Green Light Academy: Examining students' knowledge and dispositions towards environmental literacy and sustainable energy

Abstract

Green Light Academy was a 4-week summer residential program for high school students designed to improve academic achievement and reduce isolation. The program objectives focused to improve students' knowledge and dispositions about environmental conservation and sustainable energy using a guided inquiry instructional approach. The program was evaluated using an objectives-oriented mixed method strategy. Findings indicated that students entered the program having a positive environmental conservation stance but lacked the understanding of scientific and engineering concepts that facilitate "green" philosophy. Posttest findings indicated that the program significantly improved attitudes towards math and environmental stewardship as well as understanding of objectives-based content acquisitions. Finally, students were able to connect the influence of the program on their successful future affective and cognitive abilities.

Objectives

Beacon Preservation is a nonprofit organization dedicated to the preservation of lighthouses for educational, cultural, and historical preservation purposes. In order to meet its educational mission, it established the Green Light Academy (GLA), designed to promote understandings of environmental conservation, sustainable energy, and "green collar" skills for secondary students. Recruiting participants from urban, suburban, and rural communities, GLA was a 4-week summer residential program built on the philosophy that academic achievement improves when students develop new interests and appreciation for science, technology, and sustainable energy by doing real-world "applied learning" activities.

The purpose of this evaluation is to identify changes over time of students' knowledge, and dispositions towards math, science, and environmental conservation to develop a fundamental understanding of the developing green collar culture and economy. Two objectives (Table 1) were utilized to evaluate the program. Learning objectives (Table 2) guided instruction.

Theoretical Framework

Inquiry learning has long been the gold standard for quality science education (Biological Science Curriculum Study, 2007; Author, 2007; Yulo, 1967). Inquiry, as described by the National Research Council (1996), encompasses "diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (p. 23). Inquiry in its most simple and elegant definition is investigation by questioning.

Inquiry learning has the instructional goals of teaching knowledge and processes of research, promoting open-mindedness with an ability to balance alternative perspectives, and cooperative spirit and skill (Joyce, Weil, & Calhoun, 2004). Research has consistently demonstrated that students who engage in inquiry learning perform significantly better on higher order thinking assessments than students who did not (Bredderman, 1981; Costenson & Lawson, 1986; El-Nemr, 1979; Prince, 2004; Shymansky, Hedges, & Woodworth, 1990).

Guided Inquiry

Martin-Hansen (2002) described a continuum of inquiry-type teaching strategies that might take place in science instruction. One level along the continuum is termed guided inquiry. When students engage in guided inquiry, they are given responsibility and independence for problem solving techniques. The educator poses a question, often curricular in nature, and students work to develop a solution by designing their own methods and data analysis procedures to draw meaningful, thoughtful conclusions.

Providing more independence and problem solving responsibilities for students, guided inquiry offers more higher order thinking cognitive development strategies than a structured inquiry approach (Lynch, et al., 2007; Smith & Wittman, 2007). Unlike structured inquiry, where students study a well-known question with a well-known outcome using reliable and reproducible methods, students participating in a guided inquiry learning activity have more responsibility for learning is transferred to them (Nwagbo, 2006). They become responsible for constructing their knowledge.

Constructivism towards Critical Ecopedagogy

Underlying an effective guided inquiry program are philosophies associated with problem solving, critical thinking, oral and written communication and the active and reflective use of knowledge. These philosophical goals are commensurate with a constructivist instructional strategy. Constructivist theory assumes that knowledge is constructed by students. Kauchak and Eggen (1998) define constructivism as a "view of learning in which learners use their own experiences to construct understandings that make sense to them, rather than having understanding delivered to them in already organized form" (p. 184). Therefore, learning activities based on constructivism put learners in the context of antecedent knowledge to apply their understanding to authentic situations.

Driscoll (2005) outlines conditions for constructivist learning which dovetail philosophy of guided inquiry instruction. First, learning is embedded in complex, realistic, and relevant environments. Authentic learning tasks and assessment are critical to creating an environment that promotes critical thinking. When diverse, irregular, and complex ill-defined problems are provided for students, they have the opportunity to develop their own unique and varied solutions that are not predetermined (Jonassen, 1997; Spiro, Feltovich, Jacobson, & Coulson, 1995).

Integral to these learning experiences are the social interactions with teachers and, more importantly, other compatriots, as "learning . . . is a communal activity, a sharing of culture" (Bruner, 1986, p. 127). Effective collaborative becomes just as important as content acquisition. Students must be self-aware of their learning processes by having a reflective mind and epistemic flexibility to learning (Cunningham, 1992).

Environmental inquiry places emphasis on learning about, in, and for the natural world through the development of critical thinking and problem solving skills through a variety of practical and interdisciplinary learning experiences which focus on real-world problems and involve the study of a wide range of sources and types of information (Fien, 1993). In addition, environmental inquiry focuses on the integration of equity and economy by balancing approaches to promote holistic development of the individuals understanding, skills, and *attitudes* (Jacobson, McDuff, & Monroe, 2006).

Therefore, environmental inquiry goes beyond the acquisition of cognitive skills and knowledge to develop understanding that will help to shape environmental values (Palmer, 1998). Drawing some of its pedagogical foundation from critical theory, ecopedagogy builds upon the constructivist framework by having the additional affective objective of consciously seeking to help students develop a strong and enduring environmental ethic (Fien, 1993). The individual holistic environmental development comes from the understanding of concepts coupled with experience and concern, facilitated by action (Jacobsen, McDuff, & Monroe, 2006).

Monroe, Randall, and Crisp (2001) define environmental literacy as promoting awareness, knowledge, ability, motivation, commitment, and skill to collaboratively address environmental problems and improve communication, group process, and problem solving skills. Utlizing critical ecopedagogy to underpin environmental inquiry can help students develop cultural beliefs underlying ecological problems by allowing their placed-based experiences to develop into relevant concern and subsequent action (Gruenewald, 2003).

Methods

Program Description

GLA was team taught by four certified educators: two in science, one in technology education, and one in mathematics. Teachers were trained by the lead teacher with a focus on guided inquiry strategies to learning. Learning activities were introduced to students by providing a goal or problem, and students were challenged to develop their own methodologies, data collection strategies, and conclusions in order to construct concept knowledge. Appropriate scaffolding activities (structured inquiry) were utilized to assist to develop necessary prerequisite skills necessary for student success in the guided inquiry activities. Exercises to develop students' ethic and social responsibility were embedded in all activities. Activities ranged from a minimum of three hours up to three days. Samples of student learning activities are presented in Table 3.

Evaluation Strategy

An objectives-oriented design utilized to examine student knowledge and dispositions over time. A mixed methods strategy following a dialectic stance was used because engaging with methodological paradigm differences (i.e., quantitative, qualitative) can provide new insight since the assumptions of those paradigms are different yet valuable in important ways (Greene and Caracelli, 1997; Maxwell, 2004). A concurrent triangulation design framed the interpretation and analysis as both the quantitative data and qualitative data were treated equally to elucidate trends and concepts (Creswell, Plano Clark, Gutmann, & Hanson, 2003).

Quantitative instrumentation. Various instruments were used to evaluate students' knowledge and dispositions about the environment and sustainable energy technology. Specifically, to measure knowledge, *The Environment and Sustainability*, an open-ended criterion-referenced constructed response questionnaire (Cronbach's $\alpha = .89$) based on the program's learning objectives was used. It was scored using the DiNicola and Author's (2010) criteria for constructed responses. Jenkins & Pell's (2006) *Me and the environmental challenges* instrument and Turner's (2009) *Math and Science Interest Survey* were used to affectively measure dispositions towards environmental stewardship, math, and science.

Qualitative data. Written reflective comments and writings were used to further elucidate information about the program and students' ability to meet the program objectives. Student writing was often guided through prompts provided to evaluate learning after or as an activity. Summative questions, based on program objectives, were also provided to evaluate students' experiences and growth at the end of the program.

Data analysis. A pretest-postest design was utilized to examine quantitative data. This data was analyzed using descriptive statistics followed by repeated measures multiple analysis of variance (RM-MANOVA) with descriptive discriminant analysis (DDA) for post hoc on all indicators.

Qualitative data were coded and axial categorized by theme using the following procedure. Emergent codes were directly generated and interpreted from written responses (Spradley, 1979). The codes were organized to combine recurring regularities in the data to construct themes (Merriam, 1998). Units of data were grouped to meet the Lincoln and Guba (1985) criteria. First, a theme was heuristic, serving to indicate or point out revealing information relative to the study. Second, the theme was interpretable independent of other information, meaning it was clearly delineated. Quantitative and qualitative data were concurrently interpreted to justify conclusions.

Results

Quantitative Results

Descriptive statistics for each instrument (Math and Science Interest Survey, Math Subscore and Science Subscore, Me and the Environmental Challenges, The Environment and Sustainability Scale) are reported for pre and post testing in Table 4. The descriptive data indicated normal distribution with acceptable levels of skewness and kurtosis. Graphical representations of the descriptive data distribution are provided in Figures 1-4.

To examine differences over time (pre, post), a RM-MANOVA was conducted using each instrument as a dependent variable. In order to verify that assumptions of normality and homoscedacity were met, Box's M was calculated prior to RM-MANOVA calculations. Box's M (19.33, $F(10,11495) = 1.78$, $p = .059$) verified that data were appropriate for further analysis. Wilks λ (.002, $F(4,30) = 43.78$, $p = .000$, partial $\eta^2 = .85$) indicated that there was statistically significant differences with a large effect size that exist between the pretest and posttest scores.

To determine which factors were statistically significantly different from one another, DDA was utilized post hoc. A Pearson correlation of indicators was generated (Table 5) which determined that there was evidence of collinarity. This lead to the use of the structural matrix coefficients to identify differences. The structural matrix coeffients are reported in Table 6. All instruments with the exception of the Science Subscale from the Math and Science Interest Survey (dispositions towards science) demonstrated significant improvement from pretest to posttest.

Qualitative Analysis

Axial coding of the qualitative written responses demonstrated that the GLA had discrete positive influences on student behavior across several themes. Representative data samples are provided in Table 7. Specifically, students identified reinforcement with pursuing a college path, but many identified potential changes in career path towards a "green collar job." Students felt that skills and knowledge gained through the GLA would greatly improve their future science concept acquisition. In addition, the residential component of the program made students feel that they had greatly improved their social skills and were better able to interact and work with others. In addition, students reported higher levels of self-advocacy.

Significance and Conclusions

Estimated at nearly 111 million jobs worldwide, the new green workforce promises to be a vital and necessary part of the world economy (Worldwatch Insitute, 2008). However, the

United States lack the necessary personnel to properly compete in this revolution. It becomes incumbent upon precollege educators to facilitate a meaningful understanding of the future of "green" to assist in providing the necessary training and motivation for students to encourage them to pursue careers in the field.

GLA was established to provide the bridge between traditional high school science instruction and an inquiry-based, hands-on, minds-on approach for extended learning experiences that promote positive knowledge growth and dispositions to "green." This evaluation demonstrated that:

1. The GLA intensive residential program significantly improved attitudes towards math and environmental stewardship in a short timeframe, demonstrating that this extended non-traditional instructional model is effective for improved academic achievement and socially-responsible disposition and may be transferable to other content domains.
2. The GLA improved learning objectives-based content acquisition of environmental concepts.
3. Students connected the influence of the program on their future affective and cognitive abilities in environmental education and related fields thus potentially increasing career and college readiness.

The evaluation is limited by methodological considerations. Although the evaluation used pre and posttesting, there was no control group for comparison purposes. Complete data sets for the sample represented approximately 65% of the population. In addition, since this was an objectives-oriented evaluation, important outcomes not measured by objectives may not be reflected in the results, for example, the examination of skills.

References

Biological Science Curriculum Study. (2007). As BSCS begins its 50th anniversary celebration (1958-2008). Retrieved November 23, 2007 from http://www.bscs.org/50th

Bredderman, T. (1981). Elementary school process curricula: A meta-analysis. (ERIC Document Reproduction Service No. ED170-333).

Bruner, J. S. (1986). *Actual minds, possible worlds.* Cambridge, MA: Harvard University Press.

Cognition and Technology Group at Vanderbilt. (1991). Technology and the design of generative learning environments. *Educational Technology, 31,* 34-40.

Costenson, K., & Lawson A. E. (1986). Why isn't inquiry used in more classrooms? *The American Biology Teacher, 48,* 150-158.

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L. & Hanson, W. E. (2003). Advanced mixed method research designs. In A. Tashakkori and C. Teddlie (eds.), Handbook of mixed methods in social and behavioral research (pp. 209-240). Thousand Oaks, CA: Sage.

Cunningham, D. J. (1992). Beyond educational psychology: Steps towards and educational semiotic. *Educational Psychology Review, 4,* 2, 165-194.

DiNicola N., & Author. (2010). Evidence-based writing: A strategy to promote high quality responses to open-ended questions. *Connecticut Journal of Science Education* (in press)

Driscoll, M.P. (2005). *Psychology of learning for instruction.* Boston: Allyn and Bacon.

El-Nemr, M. A. (1979). *Meta-analysis of the outcomes of teaching biology as inquiry.* Boulder, CO: University of Colorado

Fien, J. (1993). *Education for the environment: Critical curriculum theorizing and environmental education.* Victory, AU: Deakin University.

Greene, J. C., and Caracelli, V. J. (1997). Defining and describing the paradigm issue in mixed method evaluation. In J. C. Greene and V. J. Caracelli (eds.), *Advances in mixed-method evaluation: The challenges and benefits of integrating diverse paradigms. New Directions for Evaluation*, (pp. 5-17). San Francisco: Jossey-Bass.

Gruenewald, D. (2003). The best of both worlds: A critical pedagogy of place. *Educational Researcher, 32,* 3-12.

Honebein, P. C. (1996). Seven goals for the design of constructivist learning environments. In B. G. Wilson (Ed.), *Constructivist learning environments: Case studies in instructional design.* Englewood Cliffs, NJ: Educational Technology Publications.

Jacobson, S.K, McDuff, M.D., & Monroe, M.C. (2006). *Conservation Education and Outreach Techniques*. New York: Oxford University Press.

Jenkins, E. W., & Pell, R. G. (2006). "Me and the Environmental Challenges": A survey of English secondary school students' attitudes towards the environment. *International Journal of Science Education, 28,* 7, 765-780

Jonassen, D.H. (1997). Instructional design models for well-structured and ill-strucutred problem-solving learning outcomes. *Educational Technology Research and Development, 45,* 65-94.

Joyce, B., Weil, M, & Calhoun, E. (2004). *Models of teaching.* Boston: Allyn and Bacon.

Kauchak, D. P. & Eggen, P. D. (1998). *Learning and Teaching: Researched-Based Methods.* Boston: Allyn & Bacon.

Author. (2007). The Connecticut Science Fair: impressions of sixty years of innovation. *Connecticut Journal of Science Education, 45,* 14-18.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry.* Thousand Oaks, CA: Sage Publications.

Lynch, S., Taymans, J., Watson, W. A., Ochsendorf, R. J., Pyke, C., & Szesze, M. J. (2007). Effectiveness of a highly rated science curriculum unit for students with disabilities in general education classrooms. *Exceptional Children, 73,* 2, 202-223.

Martin-Hansen, L. (2002). Defining inquiry. *The Science Teacher, 69,* 34-37.

Maxwell, J. A. (2004). Realism as a stance for mixed methods research. Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass Publishers.

Monroe, M., Randall, J., & Crisp, V. (2001). Improving Student Achievement with Environmental Education. Retrieved from http://edis.ifas.ufl.edu/FR114

Nwagbo, G. (2006). Effects of two teaching methods on the achievement in and attitude to biology of students of different levels of scientific literacy. *International Journal of Educational Research, 45,* 3, 216-229

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

Palmer, J. (1998). *Environmental Education for the 21st century: Theory, Practice, Progress and Promise.* London: Routledge.

Perkins, D. N. (1991). What constructivism demands of the learner. *Educational Technology, 31,* 19-21.

Prince, M. (2004) Does active learning work? A review of the research. *Journal of Engineering Education, 93,* 223-231.

Schreiner, C., & Sjøberg, S. (2004). Sowing the Seeds of ROSE: Background, rationale, questionnaire development and data collection for the Relevance of Science Education: a comparative study of students' views of science and science education. Oslo, Norway: Department of Teacher Education and School Development.

Shymansky, J.A., Hedges, L.V., & Woodworth, G. (1990). A reassessment of effects of inquiry-based science curriculum of the '60s on student performance. *Journal of Research in Science Teaching, 27,* 127-144.

Smith, T. I., & Wittman, M. C. (2007). Comparing three methods for teaching Newton's third law. *Physics Education Research, 3,* 2 1-8.

Spiro, R. J., Feltovich, P. J., Jacobson, M. J., & Coulson, R. L. (1995). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In L. P. Steffe & J. Gale (Eds.), *Constructivism in Instruction.* Hillsdale, NJ: Erlbaum.

Spradley, J. P. (1979). *The ethnographic interview.* New York: Holt, Rinehardt, & Winston.

Turner, R. C. (2009). Math and Science Interest Survey. Retrieved June 10, 2009 from http://gk12.uark.edu/programresults/Student%20Science%20Survey.pdf

Worldwatch Institute. (2008). Green economy could generate millions of jobs. Retrieved July 11, 2009 from http://www.peopleandplanet.net/doc.php?id=3410

Yulo, R.J. (1967). An exploration of the Flanders system of interaction analysis as a supervisory device with science interns. Unpublished doctoral dissertation, Harvard University, Cambridge, MA.

Table 1

Program evaluation objectives

Objective	Benchmark	Evaluation Method
Students will improve dispositions toward math, science, and environmental awareness	Students who participate in the GLA program will have significantly higher scores post test and describe the value of math, science, and environmental awareness	• Math and Science Interest Survey, • Me and the Environmental Challenges • MANOVA with DDA post hoc analysis • Reflective Comments
Students will better understand concepts of Long Island Sound Ecology and Sustainable Energy Science	Students who participate in the GLA program will have significantly higher scores post test	• The Environment and Sustainability Scale • MANOVA with DDA post hoc (combined with affective)

Table 2

Learning Objectives for GLA

Objective Scope	Theme	Objectives
Academic Content Knowledge	Environmental Conservation and Ecology	Students will understand the interplay between biological and physical factors affecting the Long Island Sound ecosystem.
	Sustainable Energy	Students will describe different forms of energy production and distinguish between each one's benefits and disadvantages.
		Students will understand the use of organic materials to create useful, sustainable products.
	Sustainable Energy and Green Collar Culture	Students will design and implement sustainable, self-sufficient operation systems at Penfield Lighthouse.
Student Dispositions	Awareness and action	Students will develop attitudes of empowerment with respect to environmental issues by interest in, engagement with, and motivation for environmental action by developing the confidence that they can contribute to effecting change through a belief that safeguarding the environment is important for the wider community (Jenkins & Pell, 2006; Schreiner & Sjøberg, 2004).

Table 3

Sample Learning Activities and Projects

Theme	Title	Description
Environmental Conservation and Ecology	Japanese Mud Crab study at Fayerweather Island	Six-hour experience. Students were trained to collect chemical water quality indices (i.e., dissolved oxygen, pH, salinity) and utilized this chemical data in conjunction with biological condition indices from invasive mud crabs (i.e., gender, mass, carapace length) to determine the health of the water. Extensive data was collected and analyzed using Excel.
Environmental Conservation and Ecology	Mummichog study at Great Meadows Marsh	Six-hour experience. Similar to the mud crab study, students collected and analyzed chemical and biological indices. Mummichogs are small marsh minnow fish.
Sustainable Energy	Construction and testing of wind turbine blades	Six-hour experience. After visiting a local ski resort which has installed a large wind turbine to generate power, students designed and tested blade distribution and shape to optimize energy output.

Table 3 (continued)

Sample Learning Activities and Projects

Theme	Title	Description
Sustainable Energy	Construction and testing of Solar Sprint and Fuel Cell Cars	Three-day experience. After participating in scaffolded structured inquiry activities to examine properties of gears, friction, wind resistance (drag), and angle of incidence for solar panels, students designed and constructed small (~30 cm) solar sprint cars without templates. Cars were evaluated for speed, aesthetics, craftsmanship, and innovative design. The cars were subsequently retrofitted with proton exchange membrane fuel cells.
Sustainable Energy	Biodiesel manufacturing	Two-day experience. Students followed a standard procedure for the manufacturing of biodiesel from used frialator oil. After conducting research, they modified the procedure to improve both the yield and depression of gel point.
Awareness and Action	This I Believe	Three-hour experience. After participating in guided inquiry activities designed to elicit distinct positions, students composed a reflective writing environmental ethic stance following the National Public Radio, This I Believe® format.

Table 4

Descriptive Statistics for Quantitative Instrumentation

Instrument	Testing	Mean	Standard Deviation	Skewness	Kurtosis
Math and Science Interest Survey (Math Subscore)	Pretest	43.00	3.23	.29	-.44
	Posttest	48.33	3.52	.58	-.42
Math and Science Interest Survey (Science Subscore)	Pretest	74.53	6.83	-.03	.79
	Posttest	78.38	10.47	-.02	-.74
Me and the Environmental Challenges	Pretest	46.79	2.89	-.01	-.49
	Posttest	50.83	4.81	-.03	.08
The Environment and Sustainability Scale	Pretest	6.29	4.36	.75	.66
	Posttest	12.21	4.91	.11	-.60

Table 5

Pearson Correlations of Indicators

	Dispositions towards math (Math Subscale of Math and Science Interest Survey)	Dispositions towards science (Science Subscale of Math and Science Interest Survey)	Dispositions towards the environment (Me and the Environmental Challenges)
Dispositions towards science (Science Subscale of Math and Science Interest Survey)	.328 *p=.01*		
Dispositions towards the environment (Me and the Environmental Challenges)	.279 *p=.03*	.093 *p=.49*	
Knowledge of the environment and sustainable energy	.538 *p=.00*	.363 *p=.01*	.061 *p=.65*

Table 6

DDA Structural Matrix Coefficients

Dimension	Value
Dispositions towards math	.70
Knowledge of the Environment and Sustainable Energy	.57
Dispositions towards the Environment	.47
Dispositions towards Science	.07

Table 7

Samples of qualitative student responses demonstrating positive affect

Theme	Quotation
Social skills	We actually got to implement our ideas and be creative during the lab, too. The research and the presentations which help our public speaking skills were nice things to do. I think being able to successfully communicate is just as important as taking in information. (Student comment)
Science concept acquisition	At first I thought it was really hard to figure things out, because we didn't get a lot of information. But now I realize that I can figure things out myself and it really isn't as hard as it initially seems if you just think about it and work things out. (Student comment)
Science concept acquisition	Another thing I like about this academy are the projects. Even thought they were challenging, they were challenging only in the beginning. I loved going through the journey, of going through the clueless ideas, and then it turns to being so easy. (Student comment)
Attitude towards "green"	I thought being green was a joke; a scam created by several companies to make profits and laugh at civilians who bought their overpriced products. I was favorably anti-green for a surplus of years. And the culprit of my ignorance was my stubborn ways, inability to care and lack of knowledge. Only 23 days ago, I got my first taste of going green. I am ecstatic to say that my beliefs on a green environment have changed. I now believe that I need to be in balance with the earth. (Student comment)

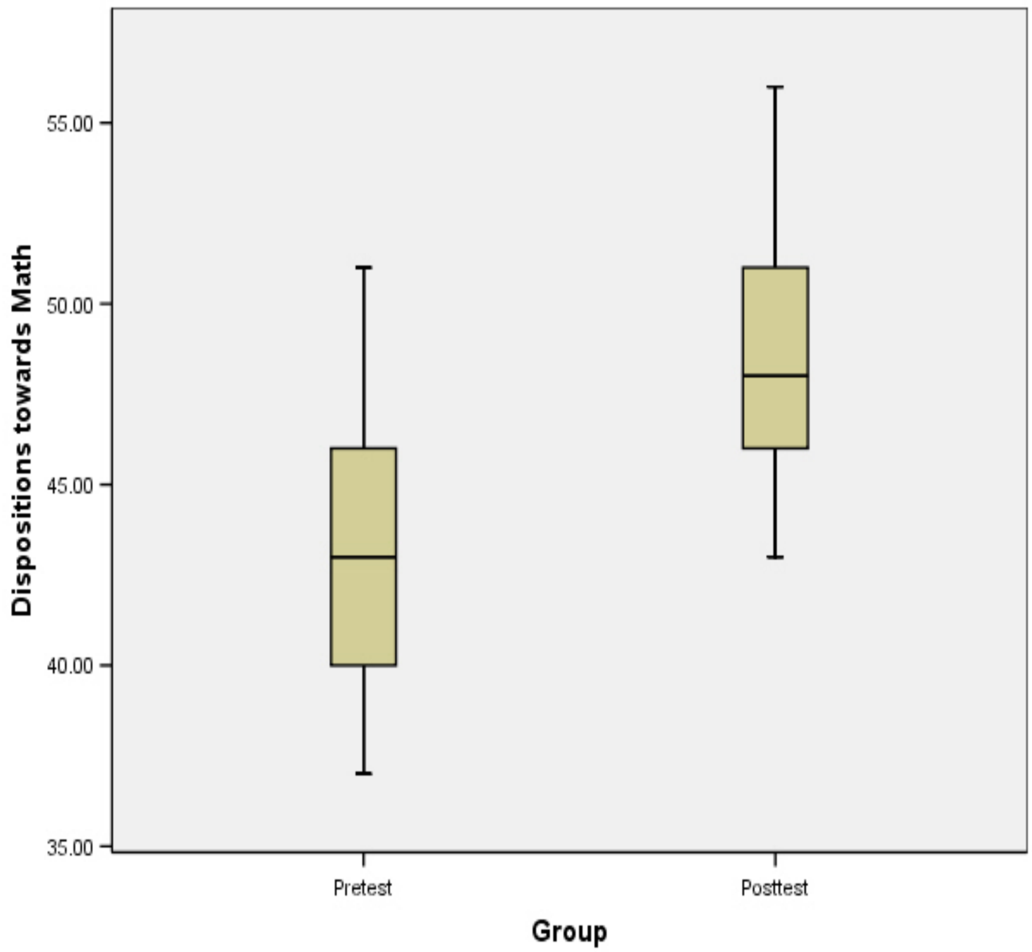

Figure 1. Dispositions to Math as measured by the Math Subscale of the Math and Science Interest Survey (Salamo, 2005) demonstrating statistically significant improvement.

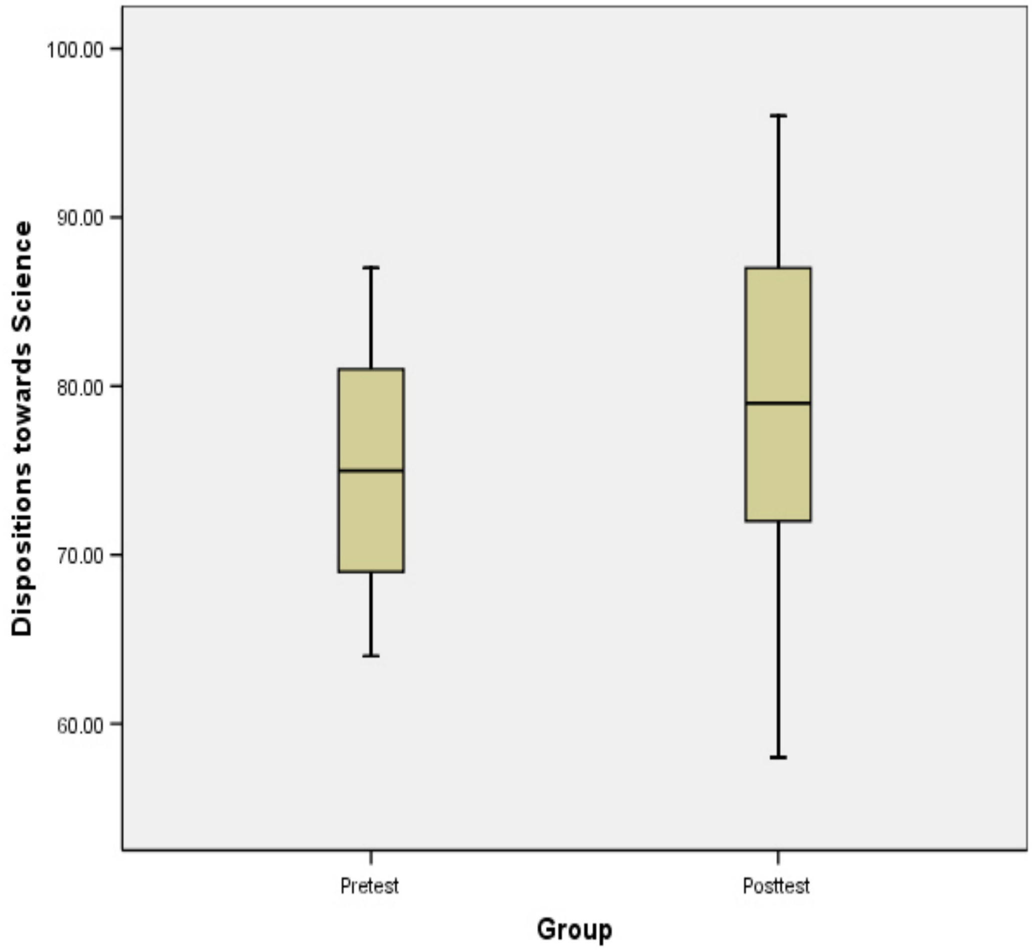

Figure 2. Dispositions to Science as measured by the Science Subscale of the Math and Science Interest Survey (Salamo, 2005) demonstrating statistical similarity

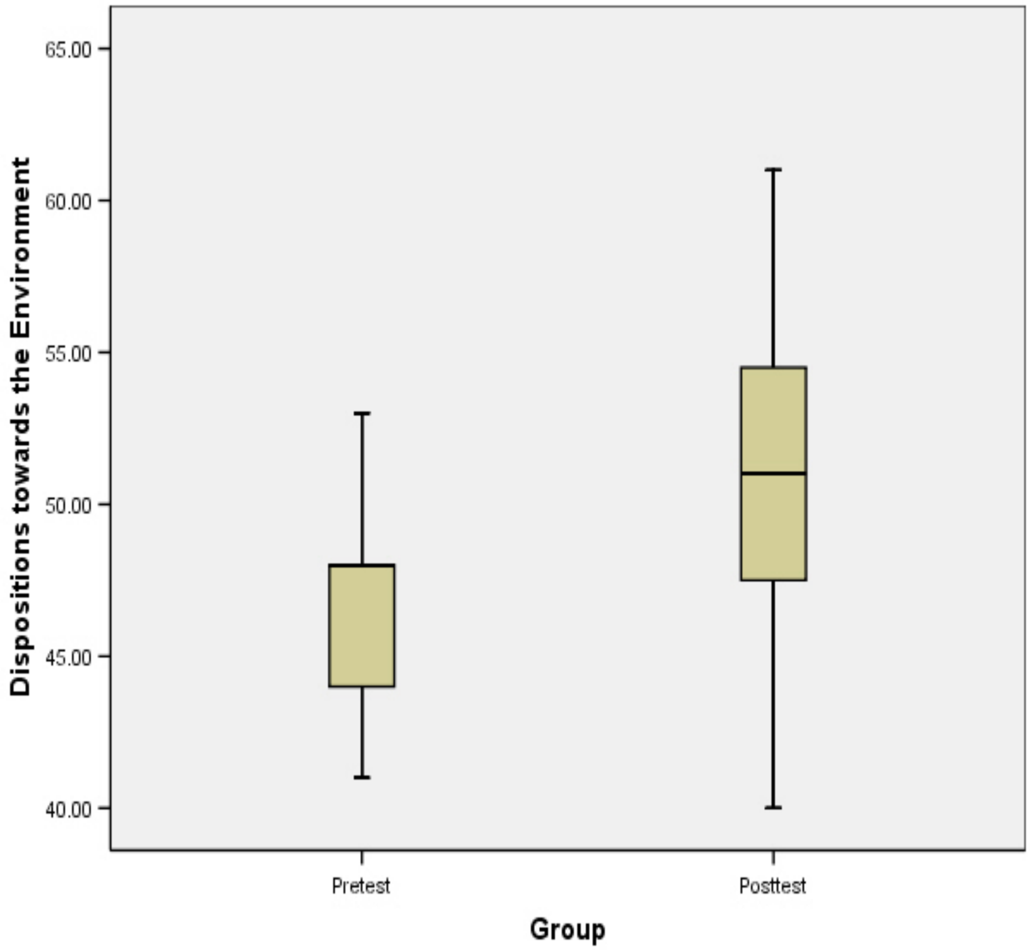

Figure 3. Dispositions towards the environment as measured by Me and the Environmental Challenges (Jenkins & Pell, 2006) demonstrating statistically significant improvement

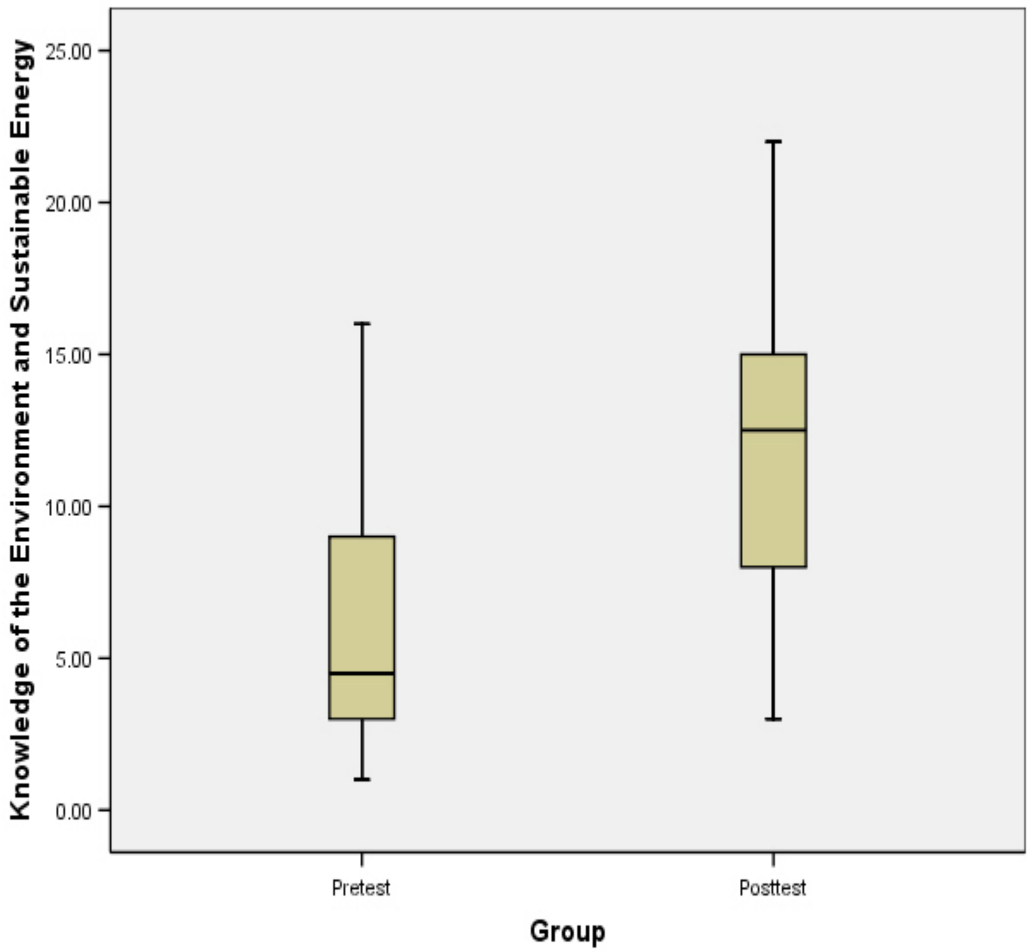

Figure 4. Knowledge of the Environment and Sustainable Energy as measured by the Environment and Sustainability Scale demonstrating statistically significant improvement