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Abstract

A course titled "The Environment" was taught in fall 2007 using the traditional lecture method. The course was used as the control group. The same course was taught as an experimental group in spring 2011 using creativity for enhancing the technological literacy of the students. Six assignments based on students on some of the most important environmental issues were given to the students. Each issue was loaded with technological literacy details. The assignments were graded using a creativity quotient on a scale of 0-7. The creative assignments comprised 20% of the course grade. The creativity assignments were the only difference between the control and experimental groups.

In a written survey the students stated that the assignments provided them with a creativity-friendly, rich, imagination-fostering environment for learning. The average grade of the control group was 64% while that of the experimental group was 78%, a 22% improvement over the control group. The t-test confirmed statistical improvement, t value of 3.6, at a significant confidence level with an alpha value of 0.05.

Introduction

The objective of this paper is to show how creativity can be used to enhance the technological literacy of non-science majors by introducing the students to basic scientific and technological principles in various areas of a course, "Environment."

Creativity involves a new product or a solution with some value. Creativity and creative acts are therefore studied across several disciplines [1]. A creative person can understand what is outside the box from within the box.

Theories of creativity use a wide variety of aspects to explain individual levels of creativity. The most important aspects are usually identified as the four "Ps" - product, process, place and person [2]. In the Wallas [3] stage model, creative insights and illuminations may be explained by a process consisting of 5 stages: preparation, incubation, intimation, illumination and verification.

Finke et al.[4] developed the "Geneplore" model. In this model creativity occurs in two phases: (1) a generative phase and (2) exploratory phase. In the generative phase, one constructs mental representations. The representations are also called as preinventive structures. Finke et al noted that in the exploratory phase the structures are used to come up with creative ideas [4]. Weisberg[5] disagrees with these models. He argued that creativity involves ordinary cognitive processes that yield extraordinary results.

The Explicit-Implicit Interaction (EII) theory

Helie and Sun[6] developed the Explicit-Implicit Interaction (EII) theory of creativity. This theory demonstrates a unified explanation of relevant phenomena. According to Roses, et. al. people often spontaneously imagine alternatives to reality when they think if only scenarios [7]. This type of alternative thinking is an example of everyday creative processes [8]. Byrne, et. al. believe that the creation of alternative thinking to reality depends on similar cognitive processes to rational thought [9].

Creativity comes in different forms. A number of thinkers suggest models of creative people. For example, one model indicates that there are kinds to produce growth, innovation, speed, etc. The four Creativity Profiles: incubate, imagine, improve, and invest can help achieve such goals [10]:

Mark Batey suggested that the creative profile can be explained by four primary creativity traits. These are: idea generation, personality, motivation, and confidence [11-12].

Creative industries and services

Today, creativity is the core activity of a growing section of the global economy known as the "creative industries." The creative professional workforce is merging as an integral part of industrialized nations' economies. Creativity produces intangible wealth. The Creative Industries Mapping Document 2001 provides an overview of creative industries in the UK. Approximately 10 to 20 million US workers can be considered creative professionals.

Definition for Technological Literacy

Technological literacy has been defined as "an understanding of the nature and history of technology, a basic-hands-on capability related to technology, and an ability to think critically about technological development It is essential that ordinary citizens are able to make thoughtful decisions on issues that affect, or are affected by, technology [13]."

A review of literature and existing programs show that there is no universally accepted definition of technological literacy. However, the basic description and general learning objectives developed by the technological literacy task force in the colleges of arts and sciences states that[14] " in the broadest sense, technology is the process by which we modify nature and society using knowledge of science and engineering to create new ways to met our needs and wants [13]. Technology comprises the entire system of people and organizations, knowledge, and processes that go into creating and operating technological devices and systems [15].

Technological Literacy and Empowerment

As per Carlson[16], empowerment of technological literacy can take a wide range of outputs depending upon our goals. The goals can vary from (a) to teach student how things work so that they can be passive employees or consumers in a dynamic and capitalist economy, (b) to enable students to comprehend how individuals and societies use technology to satisfy their needs and pursue their wishes and dreams, (c) to provide students with ways of thinking about how technology can be shaped to serve a range of goals and values.

The authors agree with Carlson[16] that we should strive to develop a technological literacy that embraces this broader and more active perspective. The course is designed to promote technological literacy by introducing students to basic scientific principles in several areas of Environment.

Motivation

The conventional system of teaching does not have a strong creativity component. Creativity is important because technology is advancing our society at an unprecedented rate and creative problem solving will be needed to cope with the challenges technology presents. Creativity can also help students identify problems where others have failed to do so. To promote creative thinking teachers need to identify what motivates their students and organize teaching around it. Very few courses provide the students with creative opportunities for learning.

Science and technology are so pervasive in modern society that students increasingly need a sound education in the core concepts, applications and implications of science [17]. The importance of these topics and their needs provided the authors with strong motivation to pursue this study.

Methodology

"The Environment" course was taught in fall 2007 using the traditional lecture method. This course was used as the control group. The same course was taught as an experimental group in spring 2011 using creativity for enhancing the technological literacy of the students.

In order to promote technological literacy among students, the experimental group was introduced to basic scientific and technological principles in six areas of the environment: (1) Environmental Health, Pollution and Toxicology; (2) Water Supply Use and Management; (3) Fossil Fuels and the Environment; (4) the Atmosphere, Climate, Global Warming; (5) Urban Environments; (6) Air Pollution. The areas were selected based on two criteria: 1) importance of the area in the environment and 2) applicability of technology in the area.

Six assignments were given to the students, one on each area. Each assignment consisted of a critical thinking issue and several questions demanding: (1) an understanding of the nature and history of technology, and (2) the ability to think critically about technological development[15].In addition students conducted three hands on laboratory experiments that addressed technological issues regarding sound pollution, acid water, and energy use. Each assignment (the issue and the student answers) and experiment was loaded with additional technological literacy details consisting of charts, tables, graphs, equations and/or number crunching exercises. The students were told that the grade would be based on their use of these technological literacy details.

In a survey the students were asked to self evaluate their performance on the assignments. They were asked to write regarding the benefit of the creative work they did in the course along with the average number of hours they spent on the course. The assignments were graded by the instructor.

Supporting Technological Literacy Details [18]

While understanding an important concept--overshoot and collapse--a graph, an equation and a number crunching exercise showing the relationship between carrying capacity (maximum population possible without degrading the environment necessary to support the population) and the human population are utilized as shown.

In the beginning the carrying capacity is significantly higher than the human population. However, since population grows exponentially, it eventually exceeds, i.e., overshoots the carrying capacity resulting in the collapse of the population to a lower level. Thus the carrying capacity reduces. Notice that the lag time is the period of exponential growth of the population. It is important to understand that there are several other systems that follow this pattern. Examples include growth or reduction/decay of money, bacteria, trees or fish. Here, the exponential equation is

$F = P\ e^{kt}$, where
F = is the future value
P = present value
K = rate per unit time
t= number of units of time
E = base of natural logarithm (a constant = 2.718)

The equation can be solved using a simple hand calculator. A number of important environmental quantities can then be estimated. For example, to find F, the estimated world population in the year 2023, you need P, the population in 2003 which is 6.3 billion and the rate of population growth which is 1.36% per year (k= 0.0136). F is estimated as shown below.

$F = (6.3 \times 10^9) * e^{0.0136 \times 20} = 8.28$ billion people.

Students were taught how to use charts and tables and evaluated based on the extent their use of the charts and tables for assignments and lab reports. The assignments addressed important topics and concepts concerning the Environment.

Example Assignment [18]

The assignment (see Appendix 1) “What is Your Water Footprint?” included the following critical thinking questions:

(1) How well do you think the variables in the extended individual footprint characterize technological issues of your water use?
(2) Do you think the water footprint you calculated is a useful concept to better understand water resources?
(3) In evaluating your individual water footprint living in the US versus several other countries, what is actually controlling the footprint that you produced? Why is individual income of GDP per person apparently so important?
(4) Has calculating you personal water footprint led you to a better understanding of some of the technological components of water use? What could you do to reduce your water footprint?

The assignments were graded using a creativity quotient scale of 0-7. The quotient consisted of 7 indices: (1) remote consequences – participants were asked to generate a list of consequences of unexpected situations; (2) fluency – strength of meaningful, interpretable, and relevant ideas generated in response to the issue; (3) originality – the statistical rarity of the responses among the students; (4) elaboration – the amount of detail in the responses; (5) independence of judgment; (6) attraction to complexity; (7) tolerance for ambiguity. Each index was worth one point. The creative quotient was the total score on the 7 indices. The creative assignments accounted for 20% of the course grade. Other than the assignments there was no difference between the control and experimental groups. Table 1 shows the grading formulas for the control and experimental groups.

Table 1. Grading Formulas

	Control Group	Experimental Group
1. Regular Assignments	10	10
2. Assignments on creativity	0	20
3. Attendance and class participation	10	10
4. Mid-term examination	40	20
5. Final Examination	40	40
Total	100	100

Results and Discussion

The control group students spent 6.5 hours per week while the experimental group students spent 8.6 hours per week on the course.

Table 2 shows the results of the students' survey (indicated by students' self evaluation) on the assignments and Table 3 shows the results of instructor's grading on the assignments. The students ranked fluency—strength of meaningful, interpretable, and relevant ideas generated in response to the issue-- the highest, as shown in Table 2. The rank agrees with the energies and time spent and interest shown by the experimental group students over the control group students. The students ranked remote consequences, where participants are asked to generate a list of consequences of unexpected situations as the least important. This is understandable because in real life remote consequences are rarely encountered. The written survey showed that students perceived the assignments as providing with a creativity-friendly, rich, imagination-fostering environment for learning.

The experimental group is exactly the same as the control group except for one variable so that the effect of that variable can be identified.[19] In this study, the variable is "Creativity." The experimental group had 20% of the grade assigned for creativity. The groups are designed as shown in Table 1 following the definition of "Controlled Experiment."

Table 2. Results of Students' Survey

Performance Index	Control Group (%)	Expt. Group (%)	Improvement (%)	t	Relative Ranking
1. Remote consequences, where participants are asked to generate a list of consequences of unexpected situations	65	72	11	3.7	7
2. Fluency – strength of meaningful, interpretable, and relevant ideas generated in response to the issue.	64	83	30	2.9	1
3. Originality – the statistical rarity of the responses among the students.	63	78	24	3.1	4
4. Elaboration – the amount of detail in the responses.	64	81	27	3.3	2
5. Independence of judgment	66	79	20	3.5	3
6. Attraction to complexity	62	75	21	2.8	6
7. Tolerance for ambiguity.	64	77	20	3.4	5

The average grade of the control group was 64% and that of the experimental group was 78%, a 22% improvement over the control group. The groups were significantly different with a calculated t value of 3.6. The t-test confirmed statistical improvement at significant confidence level with an alpha value of 0.05.

Table 3. Results of Assignment Grades

Performance Index	Control Group (%)	Expt. Group (%)	Improvement (%)	t	Relative Ranking
1. Remote consequences, where participants are asked to generate a list of consequences of unexpected situations	64	71	11	3.9	7
2. Fluency – strength of meaningful, interpretable, and relevant ideas generated in response to the issue.	66	83	26	3.6	1
3. Originality – the statistical rarity of the responses among the students.	65	79	22	3.5	4
4. Elaboration – the amount of detail in the responses.	66	82	24	3.3	2
5. Independence of judgment	68	84	24	3.1	3
6. Attraction to complexity	67	76	13	2.7	6
7. Tolerance for ambiguity.	66	78	18	2.9	5

The average grade of the control group was 66% and that of the experimental group was 79%, a 20% improvement over the control group. The groups were significantly different with a calculated t value of 3.3. The t-test confirmed statistical improvement at significant confidence level with an alpha value of 0.05.

Conclusions

1. Creativity enhanced the technological literacy of a course consisting of 15 non-science majors. The enhancement was measured by the improvements made by the students in understanding the basic scientific and technological principles in the six areas of the environment.
2. In their self evaluations, the students ranked fluency the highest among all the performance indices. The experimental group's improvement over the control group was 30%. The improvement of the experimental group's grading (evaluated the instructor) on the assignments over that of the control group was 26%.

3. In their self evaluations, the students ranked remote consequences as the least important among all the performance indices. The experimental group's improvement over the control group was 11%. The same improvement (11%) between the two groups was noted by the results of the instructor's grading on the assignments.

The authors plan to extend this strategy to two other courses over the next three years. The method presented in this study may be used at other institutions in their courses with appropriate modifications in order to prepare the students for using creativity to enhance their technology literacy.

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Appendix 1

Critical Thinking on Water Foot Print[18]

The water foot print is the total amount of water used by a person (or a community or country) per year. In Afghanistan the water foot print per person per year is 660 cubic meters. This is an example of underdeveloped country. In USA the water foot print per person per year is 2483 cubic meters. This is an example of a developed country.

1. Calculate your quick individual and extended water footprints using the website waterfootprint.org. Notice that you have to deal with the variables such as your income, eating habits and personal lifestyle.
2. Explain the importance of individual income in calculating the water footprint.
3. List the measures you need to take to reduce your water footprint. Rank the top three most effect measures and explain in detail each one.