DOCUMENT RESUME

ED 417 937		SE 061 189
AUTHOR	Schaufele, Christopher; Zumoff, Nancy	
TITLE	Earth Algebra.	
INSTITUTION	Kennesaw Coll. Marietta, GA.	
SPONS AGENCY	Fund for the Improvement of Postsecondary Education (ED), Washington, DC.	
PUB DATE	1996-00-00	
NOTE	67p.	
CONTRACT	P116B10601	
PUB TYPE	Reports - Descriptive (141)	
EDRS PRICE	MF01/PC03 Plus Postage.	
DESCRIPTORS	*Algebra; *Course Descriptions; *Curriculum Enrichment; Educational Technology; Higher Education; *Instructional Materials; Mathematics Instruction; Standards; *Textbook Preparation	
IDENTIFIERS	NCTM Curriculum and Evaluation Standards	

ABSTRACT

Earth Algebra is an entry level college algebra course that incorporates the spirit of the National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards for School Mathematics at the college level. The context of the course places mathematics at the center of one of the major current concerns of the world. Through mathematical analysis of real data, students gain new perspectives on mathematics as a tool. The course incorporates group work, written reports, simplistic mathematical models, and the use of technology. An executive summary involving a project overview, statement of purpose, background and origins, project description, evaluation/project results, and conclusions is included. Appended is a final evaluation report, "Earth Algebra Project: A Final Evaluation Report" (Pamela J. Drummond). Also appended are the evaluation instruments. (Author/ASK)

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Earth Algebra P116B10601
Executive Summary

Grantee Organization:
Kennesaw State College
Department of Mathematics
PO Box 444
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Grant Number:
P116B10601

Project Dates:
Starting Date: September 1, 1991
Ending Date: August 31, 1993
Number of Months: 24

Project Directors:
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FIPSE Program Officer: Brian Lekander

Grant Award:	Year 1	$ 30,196
	Year 2	$ 60,392
	Total	$ 90,588

Project Summary

Earth Algebra is an entry level college algebra course which incorporates the spirit of the *NCTM Curriculum and Evaluation Standards for School Mathematics* at the college level. The context of the course places mathematics in the center of one of the major current concerns of the world, i.e., environmental issues and global warming. Through mathematical analysis of real data, students gain a new perspective on mathematics as a tool. The course incorporates group work, written reports, simplistic mathematical models, and the use of technology. All these aspects remove the traditional lecture style as the means of delivery in the course, and make mathematics a "hands-on" subject.

A preliminary edition of a textbook, Earth Algebra: College Algebra with Applications to Environmental Issues, authored by the project directors, was published by HarperCollins in January, 1993.

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Earth Algebra: College Algebra with Applications to Environmental Issues, by Christopher Schaufele and Nancy Zumoff, HarperCollins, 1993

EXECUTIVE SUMMARY
EARTH ALGEBRA P116B10601

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PROJECT OVERVIEW

Earth Algebra is an entry level college algebra course which incorporates the spirit of the *NCTM Curriculum and Evaluation Standards for School Mathematics* at the college level. The context of the course places mathematics in the center of one of the major current concerns of the world, i.e., environmental issues and global warming. Through mathematical analysis of real data, students gain a new perspective on mathematics as a tool. The course incorporates group work, written reports, simplistic mathematical models, and the use of technology. All these aspects remove the traditional lecture style as the means of delivery in the course, and make mathematics a "hands-on" subject.

A preliminary edition of a textbook, Earth Algebra: College Algebra with Applications to Environmental Issues, authored by the project directors, was published by HarperCollins in January, 1993. The text can be used for a "Liberal Arts Mathematics" course or can replace traditional college algebra.

Earth Algebra was piloted and is now fully integrated into the curriculum at Kennesaw State College, enrolling approximately 2000 students. It was tested at selected institutions around the country before publication of the text, and as of this writing (ten months after publication), the text has been adopted by twenty-five institutions around the country.

PURPOSE

Courses in college algebra have until recently slipped through the cracks of the major reform efforts. Yet these are the courses taken by the vast majority of college students as their last exposure to mathematics. These are the courses in which there is minimal success on the part of students, and minimal appreciation of subject matter. Often students enter the courses with anxiety and hostility because of previous experiences or what they have always heard about “math”. Earth Algebra is designed specifically to not only teach mathematics but to alter these adverse perceptions.

Insight gained while working on this project indicates that Earth Algebra is being and will be well received as either a terminal mathematics course, or as a prerequisite to "business" calculus or statistics. Although almost all mathematics departments pay lip service to the need for change throughout the introductory curriculum, many instructors are unwilling to give up any traditional topics (no matter how irrelevant) even in a terminal course. Also, many faculty from colleges and universities feel that Earth Algebra does not cover in sufficient depth the topics or skills necessary for students who intend to enter a standard calculus course. We see these as two separate problems. We are addressing the above problems as part of new FIPSE and NSF grants awarded to develop similar courses in mathematics education and to replace traditional precalculus courses.

BACKGROUND AND ORIGINS

During the earliest stages of the development of this course the Mathematics department voted unanimously to throw out the existing college algebra course in favor of a completely new approach. Our administration provided support in the form of release time for initial development of material, and additional support in the following academic year for drafting grant proposals in support of the project. Georgia Power Company supplied a start-up grant for further development of materials, and both FIPSE and NSF cooperated in funding the Earth Algebra project.

In developing this course, one of our principal goals, perhaps we should say dreams, was to forever lay to rest the students' question "what's this stuff good for". In an attempt to answer this question, we have couched college algebra in vitally important environmental issues in which most students are interested. This course provides the opportunity to analyze real data about real problems, and for many students provides their first opportunity to use mathematics as a tool for decision making.

PROJECT DESCRIPTION

The main feature of our project was the development of a new college algebra course focused on environmental issues, incorporating collaborative learning, use of technology, written and oral communication, problem solving and decision making. We decided to put the traditional topics in a context which would be of interest to most students and to focus on a single environmental issue, global warming. Relevant real data is made available to the class and modeled through class participation and discussion led by the instructor. The class is divided into small groups, and much of the work is done in these groups. Communication skills, both written and oral, are required for the group presentations and reports, and some student research of data can be required. The capabilities of modern graphing calculators provide the technology to analyze real data without the tedium and drudgery of repetitive computation and manipulation. Throughout, the practicality of mathematics is emphasized through problem solving, interpretation of results and decision making based on simple mathematical models. Students of Earth Algebra learn that mathematics can be used as a decision making tool and understand the relevance of mathematics in modern society.

The text is a case study of CO_2 emission and its effect on global warming. Simplistic mathematical models, which are developed from real data, provide examples of algebraic techniques, use of the calculator, and the role of mathematics in decision making. Emphasis is placed on the mathematical model as a tool.

Under the direction of HarperCollins Publishers, four preliminary versions of the manuscript were reviewed extensively and class tested at some five to ten colleges and universities around the country. We are now revising the preliminary edition of the text; the first edition is scheduled for publication in December, 1994.

In addition to writing the text book, the project directors have given numerous workshops, presentations and minicourses both regionally and nationally. Thus dissemination has been extensive.

EVALUATION/PROJECT RESULTS

Highlights of the evaluation are: Earth Algebra students dramatically improved their views toward mathematics; Earth Algebra had no different effect on students' knowledge of algebra than did "Regular" College Algebra; i.e. both groups performed at an equal level in algebraic skills; after Earth Algebra replaced the traditional college algebra, the percentage of students passing their subsequent (traditional) mathematics course increased.

Dissemination of the Earth Algebra project will continue through workshops and presentations and the publication of the first edition of the text.

Regarding our future plans, we have received a new grant from FIPSE to develop and test materials (EarthMath Studies) designed in the spirit of Earth Algebra which can be used in a wider range of courses and in a variety of different institutions. Specifically, we will extend the Earth Algebra concept into those two areas for which we have received the most requests and for which the need for such courses is most critical: precalculus, both algebra and trigonometry, and mathematics education courses as a tool for training preservice teachers. In addition to Kennesaw State College, seven institutions have agreed to participate in the planning and testing of these materials. Additional funds have been awarded by the NSF for further dissemination of these new materials.

SUMMARY AND CONCLUSIONS

The major activities during the grant period are listed below.

1. A new course, Earth Algebra, was developed to replace the traditional college algebra.
2. The course was piloted at Kennesaw State Colllege and tested at KSC and five to ten institutions around the country.
3. A text book written by the project directors was published by HarperCollins in January of 1993.
4. The project was evaluated by independent evaluators.
5. Earth Algebra has completely replace the traditional college algebra course at Kennesaw State College.
6. The book has been adopted by twenty-five to thirty colleges and universities around the country.
7. Numerous workshops, presentations, and minicourses have been given by the project directors.

PROJECT OVERVIEW

In the winter of 1990, our department reviewed its course offerings, and as a result, we were appointed co-chairs of an ad hoc committee which was given the charge to do something about college algebra. One of our colleagues suggested, "If you want to make a course interesting, then you should study something of interest." This profundity could very well have been the impetus for the Earth Algebra project.

Earth Algebra is an entry level college algebra course which incorporates the spirit of the *NCTM Curriculum and Evaluation Standards for School Mathematics* at the college level. The context of the course places mathematics in the center of one of the major current concerns of the world, i.e., environmental issues and global warming. There is increased emphasis on conservation and problems of the environment, so most beginning college students enter with at least a superficial knowledge of these issues. Through mathematical analysis of real data, students gain a new perspective on mathematics as a tool. The course incorporates group work, written reports, mathematical models, and the use of technology. All these aspects remove the traditional lecture style as the means of delivery in the course, and make mathematics a "hands-on" subject.

A textbook, Earth Algebra: College Algebra with Applications to Environmental Issues, authored by the project directors, was published by HarperCollins in January, 1993. The text can be used for a "Liberal Arts Mathematics" course or can replace traditional college algebra. The course can be taken by all beginning college students with a minimal high school background of Algebra II.

Students enjoy an experience in mathematics not available anywhere else in a traditional undergraduate liberal arts program.

Earth Algebra was piloted and is now fully integrated into the curriculum at Kennesaw State College; the course enrolls approximately 2000 students per year. It was tested at selected institutions around the country before publication of the text, and as of this writing (ten months after publication) the text has been adopted by twenty-five institutions around the country.

PURPOSE

The problems in mathematics education in the United States are well known: students drop out of the pipeline at the rate of fifty percent per year from ninth grade through graduate school; the course content is viewed by students as irrelevant to one's real life needs and experiences; mathematics is considered too difficult for all but an intellectual elite; it is acceptable to not like mathematics and to not do well; and, finally, it is believed that the country will not suffer if mathematics is left to those who have some special gift enabling them to master the material.

Courses in college algebra have until recently slipped through the cracks of the major reform efforts. Yet these are the courses taken by the vast majority of college students, including preservice teachers, as their last exposure to mathematics. These are the courses in which there is minimal success on the part of students, and minimal appreciation of subject matter. For many students such courses merely rehash material they previously studied and disliked at the secondary education level. Often students enter the courses with anxiety and hostility because of previous experiences or what they have always heard about “math”. What they find does little to change those perceptions. It is indeed sad that a lack of success and appreciation of mathematics by education majors creates an antagonism which is carried into the classrooms in which they teach.

Insight gained while working on this project indicates that Earth Algebra is being and will be well received as either a terminal mathematics course, or as a prerequisite to "business" calculus or statistics. Although almost all mathematics departments pay lip service to the need for change throughout the introductory curriculum, many instructors are unwilling to give up any traditional topics (no matter how irrelevant) even in a terminal course. Also, many faculty from colleges and universities feel that Earth Algebra does not cover in sufficient depth the topics or skills necessary for students who intend to enter a standard calculus course. We see these as two separate problems. Earth Algebra is among the first of the reform projects at this level and as such could be expected to receive a certain amount of opposition. This response is inherent in radical innovation. Also, many institutions are interested in adopting this course but only offer a single pre-calculus track. However, our course is not designed for this purpose. We are addressing the above problems as part of a new FIPSE grant awarded to develop similar courses which can replace traditional precalculus courses.

BACKGROUND AND ORIGINS

"If you want to make a course interesting, then you should study something of interest." - M. Sims, March 1990.

These simple but deceptively wise words were delivered at the first meeting of an ad hoc committee at Kennesaw State College . The charge to this committee was the following: "Do something about college algebra." The project directors were appointed co-chairs of this committee as an immediate and direct response to this public statement: "We are wasting our time and the students' time teaching our existing college algebra course."

During the earliest stages of the development of this course the Mathematics department voted unanimously to throw out the existing college algebra course in favor of a completely new approach. Our administration provided support in the form of release time for initial development of material, which was first tested in the summer of 1990. Additional support was provided in the following academic year for drafting grant proposals in support of the project. Georgia Power Company supplied a start-up grant for further development of materials. Both FIPSE and the National Science Foundation cooperated in funding the Earth Algebra project.

The opening profundity of Ms. Sims could very well have been the impetus for this project. What indeed could be done to make college algebra interesting? And, what makes college algebra boring to practically every student on this planet? The answers to the latter question were easily determined by a review of questions perennially posed by its students. Here are a few familiar ones:

1. "What's this stuff good for?" (in response to most anything);

2. "Who cares?" (in response to thought provoking word problems, such as "Train A leaves New York...," or "Sally is twice as old as John...");

3. "When will I ever have to do this again in my life?" (in response to simplification of a complex fraction that only Rube Goldberg could have designed);

and lastly, our favorite:

4. "Is x always equal to 2?" (in response to having solved a hideous equation involving roots of rational expressions).

There are answers, of course, to all these. In reverse order:

4. "Yes."

3. "I'm not sure."

2. "<u>You</u> should, if you want to pass this course."

1. "Designing electrical circuits," "constructing bridges," "putting a woman on the moon," etc., etc., etc.

The first question probably encompasses all the others (except possibly number 4), so we briefly observe that all the answers provided to this query are true but rather inadequate in yielding a meaningful link between factoring and space walking to any student at the beginning college level.

One of our principal goals, perhaps we should say dreams, was to forever lay question 1 to rest, at least among students of Earth Algebra. In an attempt to provide the interest, we have couched college algebra in the vitally important issues of the environment. Neither train A, nor Sally's age, are of concern. This course provides the opportunity to analyze real data about real things.

Kennesaw State College and Its Mathematics Department

Kennesaw State college is a comprehensive and progressive regional senior college in the University System of Georgia, enrolling over 12,000 undergraduate and graduate students. The college offer opportunities for concentrated study in the arts, humanities, the sciences, and the professional fields of business, education, health and social services.

The Department of Mathematics has 28 full-time faculty, shares four faculty with the Computer Science Department, four to five faculty with the Developmental Studies Department and employs part-time faculty for fifteen to twenty sections per quarter. The Department offers a Bachelor of Science degree in mathematics, a joint BS degree in mathematics education, and support graduate courses for a master's degree in K-8 education. The University system has a ten hour requirement in core mathematics courses for all undergraduate degrees, and therefore a primary role of the department is services.

PROJECT DESCRIPTION

The main feature of our project was the development of a new college algebra course focused on environmental issues, incorporating collaborative learning, use of technology, written and oral communication, problem solving and decision making. Under the assumption that college algebra, as it existed, was a waste of students and faculty's time, we planned to throw out the existing course and start from scratch. We decided to put the traditional topics in a context which would be of interest to most students. We designed the course to be focused on a single environmental issue, global warming.

The course begins with a class discussion of environmental issues, specifically global warming, its causes and effects. Relevant real data is made available to the class and modeled through class participation and discussion led by the instructor. After initially demonstrating modeling procedures, the role of the instructor evolves into that of providing direction, motivation and serving as a guide to the students. The class is divided into small groups, and much of the work is done in these groups. Communication skills, both written and oral, are required for the group presentations and reports. Some student research of data can be required. The capabilities of modern graphing calculators provide the technology to analyze real data without the tedium and drudgery of repetitive computation and manipulation. Throughout, the practicality of mathematics is emphasized through problem solving, interpretation of results and decision making based on mathematical models. Students of Earth Algebra learn that mathematics can be used as a decision making tool and understand the relevance of mathematics in modern society. A preliminary version of the textbook, Earth Algebra: College Algebra with Applications to Environmental Issues, authored by the proposes, was published by HarperCollins in January, 1993.

The text is a case study of CO_2 emission and its effect on global warming. Simplistic mathematical models, which are developed from real data, provide examples of algebraic techniques, use of the calculator, and the role of mathematics in decision making. Emphasis is placed on the mathematical model as a tool. All the student work is related to a single environmental issue, and all results obtained are used in analysis of this issue and its contribution to the overall problem. Prerequisite algebra sections are placed at the beginning of each part, as needed.

The topics covered in Earth Algebra are: functions; linear, quadratic, exponential, and logarithmic equations and functions; systems of linear equations and inequalities; matrices; geometric series; and linear programming.

The project was served by consultants Robert Paul, Professor of Biology, Kennesaw State College; John Kenelly, Professor of Mathematics, Clemson University; and Jack Downes, Professor of Mathematics Education, Georgia State University.

Under the direction of HarperCollins Publishers, four preliminary versions of the manuscript were reviewed extensively and class tested at some five to ten colleges and universities around the country. We are now revising the preliminary edition of the text; the first edition is scheduled for publication in December, 1994.

Since the beginning of the project in 1991, we have given numerous presentations, workshops and minicourses on the Earth Algebra project. Following is a listing:

1993:

Presentation, Dekalb College, Decatur, GA (November)
Presentation, NCTM Regional Conference, Durango, CO (October)
Mathematical Association of America/ American Mathematical Society National Summer Meetings, 4 hour mini-course, Vancouver, BC (August)
Workshop, National University, San Diego, CA (June)

Coweta/Heard County three day workshop for high school students, Newnan, GA (June)
NSF Earth Algebra Workshop, Portland State University, Portland, OR (May)
TI Eighty Something Technology Conference, Presentation, Essex College, Baltimore, MD (May)
NSF Earth Algebra Workshop, San Juan College, Farmington, NM (April)
Conference on Applied Mathematics (environmental section), Central Oklahoma State University, Oklahoma City, Oklahoma, Invited Presentation (March)
Texas Junior College Association Annual meeting, Austin, Texas, Invited Presentation (February)
Presentation, Kentucky AMATYC meeting, Lexington KY(March)
National Joint Meetings: American Mathematical Society and Mathematical Association of America, San Antonio, Texas, four hour Mini-Course (January)

1992:

International Conference on Technology in Collegiate Mathematics Presentation, Chicago, Illinois (November)
American Mathematical Association of Two Year Colleges, Presentation, Indianapolis, Indiana (November)
U.S. Dept. of Education: FIPSE Project directors conference, Presentation, Washington, D.C. (October)
San Jacinto State College Technology conference, Workshop, Houston, Texas (July)
Richmond County, GA, Workshops for high school teachers and students (July)
Coweta/Heard Counties, GA. Workshops for high school teachers and students (June)
MAA South Eastern. Sectional Meeting, Earth Algebra Mini-course (April)
Mid-Atlantic conference on College Teaching and Classroom Research, Salisbury State University, MD, Workshop (April)
Excellence in Education Conference, Florence-Darlington College, SC, Workshop (February)
MAA/AMS National Meetings, Baltimore, MD, Presentation / Panel (January)

1991:

International Conference on Technology in Collegiate Mathematics, Portland, OR, Presentation (November)

MAA/AMS National Meetings, Orono, ME, Presentation (August)
Workshops: Coweta/Heard county, GA, high school students (June); teachers (August)

Scale and Intensity

At the beginning of the project we seriously underestimated the time and effort which would be required to complete our plan. We basically had to start from scratch in gathering data and developing methods. Even the "traditional " material had to be rewritten for the textbook in order to fit into our approach. In retrospect, we feel that this should have been at least a three year project.

The book contract with HarperCollins in many ways was helpful. However, four revisions of the preliminary manuscript were required for class-testing and reviewing, and we feel that meeting these deadlines took away from developmental time. We would, however, like to point out that the publisher was not responsible for this schedule. In our naiveté we thought the project could be completed much sooner and put ourselves on this intense schedule. Since the initial announcement of the project we were bombarded with invitations to speak, and more time than we had ever imagined was spent traveling to numerous workshops and presentations during the developmental stage. Fortunately, funds for much of the travel to presentations and workshops were provided by our publisher. The National Science Foundation also provided supplemental funds in support of two dissemination workshops and travel to conduct an MAA minicourse.

EVALUATION/PROJECT RESULTS

An evaluation report of the project which is included as an appendix is summarized below.

To assess the extent of the success of Earth Algebra, the results of testing six hypotheses were analyzed to determine if the course enhanced achievement in any of the four pretest and posttest variables: (a) knowledge of algebra, (b) data analysis, (c) mathematical modeling, and (d) view toward mathematics. The following listing provides the major conclusions of this investigation.

1. Supplanting the curriculum of a standard entry-level college algebra course is feasible.

2. Earth Algebra students dramatically improved their views toward mathematics.

3. Earth Algebra enhanced students' achievement in data analysis.

4. Earth Algebra enhanced students' achievement in mathematical modeling.

5. Earth Algebra had no different effect on students' knowledge of algebra than did "Regular" College Algebra; i.e. both groups performed at an equal level in algebraic skills.

6. There is a very strong relationship between the students' final course grade and View of Mathematics Inventory (VMI) Gain scores among Earth Algebra students.

7. A strong relationship existed between final course grade and Data Analysis Achievement (DAA) Gain scores among Earth Algebra students.

8. Earth Algebra can be judged successful. This conclusion is justified after reviewing the previous six conclusions (2-7).

Thus, in the final analysis, entry-level college algebra students can study a nonstandard curriculum, driven by environmental issues, while using mathematical modeling and data analysis to motivate algebraic concepts. Not only did the students in Earth Algebra experience significant gains with respect to these emphasized constructs but, surprisingly, they also achieved the similar gains in knowledge of algebra as the control group. In particular the treatment students experienced very significantly higher gains in data analysis achievement and mathematical modeling achievement and remarkably significantly higher gains in views toward mathematics.

In addition to the above, follow-up investigation of student grades reveals the following. The chart indicates the percentage of students who were successful with a grade of C or better in both college algebra and subsequent courses at Kennesaw State in the fall quarter of the year shown.

% Successful	1990 Traditional CA	1991 Traditional CA	1991 Earth Algebra	1992 Earth Algebra
College Algebra	62.3	62.9	64.0	72.2
Subsequent	71.0	66.0	66.3	74.1

The increase in percentage of students succeeding in subsequent courses with C or better in 1992 can be attributed to the formal training of instructors in the teaching of Earth Algebra. In 1991, teachers were untrained and were teaching from a very early and incomplete draft of the book. Most students exiting College Algebra at Kennesaw State College take either introductory statistics or "business" calculus.

Future Plans

Earth Algebra is being and will be well received as either a terminal mathematics course, or as a prerequisite to "business" calculus or statistics. We have received a new grant from FIPSE to develop and test materials (EarthMath Studies) designed in the spirit of Earth Algebra which can be used in a wider range of courses and in a variety of different institutions. Specifically, we will extend the Earth Algebra concept into those two areas for which we have received the most requests and for which the need for such courses is most critical: precalculus, both algebra and trigonometry, and mathematics education courses as a tool for training preservice teachers. The EarthMath Studies will initially be in the form of short studies of single environmental issues which involve modeling and analysis of real data, use of technology, group work, written and oral reports and student research. In addition to Kennesaw State College, seven institutions have agreed to participate in the planning and testing of these materials. Additional funds have been awarded by the NSF for further dissemination of these new materials.

Dissemination of the Earth Algebra project will continue through workshops and presentations and the publication of the first edition of the text.

SUMMARY AND CONCLUSIONS

The major activities during the grant period are listed below.

1. A new course, Earth Algebra, was developed to replace the traditional college algebra.
2. The course was piloted at Kennesaw State Colllege and tested at KSC and five to ten institutions around the country.
3. A text book written by the project directors was published by HarperCollins in January of 1993.
4. The project was evaluated by Prof. Pamela Drummond who was not involved in development..
5. Earth Algebra has completely replaced the traditional college algebra course at Kennesaw State College.
6. The book has been adopted by twenty-five to thirty colleges and universities around the country.
7. Numerous workshops, presentations, and minicourses have been given by the project directors.

8. Earth Algebra has received national attention on the radio on the **Paul Harvey** show.

Earth Algebra is so radically different from the traditional college algebra course, it has attracted much attention from the mathematical community. We have been astonished at the eagerness of people for innovative materials at the freshman/sophomore college mathematics level. This course has been well received by both students and faculty at institutions around the country. Many faculty are genuinely searching for new ways to present stale courses, and these have, as a rule, have found Earth Algebra to be an exciting innovation. On the other hand, the resistance to change has been significant. Some faculty are unwilling to give up any traditional topics; others dislike the environmental focus. Some object to the simplification of modeling procedures. Others like the concept, but have only one (precalculus) track and find this course not rigorous enough.

We were concerned initially about the transportability of Earth Algebra, but are already receiving positive feedback from schools teaching the course. Even though there are disagreements with the Earth Algebra approach, the positive results and excitement it generates in the classroom by far overshadows the objections. Our advice to the practitioners is the advise we received from an early reviewer: "If you're going to be radical, be radical."

APPENDIX

EARTH ALGEBRA PROJECT

A FINAL EVALUATION REPORT

by

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The purpose of this evaluation is to assess a program whose purpose is to examine the feasibility of replacing the traditional college algebra course with a nonstandard course, Earth Algebra. This technology intensive course, driven by environmental issues, uses mathematical modeling and data analysis to motivate algebraic concepts. Specifically, this evaluation focuses on the following question:

Using a sample of college students, can one successfully supplant the curriculum of a standard college algebra course with the innovative instructional materials of Earth Algebra? In particular, can one determine the extent to which this new course is successful? By "successful" is meant the following:

In assessing the success of Earth Algebra, the evaluator will address first the extent to which the students exhibit gains in: (a) knowledge of algebra; (b) data analysis achievement; (c) mathematical modeling achievement; and (d) their attitudes toward mathematics. Further, the study will seek to determine the extent to which such achievement affects the grade a student receives in the course. Lastly, the results of this evaluation will be compared with the stated intended student outcomes specified by the authors of Earth Algebra.

Research Questions

To answer this question the evaluator will answer the following research questions:

1. Does the college algebra course, Earth Algebra, enhance a student's knowledge of algebra, data analysis achievement, mathematical modeling achievement, and/or view toward mathematics?

2. Is there a relationship between the grade a student earns in college algebra and knowledge of algebra, data analysis achievement, mathematical modeling achievement, and/or view toward mathematics?

3. Are the student outcomes of the course congruent with the terminal objectives identified by the authors of Earth Algebra?

Instrument Selection

In light of the aforementioned research questions, the evaluator selected and/or designed the five instruments used in this study: the Algebra Achievement Test (AA), the MAA Algebra Test (MAA), the Data Analysis Achievement Test (DAA), the Mathematical Modeling Achievement Test (MMA), and the View of Mathematics Inventory (VMI). These instruments may be found in Appendix A.

Algebra Achievement Test (AA)

In an effort to assess knowledge of algebra the investigator devised the AA, a ten-item free response test, that would span the mathematical content typically found in a traditional college algebra course. The same instrument was used for both pretest and posttest assessments. Students received a maximum of 4 points for each of the items. Partial credit was awarded using a schema developed by R. Charles, F. Lester, and P. O'Daffer. (1987. How to evaluate progress in problem solving. Reston, VA: National Council of Teachers of Mathematics.) A copy of the partial credit delineation is included in Appendix B.

MAA Achievement Test (MAA)

The MAA contains ten multiple-choice standard algebra test items taken from a Mathematical Association of America placement test (currently being used by the Mathematics Department). The evaluator used this instrument for both pretest and posttest assessments. Each item received either 0 points or 10 points. There was no consideration of partial credit for any item.

Data Analysis Achievement Test (DAA)

Searching for situations which would allow opportunities for students to analyze and/or interpret sets of data, the evaluator and evaluation consultant selected five free response items. Used as both the pretest and posttest, the DAA assesses the ability of the student to make predictions and determine the amount of error associated with the prediction equation. Students received a maximum of 4 points for each of the first two items, 8 points for item 3 (4 points for each of the two parts), 16 points for item 4 (four parts at 4 points each), and 12 points for item 5 (three parts at 4 points each). Partial credit was awarded as per the schema found in Appendix B.

Mathematical Modeling Achievement Test (MMA)

To elicit responses and queries that would require students to model mathematics, the evaluator and evaluation consultant designed the MMA. The MMA was used as both pretest and posttest. Each of the two free-response items on this instrument contains four parts. Thus, the items received a maximum of 16 points each (4 points for each of the four parts) following the partial credit delineation found in Appendix B.

View of Mathematics Inventory (VMI)

Originally developed in 1972 by W. L. Rettig, Sr. in his doctoral dissertation at the Ohio State University, the VMI assesses possible changes in attitudes toward mathematics. The evaluator and the evaluation consultant wrote and/or selected the 32 items which encompass the instrument used as both a pretest and posttest in this study. Possible choices for responses to the items were : 1) Strongly Disagree, 2) Disagree, 3) Neutral, 4) Agree, and 5) Strongly Agree. Students received 0 points to 4 points for each of the items depending upon how closely aligned the given response was to the expected response. For example, if the correct response was Strongly Disagree, given responses would be awarded points in the following way: Strongly Disagree, 4 Points; Disagree, 3 Points; Neutral, 2 Points; Agree, 1 Point; Strongly Agree, 0 Points.

Experimental Design

This study uses a variation of the pretest-posttest control group design. Seventeen classes of MATH 105 (College Algebra) were designated either Treatment (Earth Algebra), at eight sections (149 students), or Control, at nine sections (181 students). These sections were taught during the day and met either three days per week (MWF) or two days per week (TuTh). Additionally 11 sections of MATH 105 were excluded from the study. Specifically, these were 9 sections of "Regular" College Algebra which met at night, 1 day section which emphasized writing and was taught in conjunction with an entry-level English course, and 1 section of Earth Algebra. One section of Earth Algebra had to be excluded because delay in administering the posttest.

Each of the previously described instruments served as both pretest and posttest. All students completed the battery of all five of the tests as the Pretest. However, to facilitate the evaluation process and in an effort to minimize the in-class time necessary for completion, none of the students took the entire battery of tests as the posttest. The three distinct posttests included the following instruments: 1) AA, MAA, and VMI (Algebra); 2) DAA and VMI (Data Analysis); and 3) MMA and VMI (Mathematical Modeling). Using a die, seats numbered 1-30 for each of the classes, treatment and control, were partitioned and randomly assigned one of the three posttests. Because all students had participated equally in the pretest, the participation in the posttest would be as equitable. Thus each student completed either the AA, MAA, & VMI; DAA & VMI; or MMA & VMI.

Hypotheses

To assess the effectiveness of the course the evaluator examined the following hypotheses:

1. These is no significant difference between the treatment group and control group in students' increase in knowledge of algebra from pretest to posttest based on scores from the AA.

2. There is no significant difference between the treatment group and control group in students' increase in knowledge of algebra from pretest to posttest based on scores from the MAA.

3. There is no significant difference between the treatment group and control group in students' data analysis achievement from pretest to posttest as measured by the DAA.

4. There is no significant difference between the treatment group and control group in students' mathematical modeling achievement from pretest to posttest as measured by the MMA.

5. There is no significant difference between the treatment

group and control group in changes in students' view of mathematics from pretest to posttest as measured by the VMI.

6. There is no relationship between the students' gain scores on the AA, MAA, DAA, MMA, and/or VMI and the grade earned in the course.

The results of the six hypotheses will provide information useful in answering the first two research questions. In particular, the results of Hypotheses 1-5 will be central in responding to Research Question 1: Does the college algebra course, Earth Algebra, enhance a student's knowledge of algebra, data analysis achievement, mathematical modeling achievement, and/or view toward mathematics? Research Question 2 asks: Is there a relationship between the grade a student earns in college algebra and knowledge of algebra, data analysis achievement, mathematical modeling achievement, and/or view toward mathematics? The response to this query will involve the results of Hypothesis 6.

Subjects

The students participating in this study were enrolled in Kennesaw State College (KSC), a senior college of the Georgia University System located 20 miles north of Atlanta, GA. During Fall Quarter, 1991, the enrollment of the college was approximately 11,000. With the average age of an undergraduate being 26, KSC is evolving to be more like an urban commuter university than the traditional residential university in terms of its distribution of students.

In the Fall of 1989 KSC was one of only five institutions in the South named by the *U.S. News and World Report* as one of the nation's "Top Up-And-Coming Regional Colleges and Universities." In 1990, *U.S. News and World Report* again spotlighted Kennesaw State along with George Mason University as among the "best up and coming colleges" in the South and was again singled out as a "rising star" in 1991.

Students in both the treatment group and the control group were enrolled in MATH 105, College Algebra, the lowest mathematics course yielding graduation credit offered at KSC. At the time of registration, students chose a particular section of MATH 105, instructor and time of day. None of the sections were labeled "Earth Algebra," or "Regular" College Algebra. On the first day of class, members of the treatment group were informed that they were in a section of MATH 105 which would be known as "Earth Algebra." At that time, students could participate in the drop/add process and change courses. Thus, theoretically the students were not randomly assigned as members of either group.

In addition, it should be noted that students in both groups were expected to use a graphing calculator at all times, including homework <u>and</u> class tests. For most students, especially those in Earth Algebra, the TI-81 graphing calculator was the calculator of choice.

The number of students in this investigation was 330. The treatment group contained 149 students from seven class sections which had five instructors. The control group contained 181 students from nine class sections taught by seven instructors.

Data Gathering

This study occurred during Fall Quarter, 1991 (9/20/91 - 12/8/91).

Pretests

Prior to the beginning of classes, the evaluator met with the twelve instructors who would be teaching the classes involved in the study. The purpose of this meeting was to explain the purpose of the evaluation and to delineate the procedure to be followed in administering the pretest (and later, at the end of the quarter, the posttest). In short, the mathematics instructors were to administer the pretest on either September 23 of September 24. Students were to have as long as 90 minutes to respond to the items. The instructors were to encourage the students to cooperate and make an earnest effort. A copy of the Directions: Administration of Evaluation Instrument and a copy of the Cover Sheet for the Pretest/Posttest (i.e., instructions to the students) are included in Appendix C.

Posttests

Course instructors administered the posttests on either November 20 or November 21. As previously noted, the students in both groups were randomly assigned to one of three posttests. The following diagram specifies the partitioning of the students and instruments.

Table 1

Posttest Instrument Assignation

	Treatment	Control
AA, MAA, & VMI	47	68
DAA & VMI	46	57
MMA & VMI	56	56
Total	149	181

In other words, these numbers reflect the number of students who took the pretest in September, 1991 and who also took a posttest in November, 1991. All items on the pretest and posttest were identical. The time lapse between the testing dates was slightly more than eight weeks.

Note that the actual students who were involved in this study could not be identified until the completion of the posttesting. Thus, the results of the testing were not examined until after the posttests were completed. With the direction and supervision of the evaluator, three undergraduates who are aspiring high school mathematics teachers scored all the instruments, with the exception of the VMI, following procedures previously described. One student scored the AA and MAA; another scored the MMA; and the third student scored the DAA. This last student also assisted the evaluator in scoring the VMI.

Statistical Results and Discussion

This study entails the use of five variables which will be partitioned into two groups. The pretest and posttest instruments and variables, respectively, are: Algebra Achievement Test (AA), algebra achievement; MAA Algebra Achievement Test (MAA), algebra achievement; Data Analysis Achievement Test (DAA), data analysis achievement; Mathematical Modeling Achievement Test (MMA), mathematical modeling achievement, and View of Mathematics Inventory (VMI), attitude toward mathematics. One instrument and its related variable was generated during the course: Final Course Grade, achievement in college algebra. In order to determine appropriate statistical models for data analysis, the scores from the variables listed above will be classified as to type of data and type of distribution.

For parametric statistical tests, scores should represent interval data and should be approximately normal. Scores used in the statistical analyses are gain scores, the difference in posttest and pretest. Thus we will refer to them as AA Gain, MAA Gain, DAA Gain, MMA Gain and VMI Gain.

The distributions were examined for the sets of scores generated by treatment and control groups separately. To determine which distributions are approximately normal, each distribution was compared to the standard normal or Gaussian distribution using the Shapiro Wilk W Test for Normality. The results are reviewed in the following table:

Table 2

Tests for Normality

Distribution	Mean	StdDev	N	W	Prob < W
AA Gain (T)	5.674	7.121	46	0.9829	0.8446
AA Gain (C)	5.809	7.245	68	0.9829	0.7508
MAA Gain (T)	5.106	16.66	47	0.9309	0.0105
MAA Gain (C)	12.69	25.26	67	0.9807	0.6731
DAA Gain (T)	10.46	7.771	46	0.9503	0.0761
DAA Gain (C)	5.632	5.239	57	0.9808	0.7244
MMA Gain (T)	11.04	6.838	56	0.9477	0.0305
MMA Gain (C)	5.768	5.247	56	0.9487	0.0344
VMI Gain (T)	6.382	10.15	123	0.9763	0.2809
VMI Gain (C)	0.833	7.981	156	0.9771	0.2409

Three of the distributions, AA Gain, DAA Gain, and VMI Gain are approximately normal, indicating that parametric statistical models are appropriate. The other two distributions, MAA Gain and MMA Gain do not appear normal. Tests involving using these scores will be treated using nonparametric (distribution free) statistical models. However, because the sample size is so large, parametric tests are equally valid. Thus, the results of the hypotheses involving MAA Gain and MMA Gain will include information acquired from both nonparametric and parametric statistical models.

<u>Results of Hypothesis Testing</u>

This section presents a restatement of each of the six hypotheses, along with the relevant data used either to reject or not reject each stated hypothesis at the .01 level of significance. These results will provide information useful in answering the two research questions.

Hypothesis 1. There is no significant difference between the treatment group and the control group in students' increase in knowledge of algebra from pretest to posttest based on scores from the AA.

Results of the pretest show that there is little difference in algebra knowledge between the treatment group and the control group at the beginning of the study. Because the scores are normally distributed a t-test ($t(115) = 1.75$, $p > .05$) confirms that the difference is not significant. Computing differences from the posttest and pretest, the treatment group and the control group showed AA Gain scores that were very nearly identical (mean(T) = 5.674, mean(C) = 5.809). A t-test ($t(114) = 0.098$, $p > .90$) verified that there is no significant difference between the two groups. Therefore, we fail to reject Hypothesis 1.

Hypothesis 2. There is no significant difference between the treatment group and the control group in students' increase in knowledge of algebra from pretest to posttest based on scores from the MAA.

An analysis of the MAA pretest indicates that there is little difference in algebra knowledge between the treatment group and the control group at the beginning of the study. A t-test ($t(114) = .62$, $p > .50$) verifies that the difference is not significant. At the end of the study, the MAA Gain scores were slightly different (mean(T) = 5.11, mean(C) = 12.69). However, a t-test ($t(114) =1.8$, $p = > .05$) confirmed that the difference was not significant. Even though the sample is large and a parametric statistical test is valid, the distribution of MAA Gain scores for the treatment group is bi-modal. Thus, a nonparametric model verified this result.

The distribution-free Wilcoxon / Kruskal-Wallis Tests (Rank Sums) for two samples was computed using these scores. The test statistic is not significant ($z = -1.969$, $p > .05$). Since the test statistic is negative, the control group had a higher gain than the treatment group, but not significantly higher. Therefore, there is insufficient evidence to reject Hypothesis 2.

Hypothesis 3. There is no significant difference between the treatment group and the control group in students' data analysis achievement from pretest to posttest as measured by the DAA.

The means of the DAA Gain for both groups was positive (mean(T) = 10.46, mean(C) = 5.63). Since these scores meet the assumptions for a parametric statistical test, a t-test was computed to determine if the gains were significantly different. With $t(103) = 3.75$ ($p < .001$), the treatment group is significantly higher than the control group. Therefore, we reject Hypothesis 3.

Hypothesis 4. There is no significant difference in the treatment group and the control group in students' mathematical modeling achievement from pretest to posttest as measured by the MMA.

Results of the pretest show that there is little difference in mathematical modeling knowledge between the treatment group and the control group (mean(T) = 7.38, mean (C) = 9.09). A t-test ($t(112) = 1.45$, $p > .10$) confirms that the difference is not significant. At the end of the study, however, the MMA Gain of the treatment group is nearly twice that of the control group (mean(T) = 11.04, mean(C) = 5.77). Even though the MAA Gain scores are not normally distributed, the large sample size allowed a t-test ($t(112) = 4.57$, $p < .0001$) to verify that this difference is highly significant. These results were confirmed using a nonparametric statistical model.

The distribution-free Wilcoxon / Kruskal Wallis Tests (Rank Sums) for two samples was computed. The result ($z = 4.034$, $p < .001$) indicates that the two groups are highly significantly different. Because the test statistic is positive the gain of the treatment group is higher than that of the control group. In this case, it is significantly higher. Therefore, there is sufficient to reject Hypothesis 4.

Hypothesis 5. There is no significant difference between the treatment group and the control group in changes in students' view of mathematics as measured by the VMI.

Since the VMI meets the assumptions for a parametric statistical test, a t-test was used in response to this hypothesis. The mean of the VMI GAIN for the treatment group is 6.382 and the mean for the control group is 0.833. The t-test ($t(2780) = 5.113$, $p < .0001$) indicates that the VMI Gain for the treatment group is significantly higher than that of the control group. Therefore, we reject Hypothesis 5.

Hypothesis 6. There is no relationship between the students' gain scores on the AA, MAA, DAA, MMA, and/or VMI and the grade earned in the course.

Using Grade in Class as the response, a Wald ChiSquare test was computed on each of the variables. The results of this Effect Test are summarized in table 3.

Table 3

Gain Scores as Affecting Course Grade Earned

Source	Nparm	DF	Wald ChiSquare	Prob>ChiSq
AA Gain (T)	1	1	1.543	0.214
AA Gain (C)	1	1	0.3900	0.532
MAA Gain (T)	1	1	0.3482	0.555
MAA Gain (C)	1	1	0.7061	0.401
DAA Gain (T)	1	1	4.086	0.0432*
DAA Gain (C)	1	1	0.2794	0.597
MMA Gain (T)	1	1	3.151	0.0759
MMA Gain (C)	1	1	3.593	0.0580
VMI Gain (T)	1	1	7.151	0.0075**
VMI Gain (C)	1	1	1.811	0.178

*$p < .05$
**$p < .01$

There is one relationship which is significant at the .01 level: VMI Gain for the treatment group. If we were rejecting at the .05 level, there would be one additional relationship: DAA Gain for the treatment group. However, based on the highly significant relationship between VMI Gain (T) and Grade in Class, Hypothesis 6 is rejected.

Other Notable Statistics

In addition to the results of the hypothesis testing some interesting information may be gleaned in perusing the total scores of the evaluation instruments. Specifically the pretest and posttest means are summarized by treatment and control groups in table 4.

Table 4

Analysis of Means of Total Scores

Instrument	Pre (T)	Pre (C)	Post (T)	Post (C)
AA	9.362	11.96	15.11	17.76
MAA	58.51	61.49	63.62	74.41
DAA	2.739	4.175	13.20	9.721
MMA	7.375	9.089	18.41	14.86
VMI	100.4	100.9	107.2	101.9

In every category, the control group outscored the treatment group on the pretest. Yet on the posttest, the only categories in which the control group is still outscoring the treatment group are the algebra-related instruments. And, recalling the results from Hypotheses 1 and 2, these gains were not significantly higher. A discussion of these results will follow a response to the research questions.

Research Questions

The results of the six hypotheses provide information useful in answering the first two research questions.

Research Question 1. Does the college algebra course, Earth Algebra, enhance a students' knowledge of algebra, data analysis achievement, mathematical modeling achievement, and/or view toward mathematics? In particular, the results of Hypotheses 1-5 are central in responding to this question.

With regard to data analysis achievement, mathematical modeling achievement, and view toward mathematics, it appears that Earth Algebra significantly enhances these constructs. At the beginning of the study, both groups were virtually the same with regard to their achievement level, with the control group being slightly higher. However, at the end of the treatment, the treatment group was significantly higher than the control group. In fact, in data analysis achievement and mathematical modeling achievement, the mean gains of the treatment group were approximately twice that of the control group. And, incredibly, the treatment group's mean gain in view of mathematics increased more than seven times that of the control group.

With regard to knowledge of algebra, the AA Gain scores from pretest to posttest were virtually the same for both treatment and control groups. The MAA Gain scores were more pronounced, but not at a significant level. However, one notes that the treatment classes achievement in standard courseware was remarkably similar to that of the control group. Thus, with regard to knowledge of algebra, the evidence indicates that the nonstandard course, Earth Algebra, did little to detract from gains which are typical of students in traditional college algebra courses. What is so remarkable about this result is that the traditional algebraic skills and concepts were not emphasized in Earth Algebra. In other words, at the end of the quarter, even though the gain experienced by the control group was higher than that of the treatment group, that gain was not significantly higher.

In short, the evidence seems to indicate that the course, Earth Algebra, does enhance a student's data analysis achievement and mathematical modeling achievement while allowing the student to maintain his/her knowledge of algebra. But overshadowing any cognitive academic gains are the overwhelmingly positive affective gains that Earth Algebra seems to foster in students' view toward mathematics.

Research Question 2. Is there a relationship between the grade a student earns in college algebra and knowledge of algebra, data analysis achievement, mathematical modeling achievement, and/or view toward mathematics?

For students in the traditional course, there was virtually no relationship between the final course grade and any of the above five constructs. This is not the case with Earth Algebra students. The strongest significant relationship exists between the students' grade and the VMI Gain scores. In addition to this highly significant relationship, a notable relationship occurred between the course grade and DAA Gain scores.

Table 5

Final Course Grades

	TREATMENT		CONTROL	
Grade	Number	Percentage	Number	Percentage
A	45	18.7	64	20.9
B	68	28.3	56	18.3
C	43	17.8	58	19.0
D	22	9.1	32	10.5
F	23	9.5	38	12.4
W	40	16.6	58	19.0
Total	241	100.0	306	100.1

With respect to grades, one notes that examination of the above table indicates that if one defines success in a course to be a grade of C or above, then both treatment and control groups were similarly successful (treatment at 65% successful, control at 58%). However, 47.0% of the treatment group earned a grade of A or B compared with only 39.2% in the control group. And, as previously noted, the only significant relationship exists between the VMI Gain scores and the students' final course grade.

<u>Research Question 3</u>. Are the student outcomes of the course congruent with the terminal objectives identified by the authors of <u>Earth Algebra</u>?

The <u>Earth Algebra</u> project proposed to pilot, refine, and implement a course in introductory-level college mathematics with a radically new format and context. The three main terminal objectives specified by the authors of the project are the following:

(1) to develop mathematical skills

(2) to improve problem solving and decision making ability, and

(3) to offer insight and enhance interest and appreciation of the role of mathematics in society.

Examination of the results reported above with regard to the Algebra Achievement Test (AA) and the MAA Algebra Achievement Test (MAA) directly address (1), namely, to develop mathematical skills. Using the Charles, Lester, and O'Daffer schema (1987) to assess outcomes on the AA there was no significant difference between treatment and control groups with respect to AA Gain scores. Similarly, there was no significant difference between treatment and control groups increase in knowledge of algebra from pretest to posttest based on scores from the MAA. Thus the treatment group appear to have results consistent with those obtained by the control group on certain emphasized topics even though those topics were not stressed in the curriculum provided to the treatment group students. Thus treatment students did appear to exhibit traditional algebraic mathematical skills on a par with control students. Of course, the treatment students were exposed to a richer variety of higher level and less manipulative skills associated with the concerns of the next terminal objective.

The second terminal objective centered on improving problem solving and decision making ability. The Data Analysis Achievement Test (DAA) and the Mathematical Modeling Achievement Test (MMA) were two instruments designed to assess outcomes identified in this objective. In particular the DAA called on students to make predictions and to determine the amount of error associated with certain prediction equations. The MMA required students to model situations by (a) sketching reasonable graphs showing how dependent variables were related to independent variables and (b) to provide a model including an equation suitable for making predictions. There was a highly significant gain for the treatment students with regard to the control students on the MMA. Further there was a very highly significant gain for treatment over control groups on the DAA. Such results indicate that, for the most part, treatment students did in fact exhibit higher level problem solving and decision making skills in their Earth Algebra course. Such results, together with numerous supporting anecdotal material, leads on to conclude that the second terminal objective was significantly achieved.

The third terminal objective was that the course Earth Algebra offer insight and enhance interest and appreciation of the role of mathematics. In order to assess, in part, this third outcome the evaluator and the evaluation consultant designed the 32 item View of Mathematics Inventory (VMI). Perhaps the surprising responses obtained on the VMI provided the most gratifying results of the evaluation process. Both treatment and control groups exhibited almost identical attitudinal scores on the pretest. However there was a massive gain ($p < .0001$) for the treatment students over the control students on the VMI posttest. If one accepts that positive changes in affective measures are critical to determining success, then one must conclude that the Earth Algebra course did in fact meet the third terminal outcome dealing with interest and appreciation of the role of mathematics in society.

Examination of the above remarks indicate that the results reported for the Earth Algebra course are in fact congruent with the stated terminal objectives of the course. A summary of the evaluation process in included below.

Summary

The evaluator examined the following question: Using a sample of college students, can one successfully supplant the curriculum of a standard college algebra course with the innovative materials of Earth Algebra.

To answer this question, the evaluator posed three research questions. These questions centered on the following constructs, each operationally defined by an associated variable: (a) knowledge of algebra, as measured by the Algebra Achievement Test (AA) and the MAA Algebra Achievement Test (MAA); (b) data analysis achievement, as measured by the Data Analysis Achievement Test (DAA); (c) mathematical modeling achievement, as measured by the Mathematical Modeling Achievement Test (MMA); (d) view toward mathematics, as measured by the View of Mathematics Inventory (VMI); and (e) achievement in college algebra, as measured by the final course grade.

The pretest/posttest instruments have been previously described. In addition, the six hypotheses explicitly describing the relationships among these five variables have been described, as well. The results which emanated from these hypotheses yielded information which aided the evaluator in answering the first two research questions. Ultimately, these answers address the third research question whose response resolves the foremost question of this study which focuses on the success of Earth Algebra.

Regarding the first research question, the evidence indicated that Earth Algebra does enhance a student's achievement in data analysis and mathematical modeling and dramatically enhances a student's view toward mathematics. Even though knowledge of algebra did not increase significantly, following the completion of Earth Algebra, it did increase. Moreover, it increased in the same way as traditional college algebra students. That, in and of itself, is significant. In other words, supplanting the curriculum of a standard college algebra course with nontraditional curricular materials has little effect on a student's knowledge of algebra.

Quite unexpected, an analysis of Research Question 2 showed that the strongest, and only truly significant, relationship occurred for the treatment group between the final course grade and VMI Gain scores. While VMI Gain scores is a good predictor of success in Earth Algebra, it was observed that DAA Gain scores is a fairly good predictor, as well. In addition, Earth Algebra students were more likely to receive a grade of A or B than their counterparts in the traditional course.

The examination of Research Question 3 indicated that the results of the first two research questions are fully congruent with the three main terminal objectives specified by the authors of Earth Algebra. In other words, Earth Algebra students developed mathematical skills, improved problem solving and decision making ability, and offered insight and enhanced interest and appreciation of the role of mathematics in society.

In short, the statistical evidence showed that Earth Algebra enhanced students' achievement in view of mathematics, data analysis, and mathematical modeling, while having little effect on students' knowledge of algebra. In particular, students' view toward mathematics affected the final course grade. And, the intended outcomes initially identified by the authors have been realized. Thus this analysis provides the answer solution to the problem posed in this study. Apparently, it is possible to successfully supplant the curriculum of a standard college algebra course with the innovative instructional materials of Earth Algebra.

Conclusions

To assess the extent of the success of Earth Algebra, the results of testing six hypotheses were analyzed to determine if the course enhanced achievement in any of the four pretest and posttest variables: (a) knowledge of algebra, (b) data analysis, (c) mathematical modeling, and (d) view toward mathematics. Although the results of this analysis have been discussed in detail and summarized above, the following listing provides the major conclusions of this investigation.

1. Supplanting the curriculum of a standard entry-level collegiate algebra course is feasible.

2. Earth Algebra students dramatically improved their views toward mathematics.

3. Earth Algebra enhanced students' achievement in data analysis.

4. Earth Algebra enhanced students' achievement in mathematical modeling.

5. Earth Algebra had no different effect on students' knowledge of algebra than did "Regular" College Algebra.

6. There is a very strong relationship between the students' final course grade and VMI Gain scores among Earth Algebra students.

7. A strong relationship existed between final course grade and DAA Gain scores among Earth Algebra students.

9. Earth Algebra can be judged successful. This conclusion is justified after reviewing the previous six conclusions (2-7).

Final Remarks

Thus, in the final analysis, entry-level collegiate algebra students can study nonstandard curriculum , driven by environmental issues, while using mathematical modeling and data analysis to motivate algebraic concepts. Not only did the students in Earth Algebra experience significant gains with respect to these emphasized constructs but, surprisingly, they also achieved the similar gains in knowledge of algebra as the control group. In particular the treatment students experienced very significantly higher gains in data analysis achievement and mathematical modeling achievement and remarkably significantly higher gains in views toward mathematics.

Perhaps a succinct way to assess the overall success of the project is to examine the author's response to a first question perennially posed by students, namely, "What's this stuff good for?" To this question the authors respond, "One of our principal goals, perhaps we should say dreams, is to forever lay question 1 to rest, at least among students of these notes." (Schaufele, C. and Zumoff, N. (1992). Earth algebra: College algebra with applications to environmental issues. Glenview, IL: HarperCollins. p.2.) The above report appears to indicate that the principal goals (i.e., dreams) of the authors have been significantly attained.

APPENDIX A

Evaluation Instruments

AA SSN:__________________

Attempt to answer each of the following questions. Show all work in the space provided. Partial credit will be awarded.

1. Determine the equation of the line which passes through the points (2,1) and (4,-1).

2. If $f(x) = x^2 - 3x - 6$ and the domain of f is {-11,0,1,2}, what is the smallest member of the range of f ?

3. If $g(x) = x^2 + 3x - 1$, give the value of $g(2) - g(1)$.

4. If $f(x) = x^2 - 1$ and $g(x) = 2x$, what is $f(g(2))$?

5. Find the value(s) of x for which the following is true:

$$(2^4 - 2^3)(2^3 - 2^2) = 2^{x-1}$$

6. If a*b is defined as (a+1)(b+1), determine (2*3)*4.

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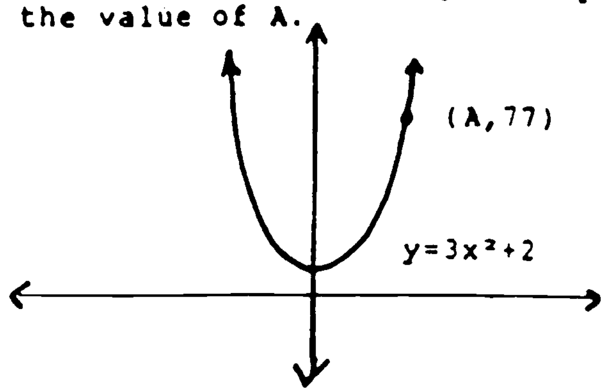
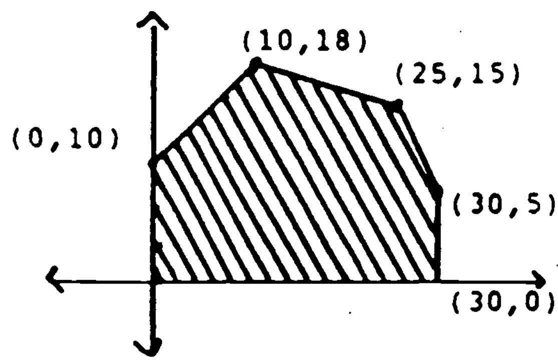
SSN: ______________________

7. A point P with coordinates (A,77) in the first quadrant lies on the curve defined by the equation $y = 3x^2 + 2$. Determine the value of A.



8. Solve the following equation for x. Express the answer to the nearest hundredth.

$$3.2 = 5^x$$

9. 

This shaded hexagon represents a feasible region satisfying the constraints from a system of linear inequalities. Use this information to maximize the objective function, $z = x + 2y$.

10. Solve the following system of two equations in two variables. Express your answer to the nearest hundredth.

$$\begin{cases} 3x + y = 17 \\ 2x - 5y = 13 \end{cases}$$

SSN: ____________________

Please use the answer sheet provided to indicate your choice of answers on the next 10 questions. You will need to use a pencil for this computer form. Please use the back of the form for this section. Feel free to write on the paper with the questions.

1. If $4x - 6 = 2 - 2x$, then $x =$

a) $\frac{-4}{3}$ b) $\frac{-2}{3}$ c) $\frac{2}{3}$ d) $\frac{4}{3}$ e) 4

2. $(2xy^2)(-4x^3y^4) =$

a) $-8x^4y^6$ b) $-8x^3y^8$ c) $-2x^{-2}y^{-2}$ d) $8x^3y^6$ e) x^3y^8

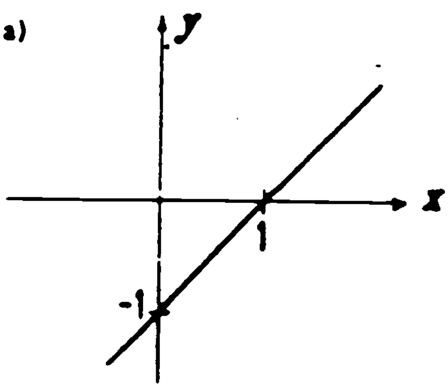
3. $3x + 2(x - 3) - 3(y - 3) =$

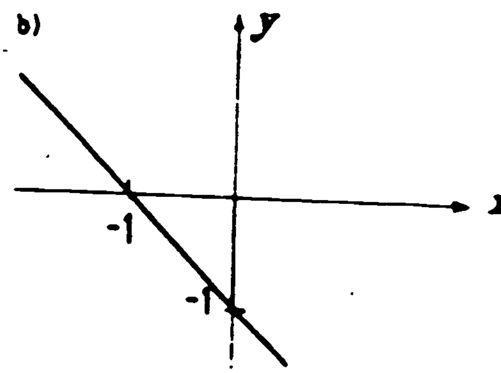
a) $5x - 3y + 3$ b) $5x - 3y - 15$ c) $5x - 3y - 6$
d) $2x - 3y$ e) $2x - 3y + 3$

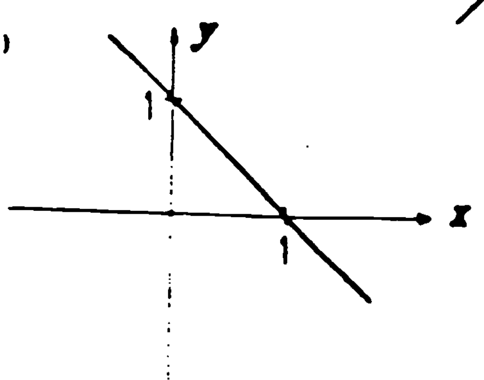
4. The solutions of $x^2 - x - 6 = 6$ are

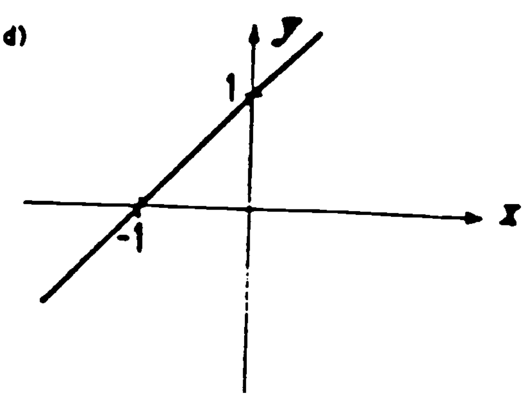
a) $-3, 2$ b) $0, 1$ c) $1, 6$ d) $4, 9$ e) $-3, 4$

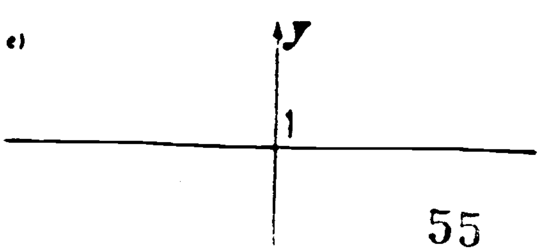
5. The graph of $x - y = 1$ is

a)


b)


c)


d)


e)


6. $\dfrac{x^2 - 9}{2x} \cdot \dfrac{6}{3x + 9} =$

a) -1 b) -3 c) $x - 3$ d) $\dfrac{x + 3}{x}$ e) $\dfrac{x - 3}{x}$

7. $\dfrac{1}{3} + \dfrac{3}{4} - \dfrac{1}{2} =$

a) $\dfrac{1}{8}$ b) $\dfrac{1}{3}$ c) $\dfrac{7}{12}$ d) $\dfrac{3}{4}$ e) $\dfrac{19}{12}$

8. $(2x + 1)(x - 5) =$

a) $3x - 4$ b) $2x^2 - 5$ c) $2x^2 - 9x - 5$
d) $2x^2 + 5$ e) $2x^2 + 9x + 5$

9. If $x = -2$ then $3x^2 - x^3 =$

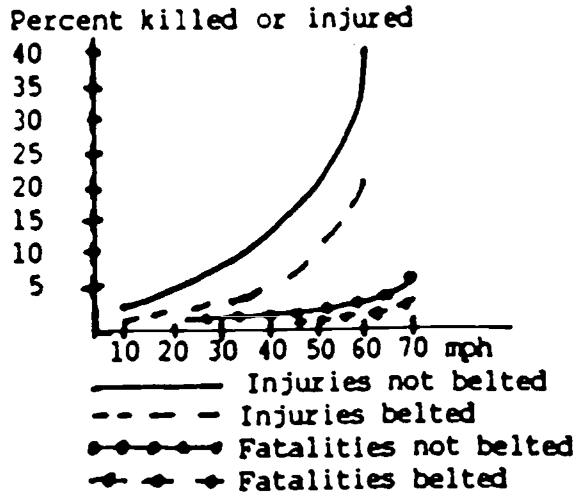
a) -4 b) 4 c) 12 d) 20 e) 36

10. If $\dfrac{5}{x} - 3 = \dfrac{11}{x}$ then $x =$

a) $\dfrac{16}{3}$ b) 2 c) $-\dfrac{16}{3}$ d) $-\dfrac{1}{3}$ e) -2

DAA SSN: ____________

Attempt to solve each of these problems. Show all your work in the space provided. Partial credit will be awarded. Please use the back of the paper if you should need more space.

1. 

A Swedish study showed the relationship between seatbelt use and injuries and fatalities at various speeds. What conclusion(s) can you interpret from these findings?

2. Each pair of n distinct data points determines an equation. The table below shows, for example, that if one is given 5 different data points, then 10 equations are determined. Complete the table by specifying the number of equations for n=6 and n=10:

Number of data points n	2	3	4	5	6	. . .	10
Number of equations	1	3	6	10			

3. Consider the three data points: (2,5), (6,3), and (10,7). Four distinct equations I-IV are offered as potential linear models:

I: $y = -0.5x + 6$ III: $y = 0.25x + 4.5$
II: $y = 0.02x + 5$ IV: $y = 0.25x + 3.5$

a) Compute the error involved with each of these equations.

b) Determine the model which is the line of best fit.

4. The probability of becoming a diabetic is a function of the percent by which the person is over the normal body weight. Suppose that these data at the right have been measured.

Excess weight	*Probability*
10%	13.4%
45%	26.8%
80%	53.6%

a) Determine an equation which models these data.

b) For what percent excess weight would the probability of diabetes be 49%?

c) Predict the probability if one weighs twice the normal weight.

d) According to this mathematical model, what is the probability for a person who is 20% underweight?

5. Based on tests made by the Bureau of Public Roads, here are the distances (in feet) it takes to stop in minimum time under emergency conditions. (Source: American Automobile Association; quoted in The Man-Made World, p.15)

mph	10	20	30	40	50	60	70
stopping distance	19	42	73	116	173	248	343

A third degree polynomial of the form $Ax^3 + Bx^2 + Cx + D = E$ is the best mathematical model for these data.

a) Determine an equation of the form described above.

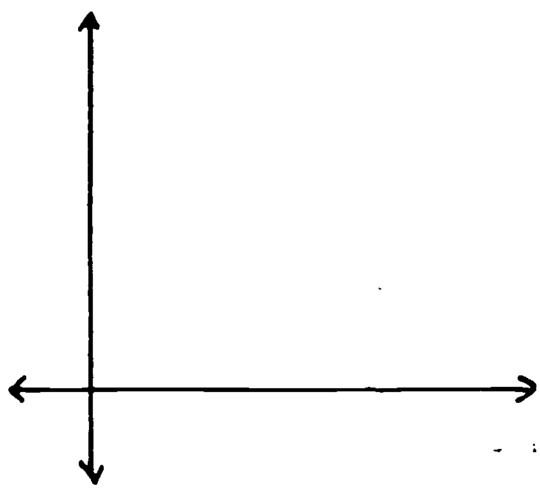
b) Use this model to predict the minimum stopping time under emergency conditions for a vehicle traveling at 80 mph.

c) What error is associated with your model?

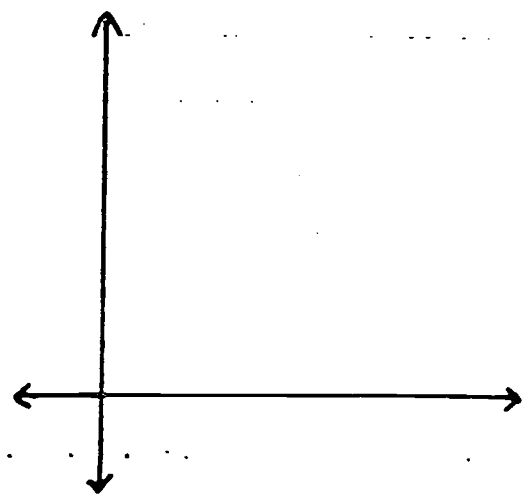
Attempt to solve each of these problems. Show all of your work in the space provided. Partial credit will be awarded. Please use the back of this paper if you should need more space.

1. For the following problems, label the axes and sketch a reasonable graph showing how the dependent variables varies with the independent one. Actual values are not important here.

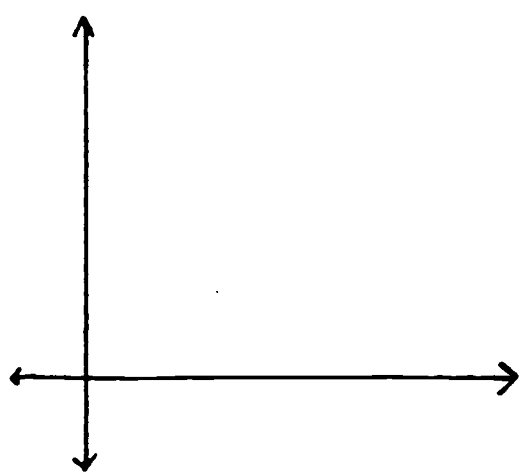
a) The depth of the water at the beach depends on the time of day, due to the motion of the tides.



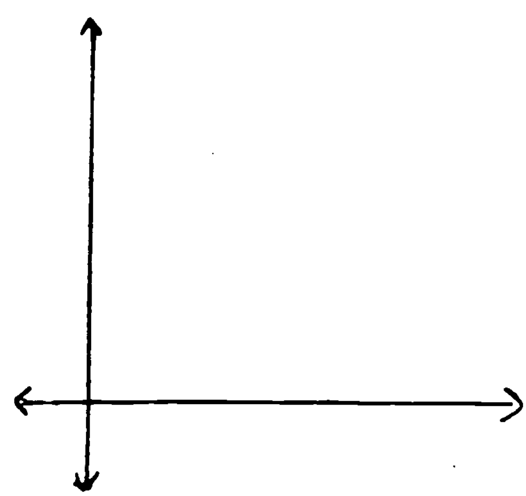
b) As you breathe, the volume of air in your lungs depends on time.



c) As you ride the Ferris wheel at the amusement park, your distance from the ground depends on the time you have been riding.



d) The time it takes you to get home from the football game is related to how fast you drive.



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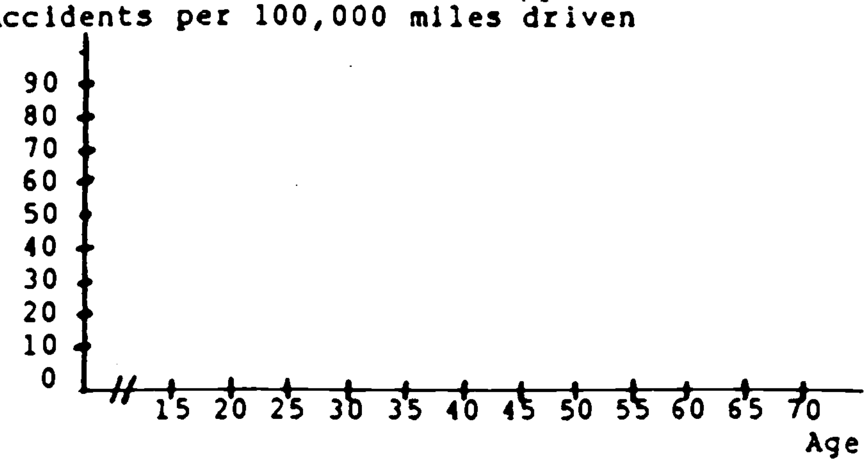
2. The table below shows the number of automobile accidents per 100,000 miles of driving for male drivers. For example 16 year old males have 80 accidents per 100,000 miles driven.

Age (males)	16	35	65
Number of Accidents/100,000 miles	80	31	42

A student assumed that these data belonged to a quadratic relation between age and number of accidents. Plot these points on the coordinate system below.

a) Under the assumption above sketch a graph that best fits these data points. Assume males begin driving at 16.



b) State an equation for your model.

c) Using your model predict the age of the male who has the fewest accidents.

d) Predict the number of accidents for the following ages:

Age (males)	30	54	60	70
Number of Accidents/100,000 miles				

VMI SSN: ______________

Please rate the following statements regarding mathematics and mathematicians according to the following rating scale representing your degree of agreement or disagreement. Record your ratings on the answer sheet provided. You will need to use a pencil for this computer form.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

1.	Mathematics is my favorite subject.	1 2 3 4 5
2.	Algebra is my favorite subject.	1 2 3 4 5
3.	Mathematics seems easy to me.	1 2 3 4 5
4.	Algebra seems easy to me.	1 2 3 4 5
5.	It takes a special talent to understand mathematics, and only a few people have this talent.	1 2 3 4 5
6.	Mathematics is a universal language.	1 2 3 4 5
7.	Advanced mathematics study provides more career options.	1 2 3 4 5
8.	Problem solving amounts to finding a rule or formula which fits the situation.	1 2 3 4 5
9.	Each person can better understand his environment by learning mathematics.	1 2 3 4 5
10.	Ability to communicate both written and orally is not important to mathematics.	1 2 3 4 5
11.	Mathematics is exciting.	1 2 3 4 5
12.	Mathematics is useful.	1 2 3 4 5
13.	Algebra is interesting.	1 2 3 4 5
14.	One should use social studies and not mathematics in the analysis of environmental problems.	1 2 3 4 5
15.	A mathematical topic is of little importance if it has no real world application.	1 2 3 4 5

SSN: ____________________

16.	Use of graphing calculators enhances the learning of algebra.	1	2	3	4	5
17.	Memorization of rules and formulas is the most essential factor for success in solving mathematical problems.	1	2	3	4	5
18.	I like working in groups with my classmates.	1	2	3	4	5
19.	I like to read my mathematics book.	1	2	3	4	5
20.	Algebra can be used to analyze the greenhouse effect and global warming.	1	2	3	4	5
21.	A student's mathematics program should emphasize applications as well as theory.	1	2	3	4	5
22.	The advent of computers has lessened the need for the study of mathematics.	1	2	3	4	5
23.	A mathematical model gives an appropriate representation of some portion of the physical world.	1	2	3	4	5
24.	One must use the correct rule or formula when solving a problem in mathematics.	1	2	3	4	5
25.	Industry often hires mathematicians because they are good problem solvers.	1	2	3	4	5
26.	Algebra will be useful to me in my choice of careers.	1	2	3	4	5
27.	There is very little interplay between pure and applied mathematics.	1	2	3	4	5
28.	Most persons do not sufficiently appreciate the beauty of mathematics.	1	2	3	4	5
29.	Getting the correct answer is the ultimate goal of problem solving.	1	2	3	4	5
30.	One learns algebra better when working with other students in groups.	1	2	3	4	5
31.	Ideas from algebra can effectively be used to investigate the crucial environmental issues.	1	2	3	4	5
32.	Adventure and excitement exist in a mathematician's work.	1	2	3	4	5

APPENDIX B

Partial Credit Delineation

Award points for free-response items in the following way:

0 points: (1) left blank, or
(2) recopied, but nothing was done with the data, or there was work but no apparent understanding of the problem,
(3) contained an incorrect answer and no other work was shown.

1 point: (1) a start toward finding the solution beyond just copying the data that reflected some understanding, but the approach used would not have led to a correct solution, or
(2) an inappropriate strategy that is started but not carried out, and there is no evidence that the student turned to another strategy, or
(3) the student tried to reach a subgoal but never did.

2 points: (1) used an inappropriate strategy and got an incorrect answer, but the work showed some understanding of the problem, or
(2) used an appropriate strategy but it was not carried out far enough to reach a solution or it was implemented incorrectly, or
(3) indicated the student had reached a subgoal but went no further, or
(4) had a correct answer but the work was not understandable or no work was shown.

3 points: (1) the student implemented a solution strategy that could have led to the correct solution but (s)he misunderstood part of the problem or ignored a condition in the problem, or
(2) the student applied appropriate solution strategies but then answered the problem incorrectly for no apparent reason, or the correct numerical part of the answer was given and the answer was not labeled or was labeled incorrectly, or no answer is given, or
(3) the correct answer is given, and there is some evidence that appropriate solution strategies were selected.

4 points: (1) the student made an error in carrying out an appropriate solution strategy, but this error does not reflect misunderstanding of either the problem or how to implement the strategy, but rather seems to be a copying or computational error, or
(2) the student selected and implemented appropriate strategies. The answer is given in terms of the problem.

APPENDIX C

Evaluation Instrument Administration Procedure

Directions: Administration of Evaluation Instrument

1. The instrument is to be administered during class on Monday, September 23, at the beginning of class, and Tuesday, September 24, after the first 75 minutes. It is expected that students will spend no more than 45 minutes, but they should not feel "rushed." Class may resume when the "test" is finished. (Note: This material includes the MAA Placement Test. You will not be asked to take any additional class time for testing purposes until the end of the quarter. See #4, below.)

2. Students will need a No.2 pencil for the computer form. Please make certain that a box of sharpened pencils has been included in your testing materials. These should be returned with the testing materials.

3. Please return all 35 instruments (and the pencils) to the box underneath the table in BB 406 as soon as your class is over.

4. The dates for the post-test will be Wednesday, November 20, and Thursday November 21. **DO NOT ANNOUNCE THIS TO THE STUDENTS!!! FOR STUDENTS THE POST-TEST WILL BE A "POP TEST"!!!**

5. Students may spend more time on the post-test than on the pre-test, as much as 90 minutes. Again, they should not feel rushed. TTh students should have no more than 90 minutes. Thus the testing on Thursday should begin after the first 45 minutes of class.

6. Thank you for your cooperation in evaluating this project. As you know, we are assessing MATH 105 students, both "regular" and "earth" --- not their teachers.

Name: ______________________

SSN: ______________________

The faculty at Kennesaw State College have requested that MATH 105 students participate in a study funded by the National Science Foundation and The U.S. Department of Education. Attempt to answer each of the questions to the best of your ability. You are encouraged to use the calculator of your choice in arriving at your answers. Please know that your solutions to these problems will in no way affect your grade. Your complete cooperation and an earnest effort on your part is expected and appreciated.