KNOWLEDGE GAINS RESULTING FROM A COMPUTERIZED WATER RESOURCE MANAGEMENT SIMULATOR IN THE CLASSROOM

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1979

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1982

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Thesis Approved:

Thesis Adviser

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PREFACE

This study is concerned with an evaluation of knowledge gained in the classroom using the Water Resources Management Simulator.

I would like to express my appreciation to Dr. Terence J. Mills, chairman of my committee and my friend for his guidance and support; and to Dr. Thomas Johnsten and Dr. Sterling Burks for their assistance on my committee.

Gratitude is expressed for the support and encouragement provided by my friends Dan Sebert, Janice Scearce, and Theresa Archer.

I would like to thank and dedicate this to my parents, Thelma and Brady Bates, who have inspired me on through their example.

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CHAPTER I

INTRODUCTION

Man exists only because his home planet possesses a unique combination of properities. Life is possible on earth because earth is the "water planet". Water, a compound almost as rare in the universe as life, is perhaps synonymous with life. Water is not only rare, not only infinitely precious, but possesses many unique physical and chemical properities. It is the unique nature of water, which results in the dynamic water system of the earth. Driven by the sun, it is this hydrologic system that makes the earth habitable. Of all the earth's resources, water is the most precious (Cousteau, 1975).

Without an adequate quantity and quality of water, mankind cannot exist (Miller, 1979). Ocean currents and atmospheric circulation of water modifies our climate by storing and redistributing heat around the earth. Water is referred to as the universal solvent for it dissolves more substances than any other compound. The ability of water to dissolve many substances results in natural and man made water quality problems. Water dissolves and distributes material such as domestic sewage, sulfates, nitrates, phosphorous, petroleum wastes, pesticides, heavy metals, and other potentially undesirable substances.

In European countries such as Norway and Sweden several thousand lakes have been acidified, and entire fish populations have been lost as a result of sulfur and nitrogen-based acidic imputs. Indications are that a similar process is underway in portions of the northeastern U.S. and Canada (Barnes, 1979; Overrein, 1981).

Worldwide, millions of metric tons of petroleum hydrocarbons enter the aquatic environment annually and are a major source of marine pollution (Travers and Luney, 1976). In aquatic settings bivalves and other aquatic organisms concentrate noxious and toxic substances from their water environment due to waters that are polluted by domestic sewage, petroleum, petroleum by-products, and industrial wastes (Mix et al., 1977a). Other problems occur with synthetic organic chemicals, agricultural chemicals, heavy metals, and petroleum when it enters the aquatic enviornment as pollutants generated by human activity. Certain pollutants are actual or potential carcinogens, which may contact aquatic organisms that will accumulate, metabolize and translocate the pollutants or its metabolites (Kraybill, 1975).

It is obvious we are polluting our waters as if there were no end to them, but we must realize that water is a finite resource. What we have is all that we have or will ever have. Yet our use of water is growing exponentially. Our per captia use during the past fifty years has increased 350 per cent. It is projected that by the year 2000 net use will be slightly below the lower limit of available usable water and near the estimated upper limit of supply by 2020 (Mills, 1977). Still, the public remains uninformed about our water woes. Students in school are not informed because water curriculum is not emphasized. In a water resource knowledge assessment of college bound high school graduates, it was indicated that a void existed in the water education of college bound public school students. The same study also pointed out a lack of knowledge in the areas of current water issues, water resource management and the influence of water in shaping our past (Mills, 1979). These concepts embody critical information required by those who would assume leadership roles. The teaching of current events seldom includes the facts of our daily dependence, whether we live on the coast or far inland, on water borne commerce (Sea Grant, 1978).

Water is our most precious resource, yet we do not seem to value it enough to teach about it or the conservation of it. A study done on the water resource needs in Oklahoma recommended that public schools should incorporate into the curriculum vigorous environmental education programs which emphasize water resources (Miller, 1979). A study done by Sea Grant says that there are schools where specialized courses in marine science and other aspects of water may be important and appropriate, but for marine and aquatic education in the broader sense to take its place and achieve its national goals, it must be incorporated into existing educational programs (Sea Grant, 1978).

How does one incorporate or implement water education into the curriculum? There are different ways to integrate a water curriculum into the classroom, such as worksheets, lectures, research papers, reading books and articles, labs, and simulation. This study deals with the use of computerized water resource management simulation and its use in the classroom.

Water Resource Management Simulator Description

The Water Resources Management Simulator (WRMS) is an interactive digital computer which models a region's water supply and demand situation. Capable of modeling one or two sequential stream basins, the simulator is operated by workshop participants using several small control consoles. Water management decisions regarding storage of surface and ground water, sources of water, rate of water use, technology of water use, and disposition of used water are made with controls on these consoles. The irrigation control module is typical of these control modules. Calibrated in multiples of "today's" water use pattern in the modeled region for ease of understanding, this control transmits its water demands to the computer in units of acre feet. The course of water for irrigation is selected by a sliding control which will select from 100% surface water to 100% ground water. The irrigation technology is selected by a second sliding control. Sprinkler irrigation is programmed to demand about half as much water as flood irrigation, but returns very little to the stream. Flood irrigation demands about twice as much water for a given irrigation setting, but returns half to the stream. This control may be set for any combination of these two technologies. Similar sliding controls on other modules permit selection of cooling technology for thermal electric plants and water treatment technology for industrial and municipal waste water. Five water use categories are provided in the model: (a) irrigation, (b) energy, (c) municipal and industry, (d) livestock, (e) inter-basin transfer. For each of these uses the water may be drawn from either the ground water or surface water resource. The simulator may be programmed for any set of ground and surface water conditions by simply changing data statements in the computer memory (Amend, 1981).

Simulation and simulation games are useful instructional techniques which can be tailored to a wide range of classroom situations. These techniques can provide many opportunities for participatory learning experiences for students.

Nature of the Problem

Computers are being used more each day in the classroom making is imperative to evaluate computer technologies applied in education. This study deals with determining the amount of basic water resource management knowledge assumed to be taught by the WRMS. Each grade 7th-12th was divided into two groups, the control group or pre-test group and the experimental group or post-test group. Interaction with the WRMS was the treatment for the experimental group. The pre-test data was then compared to the post-test data to answer the following questions.

1. What is the level of current water resource management knowledge at the 7th-12th grade levels?
2. Do students interacting with the WRMS know more than those who have not?
3. At what level does the WRMS impart information?
4. What concepts does the WRMS teach?

How these questions are answered can determine the viability of the WRMS for the various grade levels tested. Question #1 will be answered by comparing correct mean scores to the possible score.

Questions 2 through 4 are stated in the following H_o:

H_o1 There will be no significant difference between the total population mean pre-test score and mean post-test score.

H_o2 There will be no significant difference in pre/post-scores between the junior high (7-9) and senior high (10-12).

H_o3 There is no significant difference between mean pre/post-test scores by grade level.

H_o4 There is no significant relationship between pre/post-test responses for each item by grade level.

Significance of the Study

Simulation is an important and often used instructional method. With increased use of computers in public school classrooms, computer simulation as an instructional activity can be expected to increase. There is a need to determine the potential of this instructional technique. Computers can help present complex situations.

There is a need to determine what the students currently know what computerized simulation can teach them and at what grade levels. Computer simulation applied to water, our most precious resource, could assist in creating a water literate public. Public water literacy is imperative if we are to manage our water resources wisely. It is hoped that this study will lead to a better understanding of the WRMS in the classroom.

Limitations of the Study

The population for the study was drawn from selected schools within a 150 mile radius of Oklahoma State University. Conclusions cannot be extrapolated beyond the population under study.

An assumption was made that the populations were earnest in their responses. The researcher did not administer the pre- or post-test. It is assumed that teachers administering the test followed proper procedure.

Definition of Terms

WRMS Water Test--A test derived from the Water Resource Management Simulator objectives.

Interactive Computer--A computer which is designed to allow people to have input at various stages. The results of this input are continuously summarized and displayed.

Knowledge--Familiarity, awareness, or understanding of water gained through experience or study.

Pre-test--WRMS Water Test given to the control group before interaction with the Water Resources Management Simulator.

Post-test--WRMS Water Test given to the experimental group after interaction with the Water Resources Management Simulator.

Simulation--Duplicating artificially the conditions likely to be encountered in some set situation.

Marine--Environment which contains or is directly influenced by salty water.

Aquatic--In this study it means freshwater as distinct from marine or salty water.

CHAPTER II

SELECTIVE REVIEW OF THE LITERATURE

Introduction

The literature reviewed in this chapter is that which the author feels is closely related to the problem. In order to investigate this problem, it is necessary to gain an understanding of our existing knowledge concerning the evolution of simulation, nature of simulation, what can be learned, design and development of simulation games, simulation and gaming in natural resource management, and existing water curriculum. The aforementioned areas were searched back through 1960.

Evolution of Simulation

Not unlike many of the instructional techniques being used today, simulation had its beginnings in the military. The roots of the technique are easily traced to war gaming. The Chinese war game "Wei-hai" (meaning encirclement) is thought to have appeared about 3000 B.C. (Wilson, 1968). Prior to the eighteenth century, war games were played for enjoyment and the challenge of intellectual and strategic skills of the players. After the turn of the eighteenth century, war came to be viewed more as a science and less as an art. From a scientific point of view, simulation war games became an important part of training in the military. Throughout the nineteenth century, Prussia pioneered the development and the refinement of war gaming (Maidment and Bronstein, 1973). By the early 1960's there were no more than two hundred war gaming models on record, not including those used exclusively for basic military training.

Business games were a direct offshoot of the war games. In 1956 the American Management Association created top management simulation which was an instantaneous success. It was quickly adopted as a training activity by universities, industry and commerce (Taylor and Walford, 1974). Today business games are still a part of formal business education as well as an important part of the education program at many major corporate training centers.

Gaming in the Social Sciences began to appear in the mid-1950's and early 1960's. The Research and Development Corporation of America (RAND) initiated several international relations simulations originally known as "Crisis games". By simulating possible international crises they could provide foreign policy makers with policy alternatives in the event that similar real crises did occur (Guetzkow et al., 1963). Expansion into other areas was rapid. Through simulation techniques, decision makers in many fields including transportation, health care, welfare, and others were able to develop planning techniques and policy alternatives.

Simulation became popular in the classroom in the mid-1960's when they first gained popularity in elementary and secondary classrooms. Boocock and Schild (1968) classify the integration of simulation as an instructional tool in the classroom into three developmental phases. First was the "acceptance on faith" phase. This took place in the early 1960's when games were first being discovered as a classroom tool. Increased development of classroom games was fueled by glowing reports on the successful use of simulation games.

The second phase was called the "post honeymoon phase". It was marked by the attempts of researchers to document the effectiveness of the technique. Much of the resulting data was negative or inconclusive. However, even though it could not be shown that the games taught hard facts, it was noted that they improved critical thinking skills and were good motivational tools.

Phase three was that of "realistic optimsim". Once weaknesses and shortcomings had been identified, the technique could be improved. Jerome Bruner, a leading instructional theorist, made simulations an integral part of the Social Studies Curriculum Project, "Man A Course of Study" and recognized the academic variety that simulation has to offer (Bruner, 1967).

In 1956, Clark Abt founded Abt Associates which produced commercial training and education games. Abt and Company were involved in development of many of the 1960's curriculum projects. They also produced several games aimed at assisting the understanding of "internal revolutionary conflict" (a.k.a. Vietnam) for the Advanced Research Project Agency in 1964 (Taylor and Walford, 1974).

Simulation has enjoyed continuous popularity and growth. Simulation games are found at all levels of formal education and range from simple one hour exercises to sophisticated people-computer interactions which require days or weeks to complete. However, there appears to be little in the literature concerning application to water education. Within the framework of the microcomputer explosion in education, it appears that simulation as an instructional technique has a bright future in the classroom.

The Nature of Simulation

A simulation can be best described and defined in terms of what takes place when the technique is used. Taylor and Walford (1974) have identified three things which take place in any simulation. First, players take on representative roles which correspond to or model existing real world roles. Within this role-playing, they are asked to make decisions based on their assessment of the scenario in which they find themselves. Next, they experience the simulated consequences of their decisions and their overall performance in the role. Finally, they monitor the consequences or results of their actions and are asked to reflect on the relationship between the decisions which were made and the results which were experienced due to those decisions.

Taylor and Walford also identify three major attributes of a simulation which related to and logically follow the preceding areas. The technique is oriented towards activity and participation by teacher and pupils. It represents a joint effort towards understanding a situation or problem. A simulation is usually problem-based and leads to development of interdisciplinary methods of learning and problem solving. Simulations may call for use of social skills which are useful and relevant to the world outside the classroom. The technique is also dynamic. Simulations are modeled after the real and changing world. In order to meet this challenge, they require flexible and adaptive thinking.

Focusing specifically on simulation games, Maidment and Bronstein (1973) identify several similar characteristics and attributes:

> A simulation game, as the name implies, contains characteristics of both a simulation and a game. It is an activity in which participants interact within an artificially produced environment which recreates some aspect of social reality. The participants, termed players, assume the roles of individuals or groups, who exist in the particular social system being simulated. Their goals and those of the actors they represent are the same. Whether or not the players will achieve their goals will depend upon how successfully they plan their interaction strategy and use their resources. Specific rules are contained within the simulation game which govern the sequence and methods of interaction. These rules limit and guide behavior in a way that will insure that players experience success or failure in a manner similar to their counterparts in the real world who adopt the same goal attainment strategy (p. 18).

What Can be Learned

Research relative to what simulation games teach and the degree of effectiveness with which they teach it is somewhat inconclusive. While much has been written about the successes of simulation as an instructional technique, only a few situations have been subjected to empirical research (Braskamp and Hodgetts, 1971). Those which have received attention have led to conflicting conclusions (Clarke, 1970). Maidment and Bronstein (1973) list the primary areas of learning as those of knowledge, skills, and attitudes.

In the knowledge area, participants learn facts and principles. However, simulation has not been shown to be superior to more traditional instructional techniques in teaching facts and principles. If the aim of instruction is learning of facts and principles, other methods could be faster, more economical, and more efficient. Simulations do score quite well in knowledge areas relative to teaching system structure and dynamics. While it is important to understand the individual parts of a system, the real understanding may not come until the system is seen as a dynamic, integrated whole. Simulations provide an opportunity for students to see and experience first hand how variables mesh and impact on each other.

Three types of skills are evident in the skills area. Decision-making skills, analytical skills, and social skills are learned or developed in a simulation experience. The success of a participant in a simulation is not based on rote memorization of facts and figures. Success comes to those who can assimilate and analyze information and make rational, well thought out decisions based on their assessment of the situation. Social skills are necessary to communicate ideas, decisions, and opinions to fellow players. Social skills may also enhance cooperation and competition. Through role playing and modeling or real world situations, some changes in attitude may carry over into reality for the student. Shifts in attitude have been reported in some cases in areas of race and international relations and politics.

Design and Development of Simulation Games

Although countless commercially prepared simulation games are available today, one of the merits of the technique is that it lends itself to user design and development. Through careful design, simulations can be tailored to closely model an endless variety of situations. This flexibility provides the opportunity to use the technique in many diverse subject areas.

Many authors (Gibbs, 1974, Hoover, 1980, Tansey and Unwin, 1969) offer guidelines for the design and development of simulation games. A synthesis of the guidelines brings six common development and design steps to focus. First, it must be determined that simulation is the appropriate technique for material which is to be presented. The next step deals with identification and statement of objectives. Third on the list is the actual design of the game model. This step involves identification of roles, rules, and resources as well as development of the scenario which will set the stage for the interaction to follow. The fourth step takes place with the actual simulation run. The playing out of the simulation has several important components including pre- and post-simulation briefing, an instructor-assisted trial run in order to minimize confusion for the participants early in the game, The fifth and sixth steps are evaluation and redesign of the game.

Perhaps one of the simplest and most thorough approaches to simulation design and development is offered by Maidment and Bronstein (1973). Using a systems approach, they outline a model involving seven interlocking steps which lead to the design and implementation of an instructional simulation. The model is logical, well-organized, and general enough to be utilized by potential game designers in many areas. Most importantly, through the evaluation procedure, they provide the opportunity for feedback, redesign, and fine tuning of the simulation model. This evaluation procedure is based on an excellent game response sheet which serves as a critical review of the major tasks in simulation design and asks key questions of teachers that are preparing classroom simulations.

Simulation and Gaming in Natural Resource Management

Taylor and Walford (1974) point our that most simulation games set out to produce their desired effects through:

> (a) presenting a simplified abstraction of the bare essentials of a situation free from trivia and irrelevance (often called the background noise);
> (b) concentrating on making explicit essential relationships and the fundamental interplay between key roles;
> (c) unfolding time at a very much quicker rate than normal so that the implications of action in a dynamic situation can be clearly and repeatedly felt;
> (d) allowing students to 'sit in the hot seat' and feel the direct impact of the consequences of decision making;
> (e) offering opportunities for collaborative learning on self-directed lines (i.e. learning as much from one's mistakes of others as from one's successes) (p. 76).

These five characteristics interact to make simulation a valuable technique for teaching about natural resource use and management. Most of the lessons learned in natural resource management have been learned through reaction to crisis situations which were often accompanied by catastrophic consequences. Many times forethought and planning could have alleviated the impact of the problem. Through simulation techniques, students are able to learn from their mistakes without endangering the natural resources. Simulation games involving many different natural resources are in existence today.

One of the first applications of making use of computer simulation and gaming for natural resources was in the teaching of sociology. It was used because there was no quick way to impress upon students the nature of the limited resources available, the forces competing for them, and the idea of long range planning (Duke, 1970). A later study showed that educational simulation and training simulation games help demonstrate the impact of policy decisions upon the quality of life within a hypothetical state played manually or by computer or in combination (Little, 1971).

One main reason for simulation is its ability to show the big picture or large scheme of things. Such a simulation was done with a systems approach to water management which covered all aspects of water management within an overall systems context emphasizing applications in a real world situation (Biswas, 1976).

In the past, the size and expense of computers made them a luxry. With the advent of the microprocessor, the size and price have made them more available. Computers are finding their way into the classroom at a very rapid rate. They are being used to simulate real or imaginary situations that are too technical, expensive, dangerous, or time consuming to perform in the usual classroom setting. Physical science experiments, water pollution studies, and political and economic scenarios are examples of computer simulations available (Gawrowski and West, 1982). A study done with the Energy Environment Simulation computer, which is similar to the WRMS, showed that such instruction was effective in increasing energy awareness (Cartwright, 1981).

Water Curriculum

As far back as 1961 there were educators who tried to teach conservation of water to young people, but with no organized curriculum (Foster, 1961). Others tried to teach water conservation showing its interrelation to mankind and his welfare (Amick, 1965). Most of this type of teaching was done by the utilization of demonstrations of different types in the classroom to small groups (Leyendecker, 1961). But people were aware of the water problem. In 1964 a study recommended strongly that programs of water education be taught in schools along with careful use of water resources and wise legislation (Knowlton, 1964). But until recently there has not been any sequential type of water curriculum available.

A study by Sea Grant (1978) indicates that the goals of marine and aquatic education should be:

> 1) To develop a public which has a basic understanding of marine and aquatic components as part of the whole environment, and their importance to American life and society.
> 2) To create a public with awareness of and sense of responsibility for water; to evolve a new 'water ethic' embracing the proper uses, protection, and conservation of the oceans, the coastal zone, and freshwater resources.
> 3) To motivate people to take part in decisions affecting the sea and freshwater while equipping them with principles and information necessary to evaluate problems, opportunities and events (p. 4).

Achieving these goals would result in the American public becoming "literate" in marine and aquatic affairs (Sea Grant, 1978).

In all the water curriculum literature, it is emphasized that water need not be taught by itself as a course, but is well made for a multidisciplinary approach. Water & Man, Inc. has developed a conceptual framework for water education that closely follows the goals stated by the Sea Grant study. It is a carefully conceived and systematically conducted plan. Its design helps the educator to quickly identify fundamental goals, concepts and general objectives (Water &

Man, Inc., 1981). The method one uses to teach the objectives is up to the educator's discretion.

The Bureau of Reclamation Southwest Region has developed a curriculum water guide for grades four through six. The guide has activities that may be used unmodified by educators, or they can be adapted to their own classroom situations.

By far the most far reaching and dynamic water curriculum was developed by the state of California. After a severe drought and water shortage, the California Departments of Water Resources and Education, with the aid of local water suppliers, county offices of education, and local school districts sponsored by a comprehensive, Multidisciplinary Water Awareness Program for grades K-12. Waterplay for kindergarten through third grades, Captain Hydro for grades four through six, The Further Adventures of Captain Hydro for grades seven through nine, the Official Captain Hydro Water Conservation Workbook, and the more heavily academic secondary materials for grades ten through twelve. Although the workbook superficially appears to be an adventure comic book, literally hundreds of "educational handles" have been incorporated into the student material. The lessons and additional suggestions included in the teachers' guide utilize these openings to provide a wealth of educational opportunities. The results of this educational effort reduced water consumption dramatically. The drop in water consumption was so significant that the cost of the reduced amount of water used had to be increased to pay for continued expenses (Brecht, 1980).

Summary

In this chapter the author has tried to describe:

1. Simulation as it has evolved from the ancient Chinese war gaming, to business games, to the present day computer simulations.

2. The nature of simulation identifying techniques such as role playing and scenario assessment. This leads to the development of interdisciplinary methods of learning and problem solving.

3. What can be learned in simulation focusing on decision making skills, analytical skills, and social skills.

4. Design and development of simulation games where there are six common guidelines for the development of simulation games on which the author has focused.

5. Simulation and gaming in natural resource management showing how simulation games set out to produce their desired effects; and also some applications of computer simulation and gaming.

6. Water curriculum research found that there was very little water education materials available.

CHAPTER III

DESIGN AND METHODOLOGY

Introduction

The purpose of this study is to evaluate the effectiveness of an interactive Water Resource Management Simulator in the classroom. The WRMS was taken to selected schools and presentations were given to sciences classes. The presentations consisted of first a slide show and then interaction with the WRMS; questions were welcomed at any time during the presentation.

Description of the Sample

The sample was drawn from a selection of schools ranging from rural to urban school systems. A total of 746 students in grades 7 through 12 were tested. Table I shows the distribution of subjects by grade and assignment to control (pre-test) and experimental (post-test) groups.

Testing Instrument

The WRMS Knowledge Test is an instrument designed to measure a student's knowledge of concepts associated with the WRMS. Test items were written to measure hypothetical objectives stated for the WRMS. The WRMS Knowledge Tests consists of twenty-five questions, eighteen multiple choice and seven true and false. These twenty-five questions deal with knowledge that was assumed inherent in a WRMS presentation.

TABLE I

NUMBER OF STUDENTS SURVEYED

Students	Pre	Post	Total
Grade 7	107	103	210
Grade 8	103	120	223
Grade 9	28	34	62
Grade 10	57	75	132
Grade 11	18	30	48
Grade 12	29	42	71
TOTALS	342	404	746

A pre-test was given to approximately half of the population the day before they were introduced to the WRMS. The second half of the population was tested the day after interacting with the WRMS. This procedure reduced pre/post-test contamination.

Test reliability was determined using the Kuder-Richardson formula eight. The 25-item test had an acceptable realiability of .77. Since the test items were written to measure the attainment of the stated objectives of the WRMS, content validity was assumed to be high.

Administration of the Pre/Post Test

The students were told that their names were not required and that this test had nothing to do with grades. All questions were answered on a Bureau of Test and Measurements standard answer sheet and responses tabulated by computer.

The pre-test was administered to approximately one-half of the participating classes the day before they were introduced to the WRMS. Which half of the students was tested first was determined by the teacher.

The post-test was administered on the following day after the students had been introduced to the WRMS and interacted with it. The second half of the classes which were not given a pre-test were post-tested, and the teacher sent the answer sheets to the investigator via mail. Pre- and post-populations were done from each grade level with each school. Since no ability groupings into classes existed, it was assumed the pre-test populations were similar to post-test populations.

Presentation Format

The programs using the simulator began with a slide presentation (approximately 20 minutes) that introduced the simulator and its controls and some background information. The slide show had a set printed outline to follow to keep the information presented constant. After the presentation the WRMS was placed at the front of the classroom. Control panels were then assigned to students or groups of students and the interaction began. The last five to ten minutes of class were open for discussion.

Method of Analyzing Data

Pre-test and post-test responses were statistically analyzed using the analysis of variance two-tailed t-test in conjunction with Chi-square's two way classification. Computer programming was done using Oklahoma State University's main frame computer. The data results were considered for significance at the $P \leq .05$ level.

CHAPTER IV

RESULTS OF THE STUDY

The concern of the first three chapters has been a general introduction to the study, a review of related literature, and a discussion of the design of the study. Chapter IV is a presentation of the findings of the study based on pre-test and post-test responses. The presentation of the results of data analysis are presented in the same sequence as were the questions directing the study.

Analysis of Pre/Post WRMS Knowledge Test Scores

Question #1

What is the level of current Water Resource Management knowledge at the 7th-12th grade?

Table II shows the mean pre-test response by grade level. No consistant pattern appears evident when comparing mean scores with grade levels. Pre-test scores of all subjects show that fewer than 50 percent of the test items were answered correctly. In general, pre-test scores indicate a lack of water knowledge associated with the WRMS by seventh through twelfth grade public school students responding to the test questions.

TABLE II

PRE-TEST MEAN SCORES

Group	n	$\bar{x}$
7th	107	9.31
8th	103	9.64
9th	27	9.85
10th	56	9.78
11th	18	10.33
12th	29	9.72
Total students	340	9.77

Question #2

Do students interacting with the WRMS know more than those who have not?

To answer question number two the following null hypothesis was stated:

H_o1 There will be no significant difference between the total population mean pre-test score and mean post-test score.

The data presented in Table III compares mean scores of the total control (pre-) and experimental (post-) populations. As indicated in Table III there is a difference in mean pre- and post-scores and the difference favors the post test. In addition to an increase in the mean score, the range of correct responses also increased. The t-value of 3.32 called for rejection of the null hypothesis ($p \leq .05$).

TABLE III

T-TEST COMPARISONS OF TOTAL POPULATION PRE/POST WRMS KNOWLEDGE SCORES

Grades 7-12	N	$\bar{x}$	SD	DF	t	p	Range of Resp.
Pre	342	9.77	3.29	744			1-18
					3.32	0.0001	
Post	404	10.67	4.21	744			2-22

Question #3

At what level does the WRMS impart information?

H_o2 There will be no significant difference in the pre/post-scores between the junior high (7-9) and senior high (10-12).

Table IV shows pre/post comparisons between junior high (7-9) and senior high (10-12). The junior high (7-9) did not have significantly higher mean knowledge scores but the mean score was higher indicating that learning was taking place. There was a significant difference between the junior high and senior high pre/post-test. The null hypothesis was rejected.

TABLE IV

T-TEST COMPARISON OF PRE/POST WRMS KNOWLEDGE SCORES FOR JUNIOR HIGH AND SENIOR HIGH

Source	N	$\bar{X}$	SD	Deg. of Freedom	t	p	Range correct Response
Pre	228	9.60	3.26				2-18
7,8,9				483	0.192	0.100	
Post	257	9.70	3.14				3-18
Pre	104	9.86	3.32				1-18
10,11,12				249	4.69	0.0001*	
Post	147	12.39	5.19				2-22

*Significant Difference

Question #3

At what level does the WRMS impart information?

H_o3 There is not significant difference between mean pre/post-test scores by grade level.

Table V shows there is no significant difference for grades seven, eight, nine, and eleven, so the null hypothesis could not be rejected by these grades. The computed t-values of 2.14 for the tenth grade and 6.17 for the twelfth grade called for rejection of the null hypothesis for these grades ($p \leq .05$).

TABLE V

T-TEST COMPARISON OF STUDENT PRE/POST WRMS KNOWLEDGE SCORES

Source		N	$\bar{X}$	SD	Deg. of Freedom	t	P	Range of correct Responses
7th	Pre	107	9.31	3.92	208	1.70	0.09	2-15
	Post	103	10.66	2.91				3-18
8th	Pre	103	9.64	3.28	221	-1.23	0.21	1-18
	Post	120	9.10	3.13				3-18
9th	Pre	27	9.85	3.14	59	-1.69	0.09	0-16
	Post	34	8.32	3.73				0-15
10th	Pre	56	9.78	3.08	129	2.14*	0.03	2-16
	Post	75	11.16	4.25				2-22
11th	Pre	18	10.33	2.85	46	-1.21	0.23	3-15
	Post	30	9.26	3.12				5-16
12th	Pre	29	9.72	3.94	69	6.17*	0.0001	1-18
	Post	42	16.83	5.25				6-22

*Significant Difference

Question #4

What concepts does the WRMS teach?

H_o4 There is no significant relationship between pre/post test responses for each item by grade level.

To determine the type of knowledge imparted during WRMS presentations, chi-square values were determined by grade level. Table VI, comparing pre/post, correct/incorrect frequencies indicated that correct pre-test frequencies were often significantly different, sometimes in favor of the pre-test. Table VI presents a summary of significant frequency distribution that tended to favor either the pre- or post-test. A total of nineteen items had response frequencies in favor of pre-test scores by various groups; mainly eighth and eleventh grade. A total of forty-two items favor post-test frequencies by various groups. Significant post-test frequencies tended to occur with the tenth and twelfth grade students. No observable pattern exists favoring the pre-test across groups; however, for test items 3, 5, 6, 7, 12, 16, and 19, the frequency of correct responses favored the post-test for all groups in addition to those items with significant chi-square values.

Summary

1. The pre-test scores indicate a lack of water knowledge associated with the WRMS by all grades.

2. The data shows significant increases in mean post-test scores for the total population.

3. There was a significant difference between the junior high and senior high pre/post-test in favor of the senior high. The

TABLE VI

SUMMARY CHI-SQUARE DETERMINATIONS ON TEST ITEMS
RESPONSE FREQUENCIES BY GROUP

Item	Group 7	8	9	10	11	12
1	*		*	*	*	**
2		**			*	
3+	**	**	**	**		**
4						*
5+		**				**
6+						**
7+						
8				**		
9						
10		**				**
11						**
12+	**	**	**	**		**
13		*				
14		*		**		**
15						**
16+				**		
17		*	*			**
18		*				**
19+	**					**
20	*	*				
21	**	*				
22					**	*
23			*			**
24		*				**
25		*			*	

*Pre-test significant at .05 or greater
**Post test significant at .05 or greater
+Frequency of correct response favors post test for all groups

junior high scores increased, but not significantly.

4. Inconsistency appeared when the data was broken down by grade level.

5. Significant post-test frequencies tended to occur in the tenth and twelfth grade students. For test items 3, 5, 6, 7, 12, 16 and 19, the frequency of correct responses favored the post-test for all groups.

Descriptive and statistical analysis of data indicates there is value in the WRMS as a tool for simulation learning in the classroom. The twelfth grade demonstrated the highest increases in post-test scores and increases in range of correct responses.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In general, the total population did not exhibit extensive water resource management knowledge before interacting with the WRMS ($\bar{x}$ = 9.77).

The total population did show a significant increase in water resource knowledge after having interacted with the WRMS (t = 3.32). Based on results obtained from the test scores obtained in this study, there is reason to assume the WRMS does teach.

The WRMS tended to teach the senior high group more than the junior high group. The senior high group (9-12) scored significantly higher than the junior high group (7-9). The junior high did score higher, but not significantly.

An analysis of responses frequencies for each item by group identified the tendency for significant increases in correct responses for items 3, 5, 6, 7, 12, 16, and 19 (appendix). These items represent 28% of the twenty-five item test and deal with:

Item 3 the Ogallala aquifer in Oklahoma

Item 5 consumptive use of water in energy production

Item 6 tertiary sewage treatment

Item 7 consumptive use of water for irrigation

Item 12 identifying silt as a serious water pollutant in Oklahoma

Item 16 recognizing that there is no substitute for water

Item 19 understanding that the earth's water supply is finite, and its availability is often beyond our control

The increases in the number of correct responses to questions dealing with concepts and facts indicate a wide range of learning. Knowledge dealing with ground water uses in energy and agriculture, municipal sewage treatment, and pollution was imparted to all groups. General ideas such as recognizing our dependence on water and the limits of the water reserve are important basic concepts necessary for wise decision making.

The information gained in this study substantiates the assumption that the WRMS is a valuable aid in teaching basic concepts of water resource management and for imparting general ideas that are <u>not normally covered</u> in classrooms, such as items 16 and 19 on the WRMS knowledge test.

Recommendations

The following recommendations are made with the improvement of the WRMS as an educational tool in mind:

1. Have an audio tape made to go along with the slide presentation to assure each group gets the same information.
2. Ascertain that each group of students has the same amount of time of interaction with the simulator.
3. The WRMS does teach and should be utilized by schools.
4. The WRMS should be considered by school systems as a way to teach water resource management to high school students.

Recommendations for Further Research

It is recommended that further research be done to enable us to:

1. better define the parameters of the teaching ability of the WRMS.
2. determine the effect of time alloted on performance.

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APPENDIXES

Water Resource Management Knowledge Test

1. Water users can be divided into municipal, industrial, livestock and energy. Which of the following uses the most water?

    a. municipal/industrial
    b. industrial
    c. livestock
    d. irrigation
    e. not sure

2. Water in Oklahoma's rivers generally flows toward the

    a. Northeast
    b. Northwest
    c. Southeast
    d. Southwest
    e. not sure

3. A major aquifer in Oklahoma is the

    a. Perrniam
    b. Ogallala
    c. Nubian
    d. Hennesey Shale
    e. not sure

4. Water is used to cool coal and nuclear electrical energy generating plants. Which procedure uses the least amount of water?

    a. flow through in closed pipes
    b. evaporative cooling
    c. non-consumptive
    d. condensation cooling
    e. not sure

5. Water is used to cool coal and nuclear electrical energy generating plants. Which procedure returns the least water back to the surface reserve?

    a. flow through in closed pipes
    b. evaporative cooling
    c. consumptive
    d. condensation cooling
    e. not sure

6. Which of the following sewage treatment procedures returns the least polluted water back into the surface reserve?

   a. secondary
   b. floculation
   c. primary
   d. tertiary
   e. not sure

7. Which of the following irrigation methods requires the least amount of water?

   a. sprinkler method
   b. percolation method
   c. flood method
   d. hydrologic
   e. not sure

8. Which of the following irrigation methods returns the most water back into the surface reserve?

   a. sprinkler
   b. percolation
   c. flood
   d. hydrologic
   e. not sure

9. Which would you consider the most feasible solution to Oklahoma's water problems?

   a. new sources of water
   b. new reservoirs and dams
   c. conservation
   d. drill more wells
   e. not sure

10. What percent of all water used in Oklahoma is used for irrigation purposes?

   a. 20%
   b. 50%
   c. 75%
   d. 90%
   e. not sure

11. "Dilution is the solution to pollution" means:

   a. dilution reduces the amount of pollutant present
   b. adding "clean" water reduces the concentration of pollutants
   c. removal of pollutants from surface water
   d. greater stream flow reduces the amount of pollutants
   e. not sure

12. The greatest water pollutant in Oklahoma is:

    a. salt
    b. PCB's
    c. silt
    d. DDT
    e. not sure

13. The most harmful consequence of little winter snowfall in the mountains is

    a. snow mobiles are restricted to certain areas
    b. it makes for poor skiing
    c. wild game animals do not move from higher elevations to the lower elevations
    d. spring snow melt and runoff will be insufficient
    e. not sure

14. During which month of the year does irrigation in the Southwest demand the greater amount of water?

    a. September
    b. May
    c. December
    d. February
    e. not sure

15. Most of the earth's water is stored in

    a. precipitation and clouds
    b. rivers and lakes
    c. ground water and lakes
    d. oceans and snowpack
    e. not sure

TRUE OR FALSE (mark A for true, and B for false)

16. There are alternative forms of energy and water that we can develop to meet our needs.

17. The amount of ground and surface water available for use varies by geographic region.

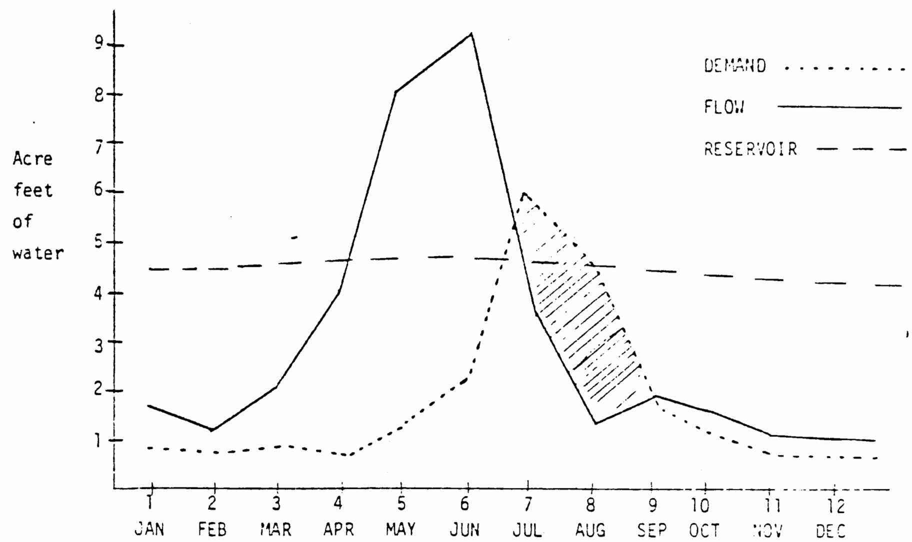
18. Where both ground and surface water are available to a community the decision as to which will be used is made by the Oklahoma Water Resource Board.

19. We have little control over the amount of water available to us.

20. The demand for water by municipal, industrial, agricultural and energy users usually peaks at the same time stream flow peaks.

21. The "life span" of a reservoir is related to the silt load carried in streams and rivers carrying water to the reservoir.

22. Water quality is subject to available technology but the choice of technologies is made through public policy.



23. How is downstream water quality affected in the dry months of July, August, and September?

   a. remains the same
   b. lower concentration of pollutants
   c. higher concentration of pollutants
   d. less pollutants in August than in July
   e. not sure

24. The increased demand in July is probably due to

    a. industrial users
    b. municipal users
    c. irrigation users
    d. not sure

25. What action would you take to end the supply/demand problem July through September?

    a. build a dam
    b. initiate conservation practices
    c. find new water supply sources
    d. not sure

VITA

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