed in this thesis: 1. How effective has the Science Van program been in terms of teaching science content to students? 2. How effective has the Science Van program been in terms of improving teacher practices and attitudes toward teaching science?

The Science Van Program was initiated in 1989 in an attempt to increase and improve science instruction in grades K-6 in all schools within the Mecosta-Osceola Intermediate School District (M.O.I.S.D.). The proposal to fund the Science Van program arose at a time when state and federal funds were available for new and innovative programs designed to find solutions for our ailing educational problems in mathematics and science. Judging from the quantity of literature, papers, and reports in 1988-1989, many people were concerned about improving science education nationwide as well as statewide. The 1988-89 Michigan Educational Assessment Program (MEAP) science scores prompted many educators to question and reevaluate science education in Michigan. This test was given to students in the fourth, seventh and tenth grades across the state every year to assess "essential literacy" in reading, mathematics and science. Its purpose was to measure the percent of students with acceptable responses to questions that they "should know" at that grade level. Test scores show a steady decline from elementary to high school in both mathematics and science (Table 1). The reading scores showed a less dramatic decline from elementary to high school.

Table 1
Statewide and MOISD MEAP test scores from 1988-89 showing the percent students who scored 75% or better. The scores from students within the Mecosta-Osceola Intermediate School District (MOISD) are indicated below the state scores.

	4th	7th	10th
Mathematics			
State	87.1	71.8	68.5
MOISD	87.4	67.4	68.3
Science			
State	41.6	27.0	29.0
MOISD	51.7	38.1	28.8
Reading			
State	83.0	83.7	81.4
MOISD	84.0	83.5	81.2

Since 1983, when the report *A Nation At Risk (1)* warned of the decline of American education and its implications for America's continued "preeminence in commerce, industry, science and technological innovation," over 100 national reports have appeared calling for improved science education and proposing a variety of reforms.

According to the report *Science For All Americans, Project 2061* (2), the problem with science, mathematics and technology education can be narrowed to three things:

1.) Few elementary school teachers have even a rudimentary education in science and mathematics, and many junior and senior high school teachers of science and mathematics do not meet reasonable standards of preparation in those fields.

2.) The present science textbooks and methods of instruction, far from helping, often actually impede progress toward science literacy. They emphasize the learning of answers more than the exploration of questions, memory at the expense of understandings in context, recitation over argument, reading in lieu of doing. They fail to encourage students to work together, to share ideas and information freely with each other, or to use modern instruments to extend their intellectual capabilities.

3.) The present curricula in science and mathematics are over-stuffed and undernourished. Topics are taught over and over again in needless detail; some that are of equal or greater importance to scientific literacy are absent from the curriculum or are reserved for only a few students.

According to Anderson (3), science teaching has not changed much in the past fifty years: it is fact oriented and didactic. The instructional pattern typically consists of students reading outdated textbooks followed by answering factual questions posed by either the teacher or the text. Topics covered have little to do with student interests and are perceived by the student to have little to do with their lives outside the classroom. Textbooks depict science knowledge as consisting of content or an array of facts, definitions, and formulas. The age of technology and communication has on the one hand brought new and infinite possibilities for acquiring information to American students. On the other hand, the potential for abuse is great as TV shows and videos substitute for real life, hands-on experiences and investigations. Nor does the once- or twice-removed, symbolic world of school (via textbook learning) constitute an enriched environment. Most of today's students do not bring sufficient prior experience of the real world with them to the school to allow them to profit from reading or writing in the abstract. (3)

There is a general consensus that teaching practices in science need to change. In fact, teachers have been handed new dictums and fads in educational methodology since 1920. Over the past seventy years they've been told to teach less, teach more, teach depth not breadth, teach process, teach conceptual, teach inquiry, teach holistic, teach hands-on, teach for the test and so on and so on. Most experienced elementary teachers are often understandably skeptical about adopting "new" methods every two to three years. In addition, they are expected to adapt to regular changes in teaching methods for reading, mathematics, social studies and language arts as well. Teachers have reported to me that adopting new programs takes a great deal of time. Classroom time, therefore, is a major constraint to new program implementation.

Most K-12 educators will agree that a change is urgently needed, but disagree about how to improve the teaching practices of public school teachers in any grade level. The American Association for the Advancement of Science (AAAS) has prescribed a systemic treatment in its *Project 2061 report, Science for All Americans (2)* which provides a clear, straightforward exposition of the particular ideas, skills, and attitudes that students should acquire:

* increased emphasis on the nature of and connections among science, mathematics and technology
* reduced emphasis on boundaries between disciplines and increased connections across them
* increased emphasis on common "themes" of fundamental ideas across disciplines

* increased emphasis upon scientific habits of mind

* increased emphasis on instruction through guided inquiry and problem solving

* decreased emphasis on traditional presentation, cookbook laboratories, and rote learning.

According to this report, to be effective, the professional teacher needs appropriate preparation, continuing education, and organizational, technological and community support. The National Science Foundation has launched a major new program designed to find a cure for the deteriorating state of science and mathematics education entitled Statewide Systemic Change Initiatives. (4) The major focus of this initiative is to work simultaneously on all components of the systems affecting science and mathematics education, including teacher training and professional development, facilities and equipment, articulation within the system, improvements in technology and the training of teachers to use it effectively. The initiative recognizes that teachers tend to teach as they themselves were taught. Therefore, changes in teacher education, both life-long as well as in preparation for teaching at the college level, will need to be made in order to achieve long -term changes in the system as a whole.

The watchwords for the current movement for reform in science and mathematics education have become "scientific literacy" and "mathematical power". The major tenet of this movement is reduced emphasis on factual details and rote procedures, and increased emphasis on ideas. In essence the report emphasizes the "less is more" approach which encourages teachers to concentrate on a relatively small number of central ideas, and treat them in depth. One report bases its assertions on the "profound changes in our economic and civic life, together with pronounced changes in the make-up of our population, pose a tremendous new educational challenge for the nation: science literacy and mathematical power." (4)

According to most studies, the majority of teachers from upper elementary through high school use the traditional textbook based approach to teaching science. (5) A few teachers rely on videos for science lessons and even fewer utilize hands-on activities. The following section summaries four styles of teaching according to a variety of educators (2), (3), (8), (9), (10). These styles were integrated into the Science Van's teaching styles in ways that will be discussed later.

1. Traditional textbook based method is straight forward--the students are assigned a chapter to read in the book, define new vocabulary words, answer the questions at the end of the chapter. The teacher discusses the concepts in review for a test that requires students to recall facts and definitions. The results of this method of instruction have been evaluated by most national and statewide achievement tests with discouraging results. As students advance from elementary level to high school, their MEAP scores in mathematics and science go down, not up. (see Table 1 and Table 2) Many teachers substitute or supplement their science lessons with video tapes which are used as a visual textbook. Students have grown up with this media and prefer it to reading. For many students the visual world provided by a good video can be very helpful in understanding science concepts and processes. Whether or not a video for today's students can substitute for hands-on experiences is doubtful, but it may be better then relying on only written methods. Both are "passive" teaching methods, in that the teacher doesn't have to understand, or enjoy the materials. Also, the focus is on content, not process.

2. The Inquiry Perspective contends that students will develop a better understanding of the nature of science and will be more interested in science if they are engaged in "doing" science. Student investigations of phenomena (not textbooks) are the backbone of the curriculum, and the focus of these investigations is on the use and development of science inquiry or process skills- predicting, hypothesizing, observing, recording data, making inferences and generalizations, etc. Students are viewed as young scientists who explore phenomena through hands-on activities and who use and develop scientific thinking skills to build up knowledge and conceptual understandings in the same ways that scientists use experimental work to construct new knowledge, concepts and theories. There is sufficient evidence that just doing more activities may be fun, but little conceptual understanding is gained in the absence of a conceptual framework. (8) The inquiry perspective in isolation from conceptual understanding does not help students gain a deeper understanding of the topic. For example, just giving students a set of magnets and a variety of materials to test, does not automatically clarify magnetism to the students.

3. The Science-Technology-Society Perspective (STS) is one of the most recent 'models on the Market'. This method argues that the overarching purpose of school science is not to create future scientists, but to create citizens who understand science in multidimensional, multidisciplinary ways that will enable them to participate intelligently in critical thinking, problem solving, and decision making about how science and technology are used to change society. (9)

The STS perspective is human and society focused, problem centered and responsive to local issues. As in the inquiry perspective, students are seen as active learners, but the activities they engage in are focused on using scientific and technological knowledge needed to solve problems and make decisions rather than on creating scientific knowledge. The content selection is based on its potential to solve the problems facing society at the moment. The effectiveness of this model has not been evaluated. One concern with this model is that students may come to view science and technology as evil and threatening or as a panacea for all that ails the planet. The challenge to teachers is to show how science and technology can both cause problems and help solve problems. For this method to be effective, teachers must have a strong background in scientific content and processes and know how the two are inter-related and then pass this information on to their students. According to Roth (10), instruction that involves students using scientific processes to change their own theories in ways that are personally meaningful and consistent with scientific explanations provides a powerful alternative to process-focused instruction.

4. **The Conceptual Change Perspective** is somewhat similar to STS view as scientific knowledge is meaningful to learners only when it is useful in making sense of the world they encounter. It is different from the STS view in that the issues need not be centered around societal issues. Scientific knowledge that can be used by learners is characterized by making connections between concepts and facts and is organized around key ideas in ways that make the knowledge accessible and able to provide broad explanatory power. This set of connected knowledge is flexible and constantly changing as the learner revises, reorganizes and deepens understandings of science principles over time - an active, conceptual change view of learning and knowledge growth. (10)

According to Watson (11), this method prescribes the integration of science processes and conceptual knowledge in ways that better reflect the complexity of science itself. The method recommends that concepts be tightly woven into the processes, and that both processes and concepts connect with the students' own personal experiences with natural phenomena and prior knowledge to provide a broader basis of understanding. Students use experimental observations as well as teacher explanations to help them rethink their ideas. Their ability to apply these concepts to a variety of real-world phenomena is a reflection of the students' conceptual understanding of the principles being studied. (11)

The Science Van's teaching style combines elements of all four of the teaching styles mentioned above, with a primary focus on hands-on activities. The activities stress science processes or are designed to stimulate curiosity and questions in students minds rather then focusing on particular facts. Written materials are provided for students and teachers to use as references and extension activities after the hands-on lessons.

In 1989 the Department of Education in Michigan made grant money available to develop new, innovative teaching methods which could easily be replicated once proven to work. I wrote a proposal to fund a mobile hands-on "Science Van" in collaboration with the Gifted and Talented Consultant-Professional Development Coordinator, Paul Bigford, from the Mecosta-Osceola Intermediate School District. Initial startup money for the sum of $35,000 was granted to us under the *Exemplary and Demonstration Project Grant for Math and Science, Dwight D. Eisenhower Mathematics and Science Improvement Act of 1988, Public Law 100-297*. In 1991 the funding for the Science Van became more stable as it fell under the umbrella operations of a *Section 99 State Aid Act* establishing a few Math and Science Centers around the state, one of which was in the Mecosta-Osceola Intermediate School District.

Information regarding teacher practices in science education was gathered from K-6 teachers within the MOISD in 1989 prior to writing the proposal to fund the Science Van. Teachers responded to a survey designed to assess their backgrounds, practices and attitudes towards teaching science in their classrooms. Fewer then nine percent had taken any science classes in preparation for teaching. The average K-5 teacher in 1989 admitted that they don't teach science at all. The vast majority of these teachers stated that they did not understand many of the concepts they were being asked to teach and therefore avoided teaching physical science topics, science processes (scientific method) and stuck primarily to teaching about dinosaurs and other animals and occasionally about plants. Given this limited performance on the part of the teachers it appears that students were learning some science from someplace other then the schools in order to correctly answer even half the questions on the MEAP test.

Item analysis of the MEAP test showed that the students within the MOISD scored higher on questions where they had to read a graph or table, but were low on questions that pertained to interpretation of data, understand uses of the data and connections or draw conclusions. Life science scores were higher then Science Processes, Earth and Space Science, Science, Technology and Society, and the lowest scores occurring in Physical Science.

Table 2
Percent Students in MOISD Scoring 75% or better in Skill Area & Objectives on the 1989 MEAP test

	4th	7th	10th
Life Science	82	73	54
Earth/Space	61	60	49
Physical Science	62	49	49
Science,Technology and Society	73	55	58
Science Process	75	66	65

The primary function of the Science Van program centered around helping the elementary and middle school teachers help their students learn about the world in which they live. This required motivating teachers to change their attitudes and practices towards teaching science.

As founder of this program I had the freedom to present any topic in science that I wanted as well as sufficient funding to purchase enough materials so everyone in the class could participate at the same time. This "time share" concept has given me the opportunity to purchase equipment and materials that the home school teachers could not afford. I was able to showcase new and better methods for science instruction to teachers who lack the time or ability to try them out on their own. These teachers can determine whether they would like to purchase similar materials or equipment for themselves. I tried to model different approaches to teaching science other then the textbook based method .

The Science Van lessons combined technology with hands-on activities and written lessons in an attempt to showcase how science could be presented on a regular basis if they (the teachers) wanted to. I've noticed that technological aides such as interactive laserdiscs and computer assisted programs improve student interest levels in content. I often supplement the "lecture" part of the Science Van program with interactive laserdisks which bring science alive with the addition of full motion. It has been my experience in working with scientists in medical research that scientists utilize technology as much if not more than written materials.

Although funding is still a major obstacle, almost every classroom currently has computer technology and VCR's at their disposal. All too frequently, however, these technologies substitute for real life experiences (videos), or are used by only a handful of students who have completed their lessons (computers). The teaching style presented during the Science Van visits was designed to provide both the teachers and their students with ample opportunity to experiment with interactive technologies in conjunction with the hands-on activities performed by everyone.

It has not been a problem to motivate the students to do the hands-on activities provided by the Science Van program. However, getting their teachers to spend the time preparing the students for the hands-on activities provided during the Science Van visit has been a problem. After five years of operation, it has been my experience that students love to perform hands-on activities. Upon numerous occasions I've heard students say things regarding the activities such as, " This is even better then gym!" or, " Do we have to go to recess, couldn't we stay here a little longer." My biggest concern was whether they were learning anything in addition to having a good time. I wondered if any significant conceptual changes could occur with just one hour of the Science Van, four times a year. Therefore, I wanted to find ways to motivate the teachers to do pre-visit activities in preparation for the Science Van and/or post visit follow-up activities. Pre-visit teacher packets were mailed to each teacher two weeks in advance of their assigned visitation date. These packets had a variation of age-graded activities and background information from which the teachers could pick and choose to prepare their classes for the Science Van day. I noticed that whenever the teacher had done some of the pre-visit activities or discussions, their students were able to get down to work faster, and be more focused and ask very good questions. The majority of teachers, however, would bring their class to the activities without even knowing what was being presented. How much conceptual understanding was gained seemed to be proportional to the amount of time spent by the teacher in preparing the class for the day of the visit activities. The teachers were encouraged to choose activities which were geared for their grade level from the materials sent to them. Both written and hands-on activities and the necessary materials to do them were provided to introduce or reinforce the topic to be covered by the Science Van visit. Pre-tests as well as post-tests were made available as well. In spite of everything we gave them, the majority of the materials went unused.

Approximately 75% of the teachers did nothing to prepare their classes for the Science Van visit. Therefore, we asked them to fill out evaluation forms requesting their input as to the usefulness of the program and how we could change it to get better teacher involvement. Only 80 teachers out of 225 returned the forms. The results of this survey can be found in Appendix A.

The majority of those who took the time to fill out the yearly evaluation form stated the main reason for not participating in the science van units was that they lacked the background required to teach the particular topic or felt their background was out of date and too sketchy to feel comfortable answering student questions. Many confessed a "phobia" for science which they stated came from their experiences while attending school.

The second most frequent reason was the lack of preparation time to set up labs as well as no money to purchase the necessary materials or equipment to perform hands-on investigations. Elementary teachers do not have "prep" periods like Middle School and High School teachers do. They also have to prep for many content areas besides science. Without a mandate from the administration to include science in their lesson plans, the majority of teachers avoided science altogether. Those who did include science lessons on a regular basis did so because they like science themselves. The number of teachers with science majors or minors in their educational background was less than nine percent.

In the past year new excuses include statements such as " the topic does not fit into my curriculum, therefore I cannot justify spending too much time on preparing for your visit, or " the materials were not appropriate for my students age", or "there is too much materials or too little materials" and so forth.

After four years of operation, I felt it was time to measure the degree of impact the Science Van program was making on both teachers and students. This is the focus of this thesis. Some questions I hoped to answer were: How much information can be assimilated by students and their teachers in just one hour of activities? Would a good video be just as useful? What if teachers had access to some of the latest and best written materials? It seems common sense that if teachers utilized a variety of media to present science concepts, that students would stand a better chance of learning from one or more of the learning styles. But, if classroom time is short, which method would have the greatest gains by itself? In an attempt to answer these questions, I designed a unit based on groundwater and attempted to measure student conceptual changes based on the three models of teaching discussed earlier. Furthermore, teachers in the study were surveyed in an attempt to assess changes in their attitudes and teaching practices in science since their experiences with the Science Van program.

II. METHODS AND MATERIALS

Demographic Description:

There are five, primarily rural, school districts within the geographic area served by the MOISD programs. Twenty-two percent of students and families within the area of this study are designated to be below the national poverty level as determined by the 1990 Census Poor data from Mecosta-Osceola Counties. Not included in the census were students who are bussed in to our ISD schools who live in outlying adjacent counties. One of these counties is ranked as the poorest county in Michigan and in the top 10 poorest counties in the nation. Student exposure to the world outside their small towns, trailer court or family farms is often limited to a weekend trip to K-Mart in Big Rapids. The Science Van program has brought hands-on science activities on a regular rotational basis to 238 Kindergarten through sixth grade teachers and over 5,000 students in 18 different buildings in five school districts.

Design and Implementation of Thesis Study:

After four years of operation, I wanted to assess the effectiveness of the program. Therefore, I picked Groundwater and You as the content theme around which I gathered data to answer two questions:

1.) Was there any difference in average classroom pre-test and post-test scores between traditional methods of instruction compared to the Science Van's methods.

2.) Has the Science Van program motivated teachers in the MOISD to improve their teaching practices and attitudes in science?

I narrowed the student population to be tested to fourth, fifth and sixth grades only. Data was gathered from over 1800 students, 78 classes and 68 teachers within the Mecosta-Osceola Intermediate School District. Each teacher in the study population was assigned an identification number. This helped me to keep track of the school district, the grade level and a variety of other information gathered in teacher surveys (Appendix A and B). All correspondences, surveys and class pre-test and post-test results were keyed to the teacher number. Three different methods of delivering groundwater content to students were carefully designed to best fit the methods described in the introduction: traditional textbook based, "visual" textbook based, and inquiry plus conceptual change perspective. The latter best represents the methods used during Science Van activities and lessons.

Table 3
The three different teaching methods used to present the groundwater unit had some features in common and some unique to the method.

Method A:	**Method B**:	**Method C**:
Pre test Content = written materials followed by teacher reinforcement Post test Science Van video optional	Pre test Content= video followed by teacher reinforcement Post test Science Van written materials optional	Pre test Content= hands-on Science Van Instructor- guided activities Post test written and video materials optional

Teachers were instructed in person and in writing regarding the design and intent of this study during a visitation at least one month prior to the start of this Science Van unit (see Appendix G). This letter also invited them to attend a four hour teacher inservice on the topic of groundwater which was offered after school and included dinner and provided a small stipend plus a $100 groundwater simulation model for those who attended. Dr. Richard Passero, Director of GEM from Western Michigan University's Institute for Water Sciences, was the workshop guide. He lead the teachers in many hands-on activities which were previews of the activities their students would perform during the Science Van visit (regardless of the method). The teachers were guided in constructing and operating their own, state-of-the-art groundwater simulator model which would be used in the hands-on activities during the Science Van visit. They also previewed a variety of hands-on activities and demonstrations which would be used during Method C. Only 10 out of the possible 68 teachers came to this inservice. Of the ten teachers attending, only three had any type of science classes during their college preparation for teaching. The teacher evaluations for the workshop were outstanding. They left with great enthusiasm regarding the subject and said they felt confident in presenting the concepts to their students. These teachers took the same pre-test that their students would take and were given written materials designed by GEMS to take home. It was interesting to note that three out of the ten teachers attending this inservice were sixth grade teachers from one school who decided to ignore the random distribution of method assigned and changed their method to that of the Science Van only. This reduced the number of sixth grade classes with Method A and B (see Table 4).

Students within each class were identified on the pre-test and post-test by their teachers' number rather then as individuals. It was assumed that if the method was effective in terms of improving student understanding of concepts, the gains made between average classroom pre-test scores and post-test scores would be a good indicator of the effectiveness of each method of instruction. Teachers drew a slip of paper of a paper bag to determine their assigned method at least two weeks prior to receiving the teaching directions and materials(see Appendix C and F). An attempt was made to evenly distribute method type across the three grades and five school districts to provide statistics between grades as well as between methods.

Table 4
The number of classes for each grade level and method varied when some teachers self-selected the method they wanted to teach instead of staying with the method that was originally assigned to them.

	Method A	**Method B**	**Method C**
Fourth Grade 25 classes	9	9	7
Fifth Grade 28 classes	12	9	7
Sixth Grade 25 classes	6	6	13
Totals: 78 classes	27	24	27

Review of teaching strategy common to all three methods

The topic of groundwater was chosen because 1.) The nature of the topic lent itself to discussing a great deal in a short time from the standpoint of science concepts, processes, and societal issues. 2.) The issues were interesting and had real world applications for the student. 3.) The effects of water pollution on human health as well as wildlife is not only interesting but the information gained could be useful in the daily lives of the students and their families. 4.) It did not appear in ANY of the schools' curriculum at that time, nor was it mentioned in any of the textbooks being used in grades four, five or six. The sixth grade book at one school dealt briefly with the water cycle in terms of evaporation, condensation and precipitation with no mention of what happened to the water that soaked into the ground. The environmental issues surrounding water pollution and human health were not mentioned in any other subject area taught in these grades.

Process skills were also incorporated in the hands-on session. For instance, students had to predict and measure which type of earth material would allow water to move through it the fastest; take the longest; hold the most water, touch the materials, write observations, measure volume and mass changes, record drainage time, and draw conclusions. Many tried to erase their prediction if their results were different. This provided a good opportunity to explain how real scientists perform experiments and adjust their concepts according to the results. The general objectives for this lesson to be assessed in this lesson for all three methods were as indicated below:

Unit Objectives:

* Students will understand that groundwater fills the spaces between soil particles and that water can move through the ground by the force of gravity.

* Students will gain an understanding of permeability, the relationship of permeability to porosity, and the relationship of both to groundwater movement.

* Students will understand that groundwater is related to surface water and to all other forms of water found on earth through the hydrogeologic cycle.

* Students will understand that pollutants travel with the groundwater and become aware of factors affecting the quality and quantity of groundwater

in their own regions.

* Students will understand how underground layers of soil and rock which can yield water to pumping wells are called aquifers and layers which do not hold or transmit much water are called confining layers or aquitards.

Pre-Test and Post Test Design:

Students were given the pre-test prior to receiving written materials or participating in classroom discussions. Teachers were asked to complete the groundwater lesson within one week's time. Some teachers, however, reported to have taken over a week to complete the unit. Some teachers gave it to the students to read at home or in class without a follow-up discussion. Students of Method A and Method B took the post test before the Science Van visit. Students of Method C took only the pre-test before the Science Van visit and took the post-test the day after the Science Van visit. The post-test was identical to the pre-test (see Appendix C).

Twenty-five multiple choice questions relating to the key scientific principles of the unit were selected to represent answers obtainable by any of the three methods of instruction. Great care was taken in writing the questions to ensure that students with lower reading abilities could understand the question being asked. I wanted to find out what they knew, not whether they knew how to read a question. Therefore, teachers were asked to read the questions out loud along with the students but not to coach them into possible answers. The post-test was identical to the pre-test. Each question had as a possible answer " I don't know". An equal number of test questions were included to represent all three methods. Graphics and visuals were included on the test which came directly from the written materials presented in Method A . Questions that were particularly well presented by the video from Method B were also included as well as processes that might be better understood by Method C.

Students were instructed in filling out a Scantron answer sheet. For many, this was a new experience, and the idea of taking a test on material they had not studied was a source of curiosity. During a teacher videotaped interview, an interesting comment was made by a fifth grade teacher. " The students were interested in knowing why they were taking a test before they even studied the topic. We got into a neat discussion about how scientists do research and all. The questions presented in the pre-test actually stimulated a good discussion and raised their curiosity." Several teachers using Method B (the Video) remarked that the students focused in on parts of the video that provided them with answers to some of the questions they remembered on the pre-test.

There were two categories of questions on the pre-test/post-test: 1.) "Concepts & Processes" and 2.) "Nature of Science". A selection of eleven " Concepts and Process" questions covered material considered critical to the understanding of specified concepts and processes for the unit. A selection of nine "Nature of Science "questions tested student awareness of some of the important ways in which science and technology not only create problems but also provide solutions. The Nature of Science questions were designed to see if students could apply the concepts they were given to new situations. These questions required them to connect certain science concepts to environmental concerns. An attempt was made to design the questions so as not to favor any one particular method.

The statistical analysis was done on a mainframe computer at Ferris State University's School of Business using the SPSS program as well as on a PC using the Minitab program with Dr. Michael Cooper, Ph.D. in

Applied Statistics serving as my statistical consultant. The analysis of variance is included in Appendix D.

Method A: Written materials followed by teacher reinforcement

The written materials were reviewed in consultation with fourth through sixth grade teachers to ensure the level of reading was appropriate for the age of their students. These written materials were selected based on simplicity of explanations of concepts with clear graphic illustrations to accompany them. Many sources of information were reviewed. Those providing the best written information were included in the teacher packet. This teacher packet included everything needed to teach the unit: Teacher background information, glossary of terms, a scripted Discussion Guide (see Appendix F) and an assortment of student reading materials, crossword puzzles, and a selection of word games all covering groundwater concepts from GEMS materials (6). Care was taken to include information that would also be delivered by the other two methods. The packet of information for this method was given to the teachers three to five weeks prior to the date of the Science Van visit to their school.

Teachers were asked to follow the Discussion Guide as closely as possible, and not to skip or omit any question and answer. It was recommended that teachers read the material out loud along with their students and conduct a class discussion afterwards. Teachers were given a variety of materials from which to choose because of great variability of abilities within and between each grade in the study. I assumed a degree of professional responsibility on the part of the teacher to pick and choose materials that fit their students' abilities. In the past I have attempted to pick materials which seem appropriate for their grade level only to be corrected and told that they would like to decide for themselves. Other teachers have told me that too much material is too overwhelming that they cannot take the time to pick and choose. These teachers preferred that I give them only one activity or lesson to accomplish for each Science Van unit. Other teachers really appreciated a diversity and enjoy selecting from the materials provided.

After careful consideration of numerous age appropriate written materials, I found the following materials to be the most useful, and included them in the teacher packet for this method:

1.) *Classroom GEMS (Groundwater Education in Michigan Schools)- a statewide K-12 Groundwater Curriculum (7)* GEM is a comprehensive effort to encourage the development of local, action-oriented groundwater protection projects.

* *Get Wet!* Utilizing pictures of globes and maps, students observe the abundance of water on the earth and discover its availability and usability as well.

* *Water Wheels:* Students read and discuss the role of circles and cycles. They learn the basic parts of the water cycle and look at drawings connecting the water cycle to groundwater, aquifers, and surface water.

* *It's a Wet, Wet World:* Students look at pictures of Earth and become aware of the limited amount of fresh water available for human use.. They are asked to discuss the importance of protecting and conserving water.

* *Dirty Water Underground:* Students relate the history of groundwater contamination in Michigan and use this information to discuss ways they can change their water-use behaviors.

* Glossary of Terms

2.) GEM Groundwater Transparencies (7).

The Hydrologic Cycle:

The Hydrologic Cycle Graphic

Water in the Hydrologic Cycle (table)

Precipitation and Runoff in Michigan (map)

Porosity and Permeability of Selected Materials (table)

Aquifers - geologic cross section

Geologic History and Hydrogeology of Michigan

Water and the Law- Environmental Laws both Federal and Michigan

Uses of Ground-Water, sources in Michigan

Ground-Water Quality in Michigan- chemical and physical characteristics

Groundwater (table); Health Effects of Selected Contaminants- inorganic and organic

Ground-Water Contamination

Ground-Water Protection

Conservation

3.) *Water Wisdom (13)* word scrambles, student worksheets, cross word puzzles and groundwater literacy test

4.) *Groundwater Contamination (14)* *What is Groundwater? (15)*

Where Groundwater Comes from: Permeability, Porosity, Aquifers, The Water Table, Groundwater Flow Rates

Groundwater Contamination: Septic Systems, House and Chemicals, landfills, underground storage tanks, Wells

Method B: Video followed by teacher reinforcement

The 1991 video "It's Found Underground: Groundwater, Our Buried Treasure" (6) production was sent to all teachers using Method B. After previewing eight other videos on this subject, I found this one to be the best in terms of content as well as being appropriate for the age of the students.

This video was aimed at teaching upper elementary and middle school students the importance of conserving and protecting groundwater. Its focus on the Great Lakes gave students an opportunity to relate the lessons to situations of concern within their own geographic area. The video provided students with an opportunity to visualize groundwater concepts and processes through motion in contrast to still graphics or written descriptions. Both teachers and students reported to me that they liked the video and found it both informative and entertaianing. They reported the video to be a combination of humor, charm and informative dialog which helped clarify many points and hold attention spans.

The video was divided into three segments which concentrated on water conservation and pollution and the effects of solid and household hazardous waste on groundwater. Teachers using the video method were provided with the same Discussion Guide (see Appendix F) that was given to those teachers using the written method. Teachers were asked to cover each question and go over the answers as outline in the Discussion Guide during a verbal briefing prior to the beginning of this study. They were also given directions by means of a written letter (see Appendix G). Care was taken to ensure that the information necessary to answer the questions in the discussion Guide could be obtained by watching the video. The content provided in the video closely matched the content available to Method A students. The materials for this method were sent to the teachers at least three weeks in advance of the scheduled Science Van visit. Students took the pre-test prior to viewing the video and the post-test within two days after watching the video. The post-test was completed prior to attending the Science Van activities.

Method C: Hands-on activities guided by the Science Van Instructor

During a brief introduction to the unit, students were asked to explain where they thought their drinking water came from and whether it was safe to drink. After listening to their answers, I performed some simple demonstrations to introduce vocabulary and explained what they were going to do to find answers to the introductory questions mentioned above. Parent and/or community volunteers had been trained to supervise activity stations which were set up from the Science Van in a multipurpose room or gym. Each station had the same set of materials and models for students to explore. Students were divided into small groups and stayed at one of six possible stations. Each station was self-contained and provided the students with all the activities required. The volunteers were given a list of questions to ask their groups of students and were asked to help guide students in conducting the experiments and arriving at acceptable conclusions. Some of the following activities are included in Appendix E. A diagram of the Groundwater Simulation Model can be found in Figure 1.

Demonstration #1: Water Table, Aquifers and Wells

Demonstration #2: Porosity and Permeability

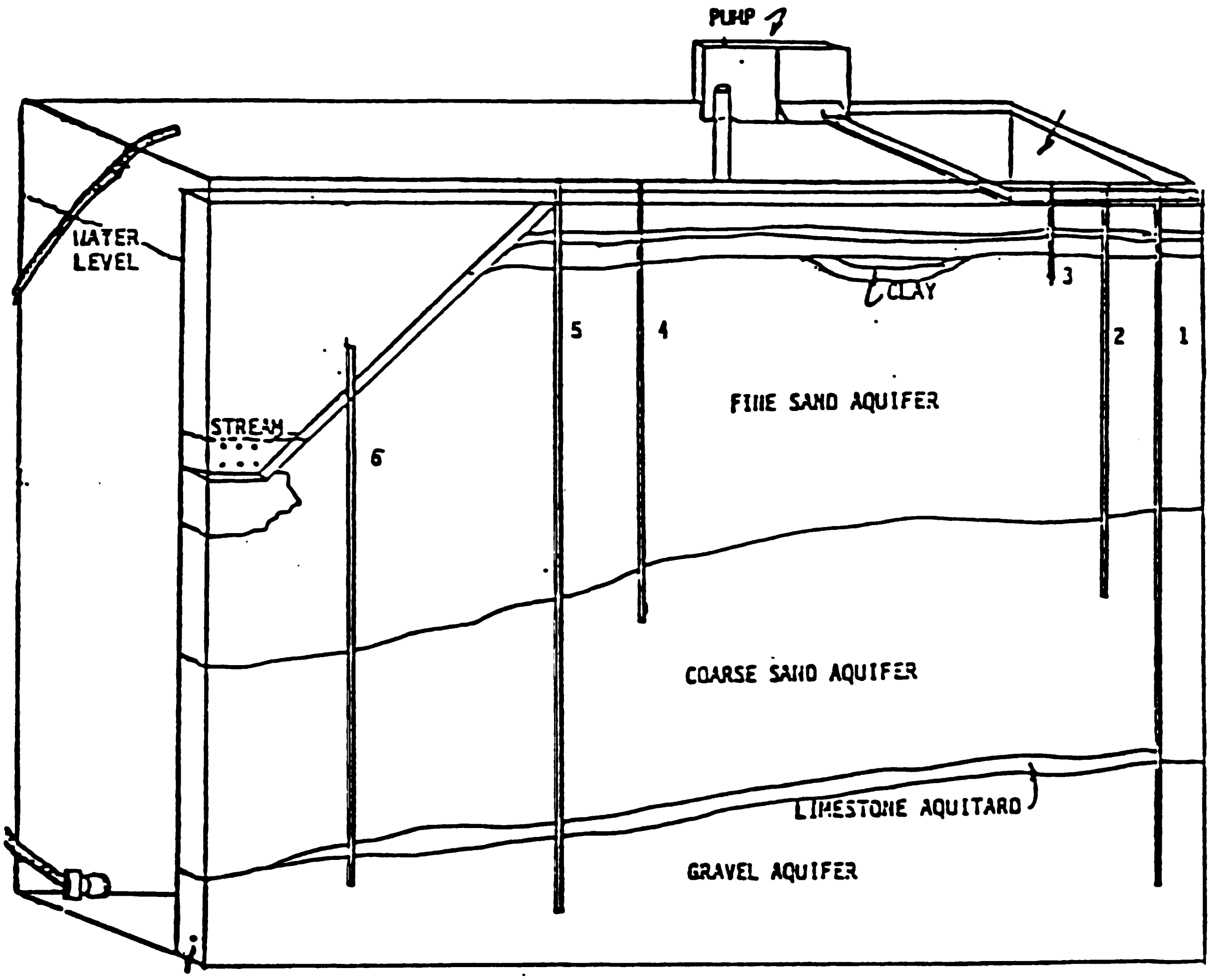
Hands-On Activity #1: Porosity

Hands-On Activity #2: Permeability

Hands-On Activity #3: Groundwater Simulator Models- cross sectional models typical of Michigan hydrogeologic layers (see Figure 1).

Figure 1

This is a graphic representation of a Plexiglas groundwater simulation model which was used during the Science Van unit for Method C students. The model is portable and gives students a good opportunity to visualize groundwater movement and contaminant flow.



The groundwater simulator models were constructed by teachers who attended the pre-unit workshop mentioned earlier under the direction of Dr. Richard Passero from the Institute for Water Sciences, GEM Regional Center located at Western Michigan University in Kalamazoo, Michigan. This groundwater model depicted three sand and gravel aquifers and one aquitard. The uppermost aquifer is find sand and represents an unconfined (water table) aquifer. The middle coarse sand aquifer is also an unconfined aquifer but is more permeable due to the larger size particles and interconnecting spaces between the particles. The confining layer (aquitard) is a pulverized, fine-grained limestone or clay material. This layer does not extend across the entire model so that the underlying gravel aquifer can be recharged with water on the right which can be discharged to the stream on the left. At the bottom of the model is a confined (artesian) gravel aquifer. The base of the model can be considered as an impermeable bedrock aquiclude. The vertical tubes represent wells of any kind (drinking water wells, wastewater disposal wells, deep injection wells for hazardous waste, etc.) and are also used to inject dyes into the aquifers to illustrate groundwater and contaminant flow. The level of the water in the wells (tubes) represents the static water level surface which can change as the amount of precipitation changes.

Red food coloring was used to demonstrate groundwater flow and the movement of contaminants. Students injected the dye into any layer and pumped water from any layer using plastic syringes and aquarium tubing which could be lowered down the wells into any of the layers. The model was used to address three important questions about groundwater:

1. How much groundwater is there?
2. How long does it take for groundwater to move?

3. How does groundwater contamination occur, and can it be cleaned up?

Activities addressing the three major questions were:

1. Students adjusted the aquarium pump to create periods of "heavy to light rainfall" as well as periods of "drought." Students observed the relationship between the level of the water table and the amount of precipitation (recharge).
2. Students observed the direction and rate of flow of the water in various layers from higher areas to lower areas, and into river and lakes.
3. Students injected red dye into aquifers above and below the confining layer and observed the direction and flow of a simulated contaminant.
4. As the students pumped water out of various wells, they tested their predictions relating to rates of withdrawal or yield from various aquifers. They observed what happens to the water table as wells pump water out for human activities faster than the water is replaced by natural processes.
5. Students simulated dumping contaminants onto the surface of the land and observed how this affected the simulated groundwater. Students concluded that wells can become contaminated as pollutants travel with the groundwater.

To conclude the lesson, students returned to their seats and were allowed to ask questions or respond to my questions. Students observed how hidden contaminants can end up in lakes and other sources through a demonstration. (7) The teachers were given a variety of follow-up activities to take back to their classroom: Discussion Guide (see Appendix F), a landfill activity (see Appendix H), and a survey for students to take into their community. (7) Student completed the post-test within two school days after the Science Van visit.

Due to constraints on time I was not able to obtain any peer review other then from the 10 teachers attending the inservice regarding my choice of materials, demonstrations and questions provided during the Science Van Presentation.

1992 Teacher Survey Design:

The second objective of this thesis was to evaluate the effectiveness of the Science Van efforts in terms of encouraging teachers to improve their science teaching methods. Frequently teachers tell me they would do more science in their classrooms if the know more science and felt comfortable with the concepts. In the same breath they mention that a lack of materials and supplies also makes implementing hands-on activities difficult if not impossible. Therefore, in preparation for teaching this unit I attempted to correct these deficiencies by providing the teacher inservice on groundwater. I wanted to find out if teachers are given the training and opportunity to do hands-on activities themselves along with the necessary materials to take back to the classroom, would it improve their science teaching practices?

The sixty-eight teachers in this study were given a survey to complete prior to implementing their assigned method (see Appendix B). The purpose for this survey was to gather information regarding teacher attitudes and practices in teaching science. At the end of every school year, teachers complete an evaluation form for the Science Van Program (see Appendix A). The information from these surveys was useful in evaluating the second objective.

Student Interviews

A selected number of students from Method A and Method B were interviewed on the same day as their visit to the Science Van Activities and asked questions regarding unit content as well as how they preferred to learn about topics in science. Some students were questioned before attending the Science Van activities to assess their retention of certain content objectives. Some students of both methods were questioned after their Science Van visit to assess student opinions and preferences to methods of learning the content. Students from Method C were not interviewed until after their visit to the Science Van, but on the same day as the visit. All responses were recorded on video tape for later transcription and analysis.

Students selected for interviews were picked by their teacher or randomly picked by me. Teachers representing each method and grade level were asked to pick three students from their class to be interviewed: one lower ability, one average ability and one high ability. Approximately half the students interviewed were male and the other half were female. Students from all three grade levels were interviewed. The capabilities of the students were not revealed to the interviewer. Student responses were coded according to the method assigned by the teacher and the grade level. (see Results)

III. RESULTS OF THE STUDY

The results of the study are divided into two categories:

1.) student conceptual changes measured by differences in pre-test and post-test scores relating to the groundwater concepts along with student interviews assessing attitudes toward learning science in general

2.) teacher surveys to assess possible changes in teacher attitudes and practices in teaching science with their experiences with the Science Van over time.

Student Pre-Test and Post-Test Results

Class average improvement scores were determined by statistical methods for the two categories of questions as well as for the overall battery of questions. The scores for each method within a particular grade level were computed. The computer averaged the number of correct responses for these sets of questions per class and assigned this value to the particular teacher who was keyed in to a particular method of instruction and grade level. This set of means was labeled pre-test mean. The post-test mean was computed in the same manner. The difference between the pre-test mean and the post-test mean is labeled 'Improvement Means' in Table 5, Table 6 and Table 7.

Table 5
'Improvement Means' for all fourth grade classes between the pre-test and the post-test according to the method of instruction. N = the number of classes.

4th grade	METHOD A N = 9		METHOD B N = 9		METHOD C N = 7	
	mean	std. dev.	mean	std. dev.	mean	std.dev.
Concepts & Processes	1.85	.80	2.20	1.25	2.46	.61
Nature of Science	1.15	1.14	.95	.66	1.08	.59
Total Score	3.38	1.95	3.28	1.18	3.96	1.34

Table 6
'Improvement Means" for all fifth grade classes between the pre-test and post-test scores according to the method of instruction.

5th grade	METHOD A N = 12		METHOD B N = 9		METHOD C N = 7	
	mean	std. dev.	mean	std. dev.	mean	std.dev.
Concepts & Processes	1.92	1.53	2.14	1.01	1.96	.57
Nature of Science	.46	1.15	.65	.80	.49	.42
Total Score	2.85	2.70	2.87	2.61	2.66	.95

Table 7
'Improvement Means' for all sixth grade classes between pre-test and post-test scores according to method of instruction

6th grade	METHOD A N = 6 mean	std. dev.	METHOD B N = 6 mean	std. dev.	METHOD C N = 13 mean	std.dev.
Concepts & Processes	1.47	.75	2.2	.78	2.05	.51
Nature of Science	1.08	.58	.61	.45	1.18	.39
Total Score	2.43	.82	2.86	.72	3.66	.95

There was no significant difference between "improvement means" by method or grade level as statistically analyzed by ANOVA. The results are inconclusive at this point due to the small sample size as defined by teacher/method. This design limited our sample size to 59 when in fact there were over 1800 individual test scores that could have been analyzed. In retrospect, more resolution or power to measure student improvement could have been achieved had we measured individual differences instead of differences between entire classroom means for each method. Overall the scores improved by about three questions out of a total of twenty five. In addition, it is possible that the reason for no significant differences in improvement scores was due to the nature of the test itself. Although I had teacher input regarding the difficulty level of the test, it still may have been too hard for many students especially in fourth grade. The unwillingness of certain teachers to stick to their assigned method occurred most often with sixth grade teachers. (Table 7) Variability in teacher cooperation made the statistical analysis less valuable then it could have been. Some difficulties stemmed from teacher inability, or perhaps confusion, regarding the directions provided to them (see Appendix G). They were given a detailed outline to follow with samples of how to fill out the ScanTron sheets so that the data could be properly analyzed. Some of the teachers failed to adequately guide their students in filling out such information as gender, teacher identification number and method of instruction. Or perhaps some students had difficulties following directions. Some teachers administered the Pre-Test, but forgot to give the students the Post-Test which eliminated them from the sample population. Out of sixty-eight teachers possible in the study, only fifty-nine could be analyzed statistically due to the failures mentioned above. Another possible explanation for teacher failure to comply could be that they did not have ownership responsibilities and therefore considered themselves not accountable for student outcomes. The Science Van program needs to look more closely at how best to get teachers and students to learn science. This problem is not unique to the M.O.I.S.D. and is currently the focus of the Michigan Statewide Systemic Initiative program. (4)

1992 Teacher Survey Results

The overwhelming majority of teachers in the Mecosta-Osceola Intermediate School District (86.7%) responded in a 1992 yearly evaluation summary that participation in the Science Van program has changed their attitude toward science to where they stated they now liked science. Sixty percent of the survey respondents indicated that they have attended more classes, workshops or inservices in science in the past two years (Appendix A). This is up dramatically from the 1989 pre-Science Van survey which showed that twenty-one percent of K-6 teachers had taken a science related class in the past two years. The opportunity to attend science and mathematics inservices has increased due to the efforts of the Science Van program and other programs offered by our Intermediate School District. Since teachers from rural areas often have to drive long distances to attend such inservices, we have taken the classes to them. This improves attendance for those teachers who otherwise would not make the effort. The relatively low attendance for the groundwater inservice can in part be blamed on the fact that it was not offered at each individual school and those wishing to attend had to drive to one location which for some was inconvenient.

Teachers participating in the Groundwater Unit filled out a " Teacher Survey" prior to the beginning of the unit. (Appendix B) The results were interesting in that 63% stated they were more willing to take science classes in the last two years. This is a big improvement since the beginning of our program in 1989 where data gathered from the M.O.I.S.D. teacher certification files showed that fewer than 9% of all Kindergarten through sixth grade teachers in all five school districts had a background in science at the post high school level. Approximately 53% of the teachers in the study population of this thesis stated that they have started using scientific method as a backbone for investigations, and 49% are integrating science into other content areas. There appears to be a positive relationship between teacher enthusiasm and confidence level with increased student interest in science as reported by the teacher yearly evaluations as well as by teacher verbal reports to me based on their observations of student behaviors and comments regarding participation in Science Van activities.

In spite of this, teachers who said they liked science have not increased the amount of time they spent teaching science nor have they increased the time allotment for hands-on science. If anything, a large percent of teachers (77%) , if they teach science at all, utilize textbooks and written materials as the backbone of their science curriculum. This reluctance to change is not unique to the academic world, but is common among teachers who have taught for many years.

Although the amount of funding for certain equipment like computers and VCR's and curriculum materials has increased since 1989, it is interesting that the amount of time spent teaching science by any method still ranks in the bottom percentiles. When teachers were asked what they required the most to help them teach science better, eighty percent responded that they needed more funding to buy materials and supplies. Almost three fourths of the teachers stated that they do not use videos to help teach science and fifty percent felt inadequately prepared to use computer technology as a teaching tool.

Student Interview Responses

Student responses were coded according to the method assigned by the teacher and the grade level. (see Table 8) Typical responses to questions asked in the videotaped interviews were:

What types of things did you find interesting about the lesson?

Method A students typically responded by saying that they did not like anything about the written materials, or they were hesitant to respond at all. I believe they wanted to say something positive to please me and when I told them to just say what they really felt and not what they thought I wanted to hear, they responded quite negatively. The fourth graders were particularly at a loss for something good to say about the lesson and the older ones responded more honestly. Only one sixth grade girl responded that she liked reading the material. Several students and their teachers indicated that they liked taking the pre test and that it helped them learn. A few indicated that the lesson was "too adult" and the words were too hard to understand and that it was not fun. Some of the older students quoted some facts that they remembered from the readings like, the percent of clean water available for drinking, or where most of the freshwater is found, etc.

Method B students typically responded by saying "they really liked Mr. Drip," (a character in the video). The overall attitude toward the subject was positive. Student responses centered around conservation of water and landfills as possible sources of contamination. Some said that the pre test made them pay attention more to the video.

Method C students typically responded by saying they really liked to inject the dye (contaminant) into the groundwater models and watch how it moves through the different layers and into simulated pumping wells or into the river. Nearly every student from this method commented that they learned a lot about polluting groundwater and drinking water. Most students used the example of an oil spill or leaking underground gasoline tanks as a likely source of contamination.

Where does your drinking water come from and is it safe to drink?

Method A: Students typically responded that their water came from a well. An equal number did not have any idea where it came from other than the end of the faucet. When pressed to explain what was at the end of the pipe attached to the faucet, they would either shrug their shoulders and say " I don't know", or would explain that the pipe was "punched" into an underground lake or stream or pond. One student believed his water came from Lake Michigan or Lake Erie. Regarding the safety of their drinking water, about half of them stated that it probably was safe to drink and the other half said probably not safe. When asked why it was not safe, they typically cited landfills as a possible source of contamination.

Method B: Most students responded that their drinking water came from groundwater or a well which got it from groundwater. Quite a few stated that it came from rainwater, but later explained how that might get into the ground and to " a place that holds the water for our well." One sixth grade girl thought that it came "out of a box". About two thirds of them thought it might be contaminated and the others were fairly confident that it was safe. When asked what things would contaminate it they mentioned landfills, detergents, motor oil, pesticides and poisons. One student stated that there was a fifty percent chance her drinking water was contaminated (this figure was one of the choices in the pre-test) .

Method C students stated that most people's drinking water comes from a well or a pump. Many explained how water evaporates from lakes, rivers and oceans and falls to the earth as rain or snow and sinks into the ground where it becomes "well water." At least half of these students stated that most of the freshwater on the earth is polluted and would not be safe to drink without being treated first. Of those who said their drinking water would be safe, it was generally because they reported that it had been tested recently. About one third of these students repeated the story I told regarding the number of leaking underground gasoline or oil tanks and the threat these chemicals pose to living things. When students were interviewed during the activity itself, they used the dye to illustrate their point such as demonstrating how fertilizer can spread into streams or rivers and end up in unconfined aquifer or, that fish in polluted streams could become contaminated and pass it on to humans who eat them. They all said dumping of motor oil onto the ground should be outlawed because of how it floats and ends up in lakes, rivers and wells. They observed how oil flows as part of the groundwater model activities

What is an aquifer?

Method A: Only one student out of ten interviewed could answer the question even partly right and he said it was groundwater. These students were confused by the terminology of the question itself and could not correctly answer the question even after considerable prompting.

Method B: Students from this method usually stated that it was an underground layer of water. Some said it was the same as groundwater, and some said it is where we get our drinking water. Some students went as far as to explain that it was somehow connected to the water table and that it was related to the nearby lakes. Nearly all concluded that an aquifer was related to our drinking water. These students seemed to have a good grasp of the vocabulary and used it correctly. These students understood aquifers the best.

Method C : Students were still confused with the term aquifer, but when asked to point out the aquifer on the model had no trouble with the correct response. Some related their response to the results they obtained during the porosity and permeability experiments. (7) When asked which type of material would make the best aquifer, they were better able to respond by saying gravel or the one with the most interconnected spaces, like a sponge.

Table 8
Frequency of verbal responses to selected interview questions among students from all three methods and grade levels. N = the number of students

Questions	METHOD A	(N)	(%)	METHOD B	(N)	(%)	METHOD C	(N)	(%)
Which material makes the best aquifer? answer = gravel	sand	5	50	sand	8	57	sand	5	31
	clay	2	20	clay	1	7	clay	1	7
	gravel	3	30	gravel	5	36	gravel	10	62
	total N	10	100	total N	14	100	total N	16	100
How do you prefer to learn science?	hands-on	7	70	hands-on	12	86	hands-on	15	94
	computer	1	10	computer	0	0	computer	0	0
	video	0	0	video	0	0	video	0	0
	mixture	2	20	mixture	2	14	mixture	1	6
	written	0	0	written	0	0	written	0	0
	total N	10	100	total N	14	100	total N	16	100
Are you worried that your drinking water might be contaminated	yes	2	20	yes	10	72	yes	13	81
	no	5	50	no	2	14	no	2	13
	not sure	3	30	not sure	2	14	not sure	1	6
	total N	10	100	total N	14	100	total N	16	100

The best assessment of the results came from the student surveys.

IV. DISCUSSION AND CONCLUSION

Problems With the Groundwater Unit

The analysis of pre and post test results were not significant, but this result may not be an accurate reflection of student results. This is due in part to the relatively small sample size defined by the number of teachers rather then by the number of students in the study. If I had measured the differences from pre-test to post-test for each individual, there would be greater power or resolution to detect if there were differences based on the type of method of instruction. There may or may not have been differences, but they were too small for the statistical analysis to detect them. The scores of the students whose teachers attended the groundwater workshop are not significantly higher according to the statistical analysis. The nature of the test may have been too hard conceptually for these students and therefore, too difficult to be discriminatory. It would have been a good idea to administer the test to similar age students outside the study to evaluate the suitability of the test for the targeted age group. If my background in statistics had been greater the results of this study might have been more discriminating.

Interviews of students indicate that hands-on is strongly preferred.

I think the personal interviews and clinical observations made during the implementation provide the most reliable insight into student attitudes towards learning science. When students were asked to describe how they like to learn about science, not a single one picked textbook based science lessons over real life experiences and hands-on opportunities. Several mentioned that they liked to use computers as much as performing experiments. Their attitude toward discovering things for themselves by hands-on activities was very positive. This also suggests that lack of significance of the statistics is not an accurate reflection of learning. However, it is important not to confuse student preference with actual learning. Better methods for assessing student outcomes need to be developed and tested in science education as well as other content areas.

According to the sample population of students interviewed, those who had the video (Method B) or had the Science Van (Method C) for their method of instruction had a better understanding of how human activities on the surface of the land can cause the groundwater to become unsafe to drink. (see Table 8) During the interview these students would use oil spills or leaking underground gasoline storage tanks as examples of ways their drinking water could become contaminated. Many had stories to tell of local contamination sites or wells in their neighborhood.

Method B (the video) and Method C (the Science Van) provided the most standardized forum for delivering a consistent lesson. The written method had more inherent variability because its delivery depended largely upon the home teacher's level of enthusiasm and amount of interest in the topic. Some teachers failed to read the material out loud with their students and merely sent it home for them to do on their own. Other teachers assigned to the written method group, spent a great deal of time going over the materials as directed but there is no way of separating these classes out from the overall improvement means for their grade or method.

How does substituting video tapes for textbooks fare with students? In the past decade, some teachers have added video tapes to their repertoire of teaching methods and occasionally use an overhead projector if the school has one. If you ask the students whether the videos have helped them understand science better or given them tools which they can use outside the classroom, they will inevitably answer that their teachers use the videos to "baby-sit" them while they (the teachers) grade papers or step outside for other business. Teachers participating in this thesis study reported that they rarely use videos to help teach science. Usually, the VCR is used for indoor recess or to watch movies on special occasions.

It is interesting to note that not one student interviewed during this thesis unit picked watching videos over hands-on activities. Teachers reported that they do not utilize videos to teach science very often (Appendix B) However, when students were asked to rank order the three methods in terms of preference they all put videos after hands-on and before written, which came dead last in their opinion. It is possible that these students were trying to please me, but I prefaced the question by asking them to be honest and not worry about hurting my feelings. I think these students were being honest in their responses. I think a good videotape is a useful teaching tool, but should not be substituted for the teacher or for student hands-on experiences.

Impact of the Science Van program on Teacher Practices and Attitudes in Teaching Science

After more then four years of delivering science activities to the same 238 K-6 teachers, I have observed a small number who have started to include more science in their weekly lesson plans. It is also of interest that attitudes toward science in general have changed in many older teachers as a result of their exposure to new technologies and opportunities to "play" with the materials during Science Van activities. These veteran teachers have confessed to me that their dislike of science came from negative educational experiences from high school on through college, and most avoided science at the college level. According to survey results administered yearly and during this study,(Appendix A and Appendix B), some teachers stated that the Science Van program has improved, not only their attitude toward science, but also has provided supplemental activities and materials which have helped them improve their science teaching.

Studies have shown that teachers teach science the way they were taught science. (4) The attitudes which accompany science lessons are often transferred to their students especially during the elementary years when the teacher is a very important role model. Therefore, if the teacher does not like the subject being presented, this could have a negative impact on the students as well. I interviewed a sample population of students during this study asking them about their attitudes toward science. Nearly every one of them stated that they liked science and preferred to learn about science using hands-on methods (Table 8). When these same students were interviewed regarding the method most often used by their classroom teachers to teach science, they reported use of textbooks and worksheets. Some stated that the only science they received was during the Science Van visits. The results of the Teacher Survey (Appendix B) confirms the students' statements. Forty-nine out of sixty-eight teachers in the thesis study responded to this survey. The respondents indicated that although funding for non-text materials,science kits and supplies has increased, they still rely primarily on reading about science. They also indicated by their responses that the amount of time they spend doing hands-on science (other then during the Science Van visits) has not increased over the last four years, nor have they increased the amount of time spent watching videos about science. The majority of these teachers responded that they do not feel prepared to utilize computers as a teaching tool . These teachers stated that they are integrating science into other content areas more often and are using scientific method as a backbone for scientific investigations and experiments. One of the recurring themes of the Science Van has been use of Scientific Method during its visits and follow-up activities. Based on four years of observations it is my opinion that the Science Van program enjoys its popularity among students primarily because of the hands-on activities it brings to all students in the school. It has been my experience that teachers who are overly concerned with an orderly and tidy classroom prefer to have their students read about science or watch videos rather then provide hands-on activities which might get students excited, noisy and messy. These teachers say they don't feel comfortable teaching topics in science unless they know the "right answer." Therefore, they prefer to have students read or watch it from the "experts". I think this is partly the reason why some of these same teachers don't do the pre-visit activities with their classes prior to the day of the Science Van visit. Many times the teachers have told me they enjoy coming to the Science Van classes and learn as much or more then their students.

Teachers have told me that if their science classes had been as fun and interesting as those presented during Science Van visits, they would have taken more science. According to the 1992 Science Van Evaluation Survey, 84 out of 141 teachers responded that they have attended more inservices, classes and workshops in the areas of science then they had in 1989 prior to their experiences with the Science Van. Teachers from kindergarten through sixth grade (87%, or 122 out of 141) stated that their attitude towards science has improved since 1989 primarily as a result of their exposure to the Science Van activities. Forty-nine percent of the teachers in this study stated that they are collaborating more with their peers to integrate science into math, social studies and reading lessons.

Areas in the teaching of science that need improvement

Suppose the test had been done right, and there was still no significant difference. It is possible that no significant differences in conceptual gains would have been detected even if the statistical design had been perfected. Teachers need to spend time discussing student results or ideas and questions resulting from their experiences with the Science Van in order to maximize the experience. Otherwise, the opportunity for making conceptual gains in the content area is lost. Hands-on activities which are not accompanied by conceptual understanding may be fun but who can tell what the student is understanding from the lesson? Perhaps relying on these teachers to process the material I present was asking too much of them.

The Science Van lessons have evolved over time to be stand alone units which do not rely heavily on teacher follow-up for understanding. This adjustment has meant a reduction in the number of yearly units which can be taught, since each unit takes more time to complete from start to finish. The method for distributing activities and materials for teachers to conduct beyond the day of the Science Van visit has changed. Teachers are encouraged to voluntarily choose materials from a table at the conclusion of their visit. Students can see whether or not their teacher takes advantage of the variety of kits, lessons and other support materials. Often the students pressure or "nag" their teacher into taking some of the activities.

It is interesting to note that even though teachers in our MOISD have taken more science related classes and have received more materials and equipment, many confess that they still feel they must teach to the MEAP test and let textbooks dictate thèir science curriculum. I've seen many science kits gathering dust at more then one elementary school while the staff worry about funding for new textbooks. Although teachers indicate that they are attending more science and mathematics related classes, workshops and inservices, the amount of time they spend teaching science by any method has not risen significantly.

Unfortunately, for many students in our ISD, the Science Van continues to provide the ONLY science lessons they get all year long. The purpose of the Science Van is to supplement existing science curriculum with hands-on activities, not to supplant it. But, if science is not being taught on a regular basis, there is nothing to supplement and the Science Van lessons become the sole source of student experience in science education. Although the success of lessons presented via the Science Van are not dependent upon teacher background, students could gain a greater understanding if the teacher were to use the activities to reinforce regular classroom science instruction. The program strives to increase teacher awareness to new methods of teaching science. I think the program has been very successful as a showcase for new methods and technologies. In some cases, teachers have called upon me as a resource person to help them order the same things that they used during the Science Van visit.

My belief is that student conceptual understanding would greatly improve if the classroom teacher took a small amount of time to reinforce ideas provided by the Science Van. Students need time to ask questions, think about their results and try variations on the experiment to test hypotheses. I also believe that teachers need to be encouraged to be managers or facilitators of scientific explorations even if they are not "experts" on the topic. Students and teachers can learn about science together. Technology can play a very important role in assisting teachers without a lot of science background. Teachers need to learn science by doing hands-on activities themselves during their teacher training in college. Teacher training within many Schools of Education is poor to abysmal in terms of preparing teachers in science methods which would stimulate and motivate students of the 90's. The Science Van program will continue to evolve and adapt to serve the needs of its population of teachers and students. The results of this study, although not conclusive regarding student conceptual gains, has shown that the teacher attitudes towards science education are slowly but surely changing for the better. Perhaps as more teachers attend interesting workshops and classes designed to help them improve their practices in teaching science, we will see an improvement in student conceptual understanding as well. The Science Van program plans on continuing its drive to provide teachers and students with fun and interesting hands-on science activities in the years to come.

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APPENDIX A

Summary of the teacher yearly evaluations of the Science Van program from 1989 to 1992

	Agree (%)	*Neutral (%)*	*Disagree (%)*
The Science Van program has stimulated interest in science in my classroom	93.5	6.5	0.0
The Science Van has supplemented our local science curriculum	95.4	4.6	0.0
The Science Van has used materials and equipment not ordinarily available to my students	98.4	1.6	0.0
I have used the supplemental materials provided by the Science Van program	59.7	38.7	1.6
Science Van visits have stimulated more hands-on activities or a continuation of a Science Van lesson.	60.4	37.7	1.9
Did you attend a science related class, workshop or inservice in the last 2 years?			
(1990-92)	60.4	2.1	37.5
(1988-90)	20.7	0	79.3
I collaborate more with other science teachers	45.0	23.4	31.6
I like science more since my experiences with the Science Van	86.7	11.1	2.2

APPENDIX B

TEACHER SURVEY, 1992
SCIENCE VAN UNIT 4- GROUNDWATER
DISTRICT: circle one

Big Rapids   Chippewa Hills   Evart   Morley/Stanwood   Reed City

1. Grade level taught:
 A. 4th   B. 5th   C. 6th   D. high school   E. Other

2. How long have you been teaching?
A. 0-5 yrs.   B. 5-10 yrs   C. 10-15 yrs   D. 15-20 yrs   E. more then 20 yrs

3. Fill in letters indicating the types of students making up your class load (include numbers in parentheses next to the letter).
A. Emotionally impaired   B. Physically handicapped
 C. mentally andicapped D. A.D.D.   E. exceptionally bright

4. Your highest level of education
A. Bachelor's   B. Master's C. Doctorate D. Bachelor's plus credit
E. Master's plus credit

5. About how much time does your class spend **per week** reading science text?
A. 0-30 min. B. 30-60 min. C. 60-90 min. D. 90-120 min.
E. more then 2 hours

6. About how much time does your class spend **per week** doing hands-on explorations in science? (includes field trips)
A. 0-30 min. B. 30-60 min.   C. 60-90 min. D. 90-120 min
E. more then 2 hours

7. How often do you use audio-visual materials **per week** to help teach science subjects? (video, computers, slides, etc.)
A. 0-30 min. B. 30-60 min.   C. 60-90 min.   D. 90-120 min.
E. more then 2 hours

8. In the past year, have you received any assistance from your school or private industry for science (curriculum materials, speakers, financial support, etc.)
A.. yes   B. No   C. don't know   If "yes" go to #9, otherwise go to #10

9. Type of assistance you have received:
A. stipends for travel or tuition
B. teacher award or scholarship

C. teacher summer employment (science related work)
D. curriculum materials
E. equipment

10. How adequately prepared are you to use computers as an instructional tool in teaching science?
A. unprepared B. somewhat prepared C. Adequate D. Well prepared
E. Very well prepared

11. In the past year, have you received any indication of parent support, concern, or interest in science education?
A. none B. some C. adequate D. above average E. great

12. Have you attended any workshops, graduate classes, conferences or seminars in science in the last 2 years?
A. Yes B. No C. Not sure If yes, please list here:

In the last year have you:	No..	.little..	moderate	...a lot	
13. Increased the amount of time you teach science	A.	B.	C .	D.	E.
14. Felt more confident in teaching science	A.	B.	C.	D.	E.
15. Collaborated with other science teachers	A.	B.	C.	D.	E.
16. Integrated science into other subjects	A.	B.	C.	D.	E.
17. Seen an increased interest in your student in science	A.	B.	C.	D.	E.
18. More funding for materials, kits, supplies (non-text)	A.	B.	C.	D.	E.
19. Used scientific methods as backbone for investigations	A.	B.	C.	D.	E.
20. Do you enjoy science yourself?	A.	B.	C.	D.	E.

21. Which of the following would best help you and your students achieve outcome changes in science literacy?
A. More technical assistance in learning to operate existing equipment.
B. More funding to purchase science equipment and materials
C. Provide staff to assist in lab set ups and operation of technology
D. Better textbooks and student worksheets
E. Take away some responsibilities if you expect us to use additional methods such as computer assisted instruction.

1992 Survey results from fourth-sixth grade teachers in the study designed to assess teacher attitudes and practices toward teaching science.

Survey Question	Count	%	Survey Question	Count	%
Grade Taught:			Number of years teaching:		
4th	19	39	0-5	14	29
5th	14	29	6-10	8	16
6th	10	20	11-15	11	23
multiple	6	12	over 16	16	33
	N = 49			N = 49	
Amount of time spent reading about science / week.			Amount of Time spent doing hands-on science / week		
0-30 min.	11	23	0-30 min.	22	46
30-60 min.	16	33	30-60 min.	16	33
60-90 min	15	31	60-90 min	7	15
2 hrs or more	6	13	2 hrs or more	3	6
	N= 48			N = 48	
Amount time watching Science Videos / week:			Have attended science classes, workshops, seminars in past 2 years:		
0-30 min	35	73			
30-60 min.	9	19			
60-90 min	1	2	Yes	30	63
2 hrs or more	4	8	No	18	37
	N = 48			N = 48	
Have received more funding for materials,kits, supplies			Number of students on free lunch program?		
			0 -10%	3	6.3
never	29	63	25%	24	50
a little	12	26	50%	20	42
moderate	5	11	75% or more	1	2
a lot	0	0			
	N = 46			N = 48	

Feel prepared to utilize computers as teaching tool. never a little moderate a lot	 18 38 20 43 7 15 2 4 N = 47	What they felt would help them teach science better. technical help increased funding more staff better textbooks fewer demands	 1 2 38 80 5 10 2 4 2 4 N = 48
Integrates Science into other content areas: never a little moderate a lot	 2 4.3 22 46.8 22 46.8 1 2.1 N = 47	Uses Scientific Method as a backbone for investigations: never a little moderate a lot	 7 14.9 15 31.9 22 46.8 3 6.3 N = 47

APPENDIX C

PRE-TEST AND POST-TEST FOR SCIENCE VAN UNIT 4- GROUNDWATER AND YOU!

APPENDIX D

Statistical Analysis of Student Pre-Test/Post-Test by Grade Level and Method

Science Concepts and Processes Questions by Grade Level and Method

Source of Variation	Mean Difference	F	Sig.of F
Main Effects	.416	.472	.756
grade level	.258	.293	.747
method	.628	.713	.495
2-way interactions grade level method	.213	.241	.913

Nature of Science Questions by Grade Level and Method

Source of Variation	Mean Difference	F	Sig.of F
Main Effects	.871	1.567	.198
grade level	1.631	2.932	.062 *
method	.110	.198	.821
2-way interactions grade level method	.251	.452	.770

* There is some significance between grade levels but not between methods within the same grade.

Total Questions by Grade Level and Method

Source of Variation	Mean Difference	F	Sig.of F
Main Effects	2.186	.685	.606
grade level	3.383	1.060	.354
method	.997	.313	.733
2-way interactions			
grade level method	.756	.237	.916

APPENDIX E

STUDENT WORKSHEET FOR METHOD C

	crushed rock	sand	dry kitty litter(clay)
size and shape of particles			
Porosity Prediction: Which do you think will hold the most water? Results: What happened?	% retained =	% retained =	% retained =
Permeability Prediction: Which lets the water move through it fastest? slowest? Results: What happened?	Drainage time =	Drainage time =	Drainage time =
Conclusions Which material would make the best aquifer? The worst? Why?			

Appendix F

Informational Letter to All 4-6th Grade Teachers Regarding the Intent of the Thesis Study

TO: ALL 4th, 5TH AND 6TH GRADE TEACHERS:
FROM: KATHY LOVGREN
RE: UNIT #4 -- PARTICIPATION IN RESEARCH PROJECT FOR MASTERS' THESIS
UNIT DATE: March 30, 1992

The last unit for this year's Science Van will address an environmentally exciting issue : Groundwater. and the study of how water is moved around both above and below the ground.. Some of the questions we hope to address by hands-on groundwater models, computer simulations and problem solving activities will be :

How is water stored and moved on planet earth?
Where is water found underground? How does it move?
What things affect the quality of groundwater ?
How can we protect the quantity and quality of groundwater?

I'd like to request your cooperation as participants in a research project the results of which can be used to benefit your science programs as well as provide data for my Master's Thesis from MSU. The major thrust of my thesis will be to study student and teacher outcome changes as a result of the Day of the Visit activities provided by the Science Van. I know you've been under a lot of pressure to increase math and science skills in preparing students for today's high tech and rapidly changing world. With everything else you have to teach, I cannot imagine having to also keep up with the latest ideas and technologies coming out daily. I believe that the "Timeshare" philosophy behind the Science Van activities can be utilized to provide you with the tools and expertise to increase science literacy in your schools. Although we know most students really enjoy the activities provided by the Science Van., we hope to provide insights into how things work , why things happen and stimulate minds for further studies after the visit.

The main goal of the Science Van program is to provide the necessary materials and expertise to enhance student curiosity about the particular topic as well as to provide students with opportunities to discover some of the processes of scientific investigation. Now that the program has been operational for four years, I would like to assess the effectiveness of the program. I picked Groundwater and You as the content theme around which I gathered data to answer two questions:

1.) Is there any difference in average classroom pre-test and post-test scores between traditional methods of science instruction versus the Science Van methods?
2.) Has the Science Van program motivated teachers in the MOISD to improve their teaching practices and attitudes in science?

I need your help to gather data. I would like to assess the effectiveness of the methods utilized during the Science Van visits and compare them to more traditional methods of instruction. I am interested not only in improving student conceptual understanding but also interested in seeing if the program has improved teaching practices and/or attitudes as they relate to science instruction. There are three methods of science instruction being studied and you will randomly be randomly pick from a bag one of the following methods:

Method A:	**Method B:**	**Method C:**
Pre test Content = written materials followed by teacher reinforcement Post test Science Van video optional	Pre test Content= video followed by teacher reinforcement Post test Science Van written materials optional	Pre test Content= hands-on Science Van Instructor- guided activities Post test written and video materials optional

After the post-test has been administered, each teacher will receive all the same materials so that everyone will have done the same thing, but in different order.

I would request that you complete this unit within one week's time. Use your best judgment regarding the appropriate choice of materials for your grade level. A detailed "Discussion Guide" with answers will be provided in the Teacher Packet for both Method A and Method B teachers. Take the time to read the materials and the pre-test and post-test out loud in class and answer any questions to the best of your ability. There is additional background information provided in your teacher's packet to provide you with an opportunity to upgrade your background on the topic if so desired. If you have

Method A or B, be sure the students have completed the post-test prior to coming to the Science Van activities.

TEACHER EDUCATION OPPORTUNITY + FREE "STUFF" We have funding to provide ten groundwater simulation models for you to make and keep valued at $100.00 each to teachers willing to attend the four hour workshop mentioned below. If you are interested, please fill out the form and mail it in to the Intermediate School District before March 1, 1992.

TEACHER INSERVICE FOR GROUNDWATER UNIT:
by Dr. Dick Passerro
from Western Michigan University's Water Institute and GEMS director.
GEMS = Groundwater Education in Michigan Schools.
DATE: March 16, 1992
TIME: 4:00 -6:00 P.M.
PLACE: M.O.I.S.D.

I hope you will assist me in this academic endeavor. I think this is a win-win situation where we can mutually benefit. The students will greatly enjoy the activities I assure you. All information on individual students, teachers and schools will be kept confidential. I will be interviewing some students randomly during the visit as well. Please let me know if you object to being in this study as soon as possible. I hope you can attend one of the workshops. Please indicate which one and return the bottom half of this form as soon as possible. Also feel free to call me for any further information at home or work. Home phone : 616-796-9318 Work: 616-796-3543
Thank you for your continued support of our program.

PRE-TEST AND POST-TEST FOR SCIENCE VAN UNIT 4-
GROUNDWATER AND YOU!

1. WHICH SOIL TYPE HOLDS THE GREATEST VOLUME OF WATER? (CONCEPT)

A. SAND
B. CLAY
C. PEA GRAVEL
D. POTTING SOIL
E. I DON'T KNOW

2. WHICH TYPE OF SOIL LETS WATER MOVE THROUGH THE FASTEST? (CONCEPT)

A. SAND
B. CLAY
C. PEA GRAVEL
D. POTTING SOIL
E. I DON'T KNOW

3. WHAT IS AN AQUIFER? (CONCEPT)

A. A HUGE UNDERGROUND POOL, LAKE OR RIVER
B. AN OPEN BODY OF WATER SUCH AS A STREAM OR A LAKE
C. A WATER HOLDING LAYER UNDERGROUND THAT SUPPLIES DRINKING WATER
D. A PERSON WHO LOVES WATER AND PARTICIPATES IN WATER SPORTS
E. I DON'T KNOW

4. WHERE DOES MOST OF THE DRINKING WATER FOR PEOPLE IN THE UNITED STATES COME FROM?(CONCEPT)

A. THE GREAT LAKES
B. A NEARBY RIVER
C. GROUNDWATER
D. FROM THE OCEANS ONCE SALT IS REMOVED
E. I DON'T KNOW

5. WHICH OF THE FOLLOWING IS A TRUE STATEMENT REGARDING WATER AS A RESOURCE? (CONCEPT)

A WATER IS NOT RECYCLABLE, ONCE WATER IS POLLUTED IT CAN NEVER BE REUSED.
B. THERE IS NO OTHER SOURCE OF FRESH WATER. THE WATER YOU DRINK TODAY COULD HAVE BEEN THE SAME ONE THAT DINOSAURS SWAM IN.
C. THE ONLY WAY WATER RECYCLES IS THROUGH EVAPORATION AND PRECIPITATION (RAIN OR SNOW).
D. I DON'T KNOW

6. LET'S SAY YOU LIVE IN A SANDY FARM AREA WHERE CHEMICAL FERTILIZERS AND WEED KILLERS ARE HEAVILY USED. HOW LIKELY ARE THESE CHEMICALS TO GET INTO YOUR DRINKING WATER? (NATURE OF SCIENCE)

A. NOT VERY LIKELY
B. 50 % CHANCE
C. DEPENDS ON HOW CLOSE I LIVE TO THE FARMER
D. OVER TIME, VERY LIKELY
E. I DON'T KNOW

7. IF YOU LIVED IN THE COUNTRY WHAT WOULD HAPPEN TO YOUR WASTE THAT GOES DOWN THE SINK, TOILETS, AND DRAINS? (NATURE OF SCIENCE)

A. IT ENDS UP IN A LANDFILL OR DUMP.
B. IT GOES TO A SEWAGE TREATMENT PLANT
C. IT GOES TO SEPTIC TANKS WHICH DRAIN INTO THE SOIL
D. IT SEEPS INTO THE GROUND AND THEN THE WATER PART EVAPORATES.
E. I DON'T KNOW

8. WHAT IS THE DRIVING FORCE BEHIND THE HYDROLOGIC CYCLE? (CONCEPT)

A. ENERGY FROM THE SUN AND GRAVITY
B. THE OCEANS AND RIVERS
C. HUMAN ACTIVITIES
D. THE AMOUNT OF RAINFALL
E. I DON'T KNOW

9. IN NATURE, HOW DO AQUIFERS GET RECHARGED? (CONCEPT)

A. FROM MELTING GLACIERS
B. IT SEEPS INTO SOILS FROM SURROUNDING LAKES, RIVERS AND WETLANDS
C. IT DOESN'T. ONCE IT IS SUCKED OUT, THE WELL DRIES UP FOREVER.
D. FROM RAIN AND SNOW MELT.
E. I DON'T KNOW

10. GROUNDWATER FLOW REFERS TO: (CONCEPT)

A. SURFACE RUNOFF OF WATER FROM MELTING SNOW, ICE OR RAINFALL
B. MOVEMENT OF UNDERGROUND RIVERS, STREAMS TO SURFACE OUTLETS
C. MOVEMENT OF WATER THROUGH UNDERGROUND SOIL OR ROCK TO A SURFACE BODY OF WATER OR WELL.
D. ALL OF THE ABOVE
E. I' DON'T KNOW

11. HOW FAST WATER MOVES THROUGH SOIL AND ROCK DEPENDS ON: (CONCEPT)

A. THE SIZE AND SHAPE OF THE ROCKS
B. THE SHAPE AND COLOR OF THE SOIL CRYSTALS
C. THE TYPE OF MINERALS IN THE SOIL

D. THE AMOUNT OF PORES (OPEN SPACES) AND CONNECTIONS AMONG THEM
E. I DON'T KNOW

12. WHICH OF THE FOLLOWING PRACTICES ARE LEGAL IN MICHIGAN?(NATURE OF SCIENCE)

A. BURYING HOUSEHOLD TRASH OR FARM WASTE ON YOUR OWN PROPERTY
B. DISPOSAL OF USED MOTOR OIL, PAINT THINNERS AND CLEANING CHEMICALS IN LANDFILLS
C. ALL THE ABOVE ARE LEGAL AT THIS TIME
D. ALL ARE AGAINST THE LAW
E. I DON'T KNOW

13. YOU HAVE JUST BOUGHT A HOUSE IN THE COUNTRY. YOU ARE 2 MILES AWAY FROM AN OLD LANDFILL THAT HASN'T BEEN USED IN 50 YEARS. WHAT ARE THE CHANCES OF YOUR WELL WATER BEING CONTAMINATED FROM THIS LANDFILL? (NATURE OF SCIENCE)

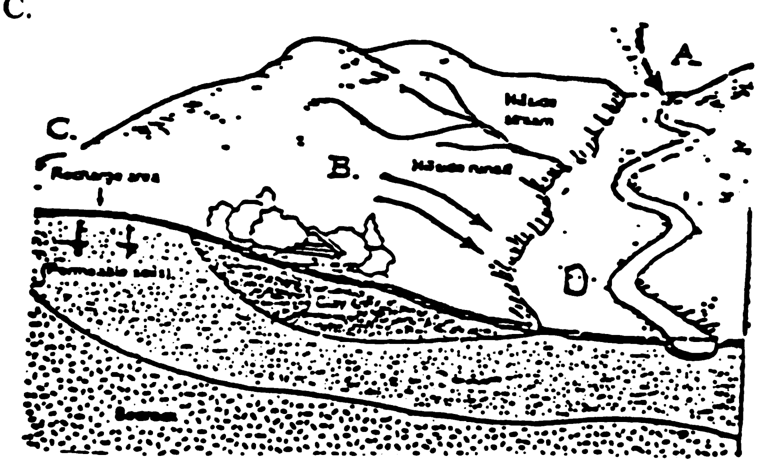
A. HIGH RISK, GROUNDWATER MOVES VERY SLOWLY
B SLIGHTLY RISKY, BUT MIGHT BE OK FOR FARM ANIMALS
C LOW RISK ,SINCE 50 YEARS HAVE PASSED
D. LOW RISK SINCE IT IS 2 MILES AWAY AND GROUNDWATER MOVES DOWNWARD NOT SIDEWAYS.
E. I DON'T KNOW.

14. YOU CAN TELL IF THE WATER SUPPLY IS POLLUTED BY: (NATURE OF SCIENCE)

A. THE WAY IT TASTES
B. THE WAY IT SMELLS
C. THE WAY IT LOOKS
D. YOU CAN'T ALWAYS TELL BY YOUR SENSES
E. I DON'T KNOW

15. WHICH LETTER SHOWS HOW GROUNDWATER MOVES? (CONCEPT)

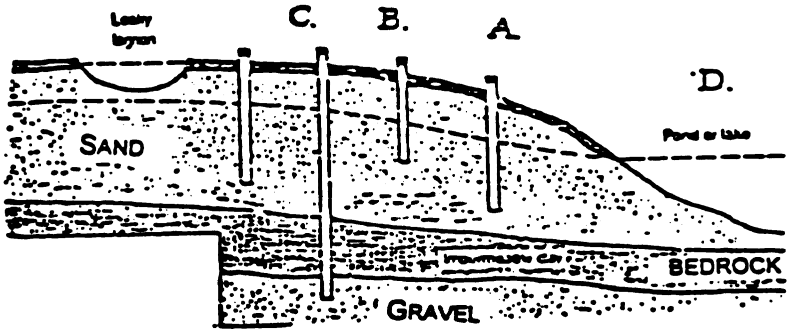
A. B.
C.



E. I don't know

16. **WHICH WELL WOULD NOT BE AS LIKELY TO BECOME CONTAMINATED? (NATURE OF SCIENCE)**

A. B.
C.



17. **A PUMPING WELL CHANGES THE WATER TABLE AROUND IT BY: (NATURE OF SCIENCE)**

A. RAISING THE SURROUNDING WATER LEVEL
B. LOWERING THE LEVEL OF NEARBY LAKES OR STREAMS
C. DOES NOT CHANGE IT AT ALL
D. DEPENDS ON HOW MUCH WATER IS BEING PUMPED OUT
E. I DON'T KNOW

18. **WHAT MATERIALS MAKE UP A GOOD AQUIFER BUT ALSO LET POLLUTANTS FLOW EASILY? (CONCEPT)**

A. GRAVEL
B. SAND
C. CLAY
D. BEDROCK
E. I DON'T KNOW

19. **THE REASON MICHIGAN HAS A HUGE GROUNDWATER RESOURCE IS: (NATURE OF SCIENCE)**

A. BECAUSE THE WATER FROM THE GREAT LAKES SEEPS INTO THE SOILS
B. BECAUSE WE LIVE IN A CLIMATE THAT PROVIDES A LOT OF MOISTURE
C. BECAUSE OF THE LARGE DEPOSITS OF SANDY SOILS LEFT FROM THE RETREATING GLACIERS
D. BECAUSE MICHIGAN IS LIKE AN ISLAND BETWEEN THE GREAT LAKES, AND IF YOU DIG DEEP ENOUGH YOU WILL TAP INTO THE UNDERGROUND LAKE THAT CONNECTS THEM.
E. I DON'T KNOW

20. WHICH FARMING PRACTICE WOULD KEEP THE MOST WATER IN THE SOIL? (NATURE OF SCIENCE)

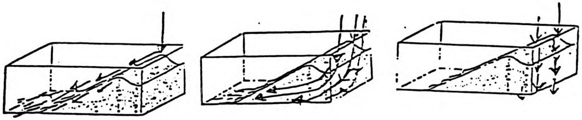
A. B. C.

21. HOW FAR UNDER GROUND CAN GROUNDWATER BE FOUND? (CONCEPT)

A. NOT VERY FAR BECAUSE OF ROCK LAYERS THAT STOP IT
B. 10-25 FEET
C. 50-100 FEET
D. CAN VARY FROM SURFACE TO HUNDREDS OF FEET, EVEN BELOW SOLID ROCK FORMATIONS
E. I DON'T KNOW

22. CHOOSE THE LETTER THAT CORRECTLY SHOWS HOW WATER MOVES ONCE IT HITS THE GROUND.(NATURE OF SCIENCE)

A. B. C.



23. HOW DO MOST POLLUTANTS GET INTO OUR DRINKING WATER?(NATURE OF SCIENCE)

A. THEY ARE DISSOLVED BY WATER AS IT MOVES THROUGH SOIL TO ROUNDWATER.
B. THEY COME DOWN IN THE RAIN OR SNOW
C. BY LEAKING GAS TANKS
D. BY DUMPING HOUSEHOLD CHEMICALS DOWN OUR SINKS
E. I DON'T KNOW

24. WHO CAN MAKE THE BIGGEST DIFFERENCE IN CONSERVING OUR PRECIOUS WATER? (NATURE OF SCIENCE)

A. CITY MANAGER AND STAFF
B. PRESIDENT OF THE UNITED STATES
C. SCIENTISTS
D. INDIVIDUAL FAMILY PRACTICES
E. I DON'T KNOW

25. WHICH LETTER INDICATES WHERE THE WATER TABLE IS FOUND?(CONCEPT)