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SCIENCE FOR NON-SCIENCE MAJORS

Abstract

A certain level of scientific knowledge is needed for non-engineering and non-science majors because their success often demands effective use of and making informed decisions about scientific issues. This paper focuses on developing a strategy for providing non-science majors with a basic level of scientific knowledge for successfully dealing with real world technological issues.

"The Environment" course was taught in Fall 2007 to non-science majors as a science core requirement using the traditional lecture method. This was the control group. An experimental group was taught in spring 2010 using four indices: (1) learning from three Hands On and Minds On labs, (2) using Closer Looks, (3) case studies, and (4) development of critical thinking abilities. The method of selecting these indices is explained in the paper.

The average grade of the control group was 64% and that of the experimental group was 77%, a 20% improvement over the control group. The groups were significantly different with a calculated t value of 2.6. The t-test confirmed statistical improvement at significant confidence level with an alpha value of 0.05. The students ranked learning from three Hands On and Minds On labs.

Introduction

Scientific literacy can be defined as a broad range of knowledge about science and how humans develop, use and are affected by science. A certain level of scientific knowledge is needed for non-science majors because their success often demands effective use of and making informed decisions about scientific issues.

Non-major classes draw students from the arts, humanities, journalism, law, social sciences, and other disciplines. Students are enrolled for two reasons: 1) they're deeply interested in the subject or 2) general education requirements force them to attend. The courses usually do not have prerequisites therefore while some students have extensive science backgrounds, others have none. It is a challenge for teachers of these courses to take into account the wide range of scientific knowledge of their students.

Non-science majors are faced with numerous forces that pull them in different directions—socialization, career, and scientific literacy. They are not well equipped to lead the nation, through its diversified and challenging problems by making informed decisions about issues such as industrial globalization, sustainability or alternative energy [1-5].

Objective

This paper focuses on developing a strategy for providing non-science majors with a basic level of scientific knowledge for successfully dealing with real world technological issues.

Motivation

A certain level of scientific knowledge is needed for non-engineering and non-science majors because their success usually demands effective use of and making informed decisions about scientific issues. The authors believe it is important to help their students gain the knowledge and expertise necessary to make informed decisions about scientific issues.

What is new in this paper?

Even though several universities and institutions have been working on these or similar issues, this study presents two new aspects: (1) exact quantification of the improvements of the four performance indices supported by statistical data, and (2) the way the four indices were integrated in teaching.

Methodology

While learning about science, non-science majors need to gain expertise in the following four areas: 1) science literacy, 2) critical thinking 3) problem solving, and 4) understanding the role of science in society[6].

1. Science literacy: students are taught how to read science newspaper articles by becoming familiarize with scientific jargon, data collection and interpretation through qualitative and quantitative reasoning.
2. Critical thinking: students are taught how to 1) distinguish between science, pseudo science, art, religion, and 2) identify high, medium and low quality sources.
3. Problem solving: students are taught different avenues of knowing the world by understanding that real world problems often are open ended. For example, students examine the impact time lag, non-linearity and irreversible consequences have on problem solving.
4. Understanding the role of science in society: students are taught how to 1) understand the connection between science and global issues such as global warming, energy sustainability, clean water, hunger, and disease and 2) appreciate the necessity of funding scientific studies and education[6].

"The Environment" course was taught in fall 2007 to non-science majors as a science core requirement using the traditional lecture method. An experimental group was taught the above four areas in spring 2010 using four indices: (1) learning from three Hands On and Minds On labs, (2) using Closer Looks, (3) case studies, and (4) development of critical thinking ability. The four areas were properly balanced and applied in the four indices. The performance of the students was evaluated using a series of special assignments reflecting the four indices. The assignments accounted for 20% of the course grade. The grading formula for the control and experimental groups are shown in Table 1. Appendices 1, 2, and 3 show examples of assignments that addressed critical thinking, case study, and closer look respectively [7].

Integration of four indices in teaching

Students were encouraged to refer to professional engineering and science journals and news papers when collecting data. They were discouraged from using hearsay and yellow journalism sources in their works. Students were given ten exercises for each index. The following paragraphs give an example for each index. In the first and second steps index 1 and 2 are worked out. In the third step the knowledge gained in the first two steps is used. In the fourth step the first 3 steps are used as feedback. Step 4 is fed into first two steps again. Thus a continuous do-loop system is developed while each exercise is completed using all four indices.

Learning from a Hands On and Minds On lab

The three hands on and minds on labs were: 1) Measuring pH, 2) Measuring Sound, and 3) Measuring Energy. Measuring pH is considered in this example. The students are asked to become familiar with technical jargon such as aqueous solution, logarithm, molar concentration, hydronium ions, activating factor by reading newspaper articles. The technique for measuring pH is taught using hands-on experimental equipment and qualitative and quantitative reasoning. The students begin by using familiar liquids such as coca cola, sugar solution and drinking water. The instructor then explains the importance of pH in the formation of acid rain. Students are taught that 1) several decades of valuable time has been lost (time lag) in finding solutions for reducing acid rain; 2) industrial air pollution (consisting of acid rain precursors such as sulfur dioxide, nitric oxide, and nitrous oxide) have caused irreversible damage; 3) acid rain has reached increased disproportionately by following no-liner trend. Students then learn how to use buffers to mitigate acid rain problems in bodies of water. They are provided with strategies to reduce air pollution, which contains acid precursors, thus reducing the acid rain problem. The goal is to increase students' awareness of the necessity for funding strategies that mitigate air pollution with acid precursors.

Using Closer Looks

This section deals with a closer look at the topic, "What does history tell us about global warming's potential consequences for people?" The students are asked to familiarize themselves with the technical jargon (e.g. climatic systems, green house gases, climate models, anthropogenic climate change, ice-albedo feedback, intergovernmental panel on climate change) through extensive reading of science newspaper articles. Projected carbon dioxide levels for the next two decades are worked out in the class using qualitative and quantitative reasoning.

Students are taught that 1) several decades of valuable time has already been lost (time lag) in acting on solutions on global warming; 2) fossil fuel burning has caused irreversible consequence of global warming; 3) the global warming problem has reached a disproportionately larger size by following non-linear trends; 4) strategies planned and implemented at personal, local national and world level can mitigate global warming. An appreciation of the necessity to fund strategies to reduce global warming is created.

Using Case Studies

This section dealt with a case study on the topic, "Measurement of carbon stored in vegetation. The students are asked to familiarize with technical jargon (e.g. carbon sequestration, long term carbon storage, kyoto protocol, carbon credits, terrestrial ecosystems, carbon sinks) by reading science newspaper articles. Measurements of the amount of carbon stored in vegetation are worked out in class using qualitative and quantitative reasoning. Students are taught that 1) several decades of valuable time has already been lost (time lag) in acting for solutions on environmental problems such as global warming; 2) capturing of long-term storage of carbon in forests, for the build-up of carbon dioxide (one of the principal greenhouse gases) in the atmosphere will reduce or slow by buying valuable time to address the ultimate challenge of reducing greenhouse gas emissions; 3) deforestation has contributed to the irreversible consequence of global warming; 4) the deforestation problem has reached disproportionately larger size by following non-linear trend; 5) growing trees can throw a couple of cents in producing clean atmosphere. Appreciation of the necessity for funding reforestation is created.

Development of Critical Thinking ability

The issue is, "Should wind turbines be installed in Nantucket sound?". The students are asked to become familiar with technical jargon (e.g. kinetic energy, mechanical energy, angular momentum, wind charger, auxiliary power, commercial electric power, wind power density, and renewable energy source) through extensive reading of scientific newspaper articles. Students calculate electrical power from various real life scenarios using qualitative and quantitative reasoning. Students are taught that 1) several decades of valuable time was already lost (time lag) in acting on solutions for the world's energy crisis; 2) fossil fuel burning has irreversible consequences such as global warming; 3) the energy crisis has reached a disproportionately large size by following non-linear trend; 4) wind turbines can throw a couple of cents in producing clean and sustainable energy. Appreciation of the necessity for funding wind turbines is created.

Method of selecting the indices

At the beginning of the experimental group a list of 12 common teaching tools were supplied to the students. They were asked to rank the tools. The top four were selected to teach the class. Table 2 shows the relative rankings of the 12 teaching tools.

Results and Discussion

The average grade of the control group was 64% and that of the experimental group was 77%, a 20% improvement over the control group. The groups were significantly different with a calculated t value of 2.6. The t-test confirmed statistical improvement at significant confidence level with an alpha value of 0.05 [8-10].

The students ranked "learning from three Hands On and Minds On labs" the highest as shown in Table 3. In a written survey the students stated that they spent most of their time, interest and energy on this category. The students ranked "using closer looks" as the least important. This is probably due to the closer looks' abstract nature of this index. Table 4 shows the statistical analysis of the four indices. 82% of the students' written comments indicated that the integration of the four indices helped them learn the subject effectively.

Both the (experimental and control) groups were populated by 100% non-science majors. In both the groups, no student has taken any science course earlier. The prime author verified this fact. Therefore, it is established that the improvement is due to teaching methods and not due to the composition of the background of the students.

Conclusions

1. The experimental group showed 20% improvement over the control group in obtaining scientific knowledge.
2. Among the four indices the students ranked learning from labs the highest
3. These practices can be used in other science and engineering courses. The authors plan to use the strategy in two other courses over the next three years. The practices can be used in other courses or schools with appropriate modifications in order to help our students acquire the knowledge they need to make informed decisions about technology.

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Table 1. Grading Formulas

	Control Group	Experimental Group
1. Regular Assignments	10	10
2. Special Assignments	0	20
3. Attendance and class participation	10	10
4. Mid-term examination	40	20
5. Final Examination	40	30
The 4 indices component	0	10
Total	100	100

Table 2 Teaching Tools and Their Relative Ranks

Teaching Tool	Relative Rank
Learning from Hands On and Minds On labs,	1
Using closer looks,	2
Using case studies	3
Development of critical thinking ability.	4
Connection of educational objectives of the course to each lecture	5
Conducting in-class exercises	6
Conducting group discussions on various topics	7
Conducting debates for arguing pros and cons on selected topics	8
Assigning assignments for increasing analytical ability	9
Assigning assignments for increasing number crunching capability	10
Assigning assignments for increasing equation solving ability	11
Development of creativity	12

Table 3. Improvement of the Experimental Group over the Control Group

Performance Index	Control Group (%)	Experimental Group (%)	Improvement (%)	Rank
(1) learning from three Hands On and Minds On labs	64	79	23.4	1
(2) using closer looks,	64	75	17.1	4
(3) case studies,	64	78	21.8	2
(4) development of critical thinking ability.	64	76	18.7	3

Table 4. Statistical analysis of Performance Indices

Performance Index	Standard Deviation		t value
	Control Group	Experimental Group	
(1) learning from three Hands On and Minds On labs	9	12	3.4
(2) using closer looks,	8	13	3.2
(3) case studies,	12	11	2.9
(4) development of critical thinking ability.	10	10	3.1

Appendix 1

Critical Thinking-Wind Turbines, Yes or No?[7]

The critical thinking focuses on your recommendation whether wind turbines should be installed in Nantucket sound?

The 130 wind turbines can supply electricity to approximately half a million of homes. However it has some adverse affects on fish habitats.

1) Give an example of cultural justification and utilitarian justification against the Cape Wind Project
2) List the reasons for and against the Cape Wind Project. Explain each reason.

Appendix 2

Critical Thinking – What are the Adverse Results of Global warning on People in the Known History?[7]

1. Focus on Medieval warm period and answer the consequences on Viking explorers.
2. Focus on Medieval warm period and answer the consequences on people of the Mayan Civilization in the Yucatan of Mexico and Central America, Mono Lake in California, and Chaco Canyon in New Mexico.
3. Focus on the Little Ice Age period and answer the consequences on the people of Western Europe and North America.
4. Explain how Black Plague is connected to the answer of Question 3?
5. What is the single most factor that is different between the answers of the four questions above and the consequences of global warming of toady and future?

Appendix 3

Critical Thinking- How much Carbon can be Stored in Trees?[7]

1. Comment on a massive worldwide program of tree planting for reducing global warming.
2. What is the role of estimate of error in predicting how much carbon is stored in a tree? Your answer should focus on reduction of error by replacing guesses.
3. Suppose you have old data with an estimate of error and new data without an estimate of error which one do you prefer to predict how much carbon can be stored in trees?