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Table of Contents

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Scientific Visualization: A Pilot Study in the Technology Education Middle School Classroom

Emily S. Quadrio, Aaron C. Clark

Abstract

Scientific Visualization is the practice of communicating information and ideas visually to a wide variety of audiences. Recently, this application has been incorporated into technology education. VisTE is a project where scientific visualization techniques are integrated with the International Technology Education Associations "Standards for Technological Literacy". The goal of this study was to determine how this new curriculum taught in a technology education classroom affected middle school student performance and interest in technology. How the curriculum was implemented and student activities will also be discussed.

Introduction

Visualization is when a person can conceptualize an idea or concept in his or her mind. Most often our thoughts and memories occur as images. Recently, the practice of using visualization techniques that were reserved for the arts is becoming more prevalent in the disciplines of science, technology, finance, and mathematics. This transition has been orchestrated by the fields of computer graphics, simulation, and applied-art by the use of computers and multimedia to transfigure information into illustrative symbols. (Silverstein, 1994). Graphic tools can further student understanding of abstract and numerical concepts in the classroom by teaching students how to conceptualize knowledge (Clark & Wiebe, 2000).

A scientific visualization image, graph, model, etc. is colorful and formed from data that creates a visual representation of the concept or phenomena that might be discussed; generating a physical picture of the way things happen (Polland, 1994). Examples include: a map of a country showing color variances in temperature, material scientists examining the topography of atoms and molecules, a conceptual model of an organ, or even a physics student animating a rubber and bowling ball rolling down a hill to depict how force = mass x acceleration. It is then that students can find patterns that parallel with theories or concepts previously learned making comprehension more logical. These types of applications also demonstrate how visualization is practiced in professional communities, where students experience the design process that mimics real world application (Wiebe, Clark & Hasse, 2001).

An additional student outcome of utilizing scientific visualization practices includes the advantage of using graphics instead of text or numerical notation (Clark & Matthews, 2000). An example where this could be applied is algebra, where many students of different ages find the subject difficult to learn due to quantity of numeric and alphabetic notation. It is recently that scientific visualization has been utilized in technology education classrooms to integrate the above mentioned areas into the curriculum.

This particular study involved a pilot study of scientific visualization curriculum. VisTE is a project designed for grades 8-12 which connects the "Standards for Technology Literacy" to the disciplines of math, science, and technology through the practice of visualization. The National Science Foundation provides funding and the curriculum writing team is located at North Carolina State University. Over the course of three years, 12 units will be developed. The material is intended to help students become technologically literate by providing practical applications of math, science, and technology through scientific visualization activities. VisTE has synthesized computer activities that will raise student interest in technology and encourage their creative processes. Proposed goals for students learning include manipulating and managing data including the use of spread sheets, creating visualizations using 2-D and 3-D modeling and multimedia presentation, and exploring careers in technical visualization (http://www.ncsu.edu/viste/index.htm). These skills can be derived through problem-solving, real-world application exercises, and combining visualization techniques with Technology Education.

Two units, Energy and Power Technologies and Medical Imaging, were chosen in particular to pilot at Culbreth Middle School in the fall semester of 2003. Although the VisTE project was in its second year of piloting and evaluating, 2003 was the first year it was tested at this site. The Medical Imaging unit was in its second trial while the Energy and Power Technologies unit in its first. Both units arrived in the classroom as CD-ROMs where the teacher had access to background information pertaining to the unit and a sequence of detailed activities for introductory, intermediate, and advanced students. Design briefs, student and teacher resources, software, and evaluation rubrics were also included.

The purpose of this pilot test was to determine:

- Whether or not scientific visualization increases student opinions of technology in general.
- How the material taught affects student interest of energy and power and medical imaging technologies.
- If the VisTE curriculum increases middle school students understanding of energy and power technologies and medical imaging according to pre- and post-test scores.

A synopsis of the introductory Energy and Power Technologies unit and sequence of activities:

Project one: Students were asked to investigate the history of a type of energy and power technology that converts less useful energy into more useful forms. A worksheet was created for students to complete and a variety of resources (Internet, books, cd-roms, etc) were provided. Students were paired and allowed to choose their own type of energy such as wind, nuclear, or hydroelectric. The evaluation of this project was based on content and accuracy of information found.

Project two: A video was shown identifying types of energy that are commonly used in society. A lecture was also given where students took notes on different forms of energy that are used to meet our everyday needs. Kinetic and potential energies were discussed along with the operation of a battery and photovoltaic cell. A design brief provided by VisTE was distributed to the students that described project two as a role-play where the students would be demonstrating to a science class how an energy source is converted into a more useful form of energy. The students decided on the visualization media and energy type, whether it was a working model, animation, experiment, or prototype. A rubric was used to evaluate students based on their graphic skills, design, communication, and teamwork effort.

Project three: The law of conservation of energy was discussed in class. Students were then placed in groups of three of four and received a design brief. This project called for students to design and create an energy transfer device that used a series of three *different* energy transformations. The final product was a visualization of the design that showed how energy flowed through the device. A list of design constraints was provided and included size and weight limitations, and a mandatory mechanical release of the ball. The visualization was to indicate types of energy being used at different points of the golf balls route and where the energy transformations took place. All types of energy must be accounted for in the visualization. The extension project was for students to build the device and complete the following task: release a golf ball form a starting point and end by having the golf ball fall into a cup using a series of three energy transformations. The same evaluation rubric was used as project two.

Project four: Students researched the Internet for documentation and news articles pertaining to the proper disposal of different types of batteries and their hazard to the environment. After pairing students for the project again, a design brief was distributed where students would create a presentation that would inform the general public of the impact of improper battery disposal and the proper way to dispose of used batteries. Students chose the type of media used to present their findings such as a brochure, web page, or public service announcement that was videotaped. Students were graded on content, accuracy of information, and their graphic skills.

A synopsis of the introductory Medical Imaging unit and sequence of activities:

Project one: Students worked individually and given a graphic organizer to complete. This allowed students to see the information as a visual representation. The four major branches of medical imaging were labeled- radiology, nuclear medicine, magnetic resonance imaging, and ultrasonography. Students were asked to investigate the scientific principles behind the imaging technique and their technological application. Key people involved in the scientific discoveries were also identified. The graphic organizers were graded on accuracy and completion.

Project two: A brief lecture was given on wave properties, behavior, and how electromagnetic waves interact with a medium. Students then determined which medical imaging technique uses which electromagnetic radiation by using a VisTE-created table as a reference. An excel spread sheet was provided in the resource materials which requesting students to graph frequency versus wavelength and determine that the relationship between the two is inversely proportional. After filling in the x and y values, individuals made a graph visualizing the relationship. Each graph and spreadsheet was turned in for a grade based on the visual representation of the inverse relationship. Students also identified and recorded which regions of the electromagnetic spectrum are utilized in medical imaging technologies.

Project three: The class briefly discussed the DICOM file format (Digital Imaging and Communication in Medicine). A software package called eFilm Lite, provided by VisTE, allowed students to look at CT scans of dog skulls. A demonstration of the program was given showing student how to open files, adjust the picture, and take accurate measurements. Students then measured the length and width of three different skulls and calculated the skull indices. Reference diagrams were provided. After completing a chart documenting the measurements and indices, students created bar graphs displaying the measurements they had determined to the actual average measurements for each dog skull type. It was after this that students analyzed the data they had found and concluded which dog skull was Brachycephalic, Dolichocephalic, or Mesaticephalic. The evaluation of this project consisted of completion of the charts and graphs. Accuracy of skull measurements and determination of skull type was also accounted for.

Project four: A lecture was given to the class on sources of radiation and its specific units of measurement. Students then completed a questionnaire when, upon completion, would determine individual estimated annual radiation dosages in mRem (Roentgen equivalent mass). Examples of questions asked included: How many dental, chest, skull or pelvic x-rays have you had in the past year?, How many CAT scans have you had in the past year?, Do you use a computer monitor?, and Do you live within 50 miles of a nuclear power plant? Individuals printed a copy of their annual radiation dosage calculation and turned it in to be graded for completion after comparing their dose to that of a nuclear power plant worker, airline crew member, X-ray technician, uranium miner and astronaut. Data was complied for the class and an average was taken and again compared to the annual radiation dose of the occupations previously mentioned.

Methodology

Research Triangle Institute, the outside evaluator of the VisTE project, designed a survey instrument for the pilot. It was based on International Technology Education Association surveys from previous years. The instrument was divided into five parts. The first section collected opinions on how difficult students felt it was to learn math and science. The second and third sections examined students' general interest of technology and the opinion of the respective VisTE curriculum that was taught. A Likert scale of levels 1-5 was utilized for the first three sections. The fourth section of the instrument included a multiple choice pre-and post-test to prelude and conclude the unit. These test scores were used to determine gains in student performance. The fifth section of the instrument asked for demographic information from the student. The instrument was complied and distributed to students twice. Once completed, Research Triangle Institute reviewed the unit assessments and compiled data from other pilot sites. For the purpose of this study, the classroom instructor performed qualitative analysis and descriptive statistics on the data collected from the pilot study.

The VisTE project team chose the pilot site. All sites chosen were a random sample. Culbreth Middle School represents an urban, upper-class population. The facilitator of the pilot site was female and chose two eighth grade Exploring Technology Systems classes to pilot the curriculum. Students in both groups normally received a mix of traditional classroom teaching and modular workstations over the course of an 18-week semester. Both VisTE units were taught using whole-group instruction. A total of 33 students participated in the study, 19 were in the Medical Imaging group and 14 in the Energy and Power Technologies Unit group. Two students did not provide data due to excessive absences. Five females participated.

Findings

Table 1: Demographics Data of Population Surveyed, Energy and Power Technologies Class

Factor	(n=14)	%
Male	11	78.6%
Female	3	21.4%
White	10	71.4%
African-American	2	14.3%
Asian	1	7.1%

Hispanic	1	7.1%

Table 2: Demographics Data of Population Surveyed, Medical Imaging Class

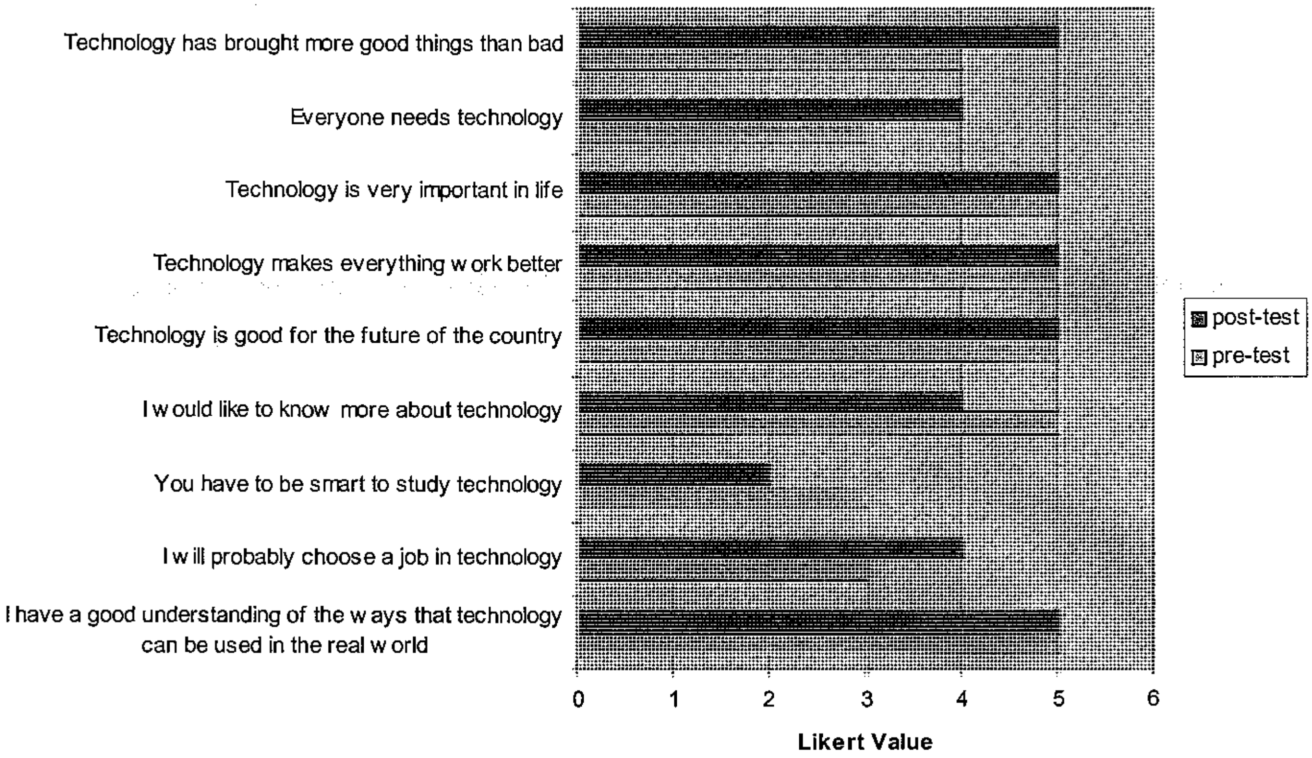
Factor	(n=19)	%
Male	17	89.5%
Female	2	10.5%
White	15	78.9%
Asian	2	10.5%
*Mixed	2	10.5%

**Students responded to more than one ethnic group.*

The survey instrument gathered demographic data from the students. *Tables 1 and 2* indicates the major demographic variables as race and gender. The Energy and Power Technologies unit included three females, one Hispanic and one Asian, the Medical Imaging unit two females. Both African- American males were in the Energy and Power Technologies unit. The Asian male and two mixed males were in the Medical Imaging class. White males made up the majority of the population in both pilot groups.

The first set of survey questions asked students to rate their opinions of technology in general. The questions were very general and students were not given a specific definition of technology. Student ratings were also not dependent on what was being taught in the Exploring Technology Systems class that semester. Individuals were asked how much he or she agreed with the following statements and to check the box that matched his or her choice. Although the survey questions were the same for each VisTE unit, data remained separate for each class to determine if the curriculum affected student opinions. The mode was taken for each individual survey question with an average calculation if there was more than one mode.

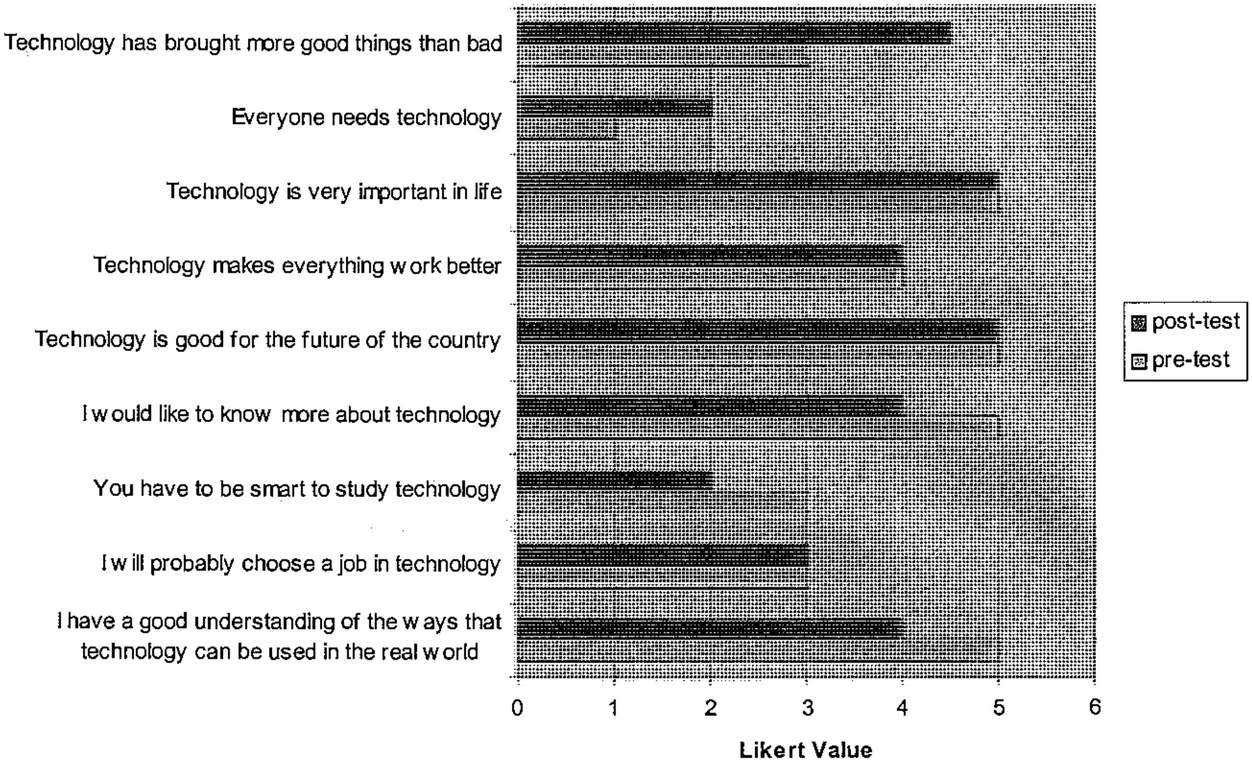
Figure 1: Student Interest in General Technology, Energy and Power Technologies Group



Note: *Likert values 1= disagree, 2=tend to disagree, 3= neutral, 4= tend to agree, 5= agree*

Overall student opinions changed very little in the Energy and Power Technologies class *(Figure 1)*. Three out of nine questions showed a 20% increase in general technology. There was a slight increase in the perspectives of society needing technology, how technology has brought more good than bad, and whether or not the group would consider a career in technology. Two out of nine questions established that there was a 20% decrease in the notion of one having to be smart to study technology and if students would like to know about technology. Four out of nine questions designated no change in student perception of technology in general.

Figure 2: Student Interest in General Technology, Medical Imaging Group

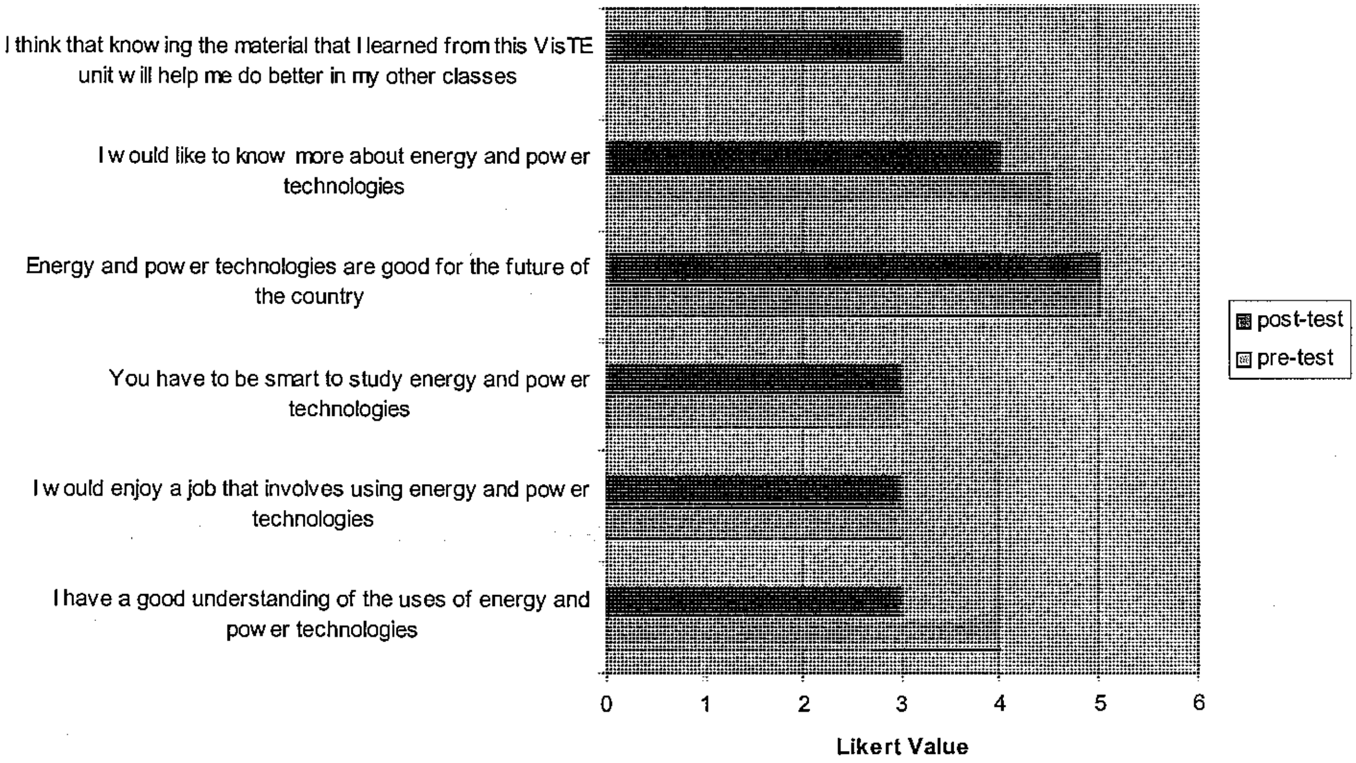


Note: *Likert values 1= disagree, 2=tend to disagree, 3= neutral, 4= tend to agree, 5= agree*

The Medical Imaging pilot group *(Figure 2)* showed an increase in two out of nine questions. Technology bringing more bad things than good and whether everyone needs technology proved a 20% gain according to the data. Three out of nine questions, understanding how technology is used in the real world, the necessity of being smart to learn technology, and interest in studying more about technology, showed a 20% decrease in opinion. Four out of nine questions presented no change in opinion.

A second set of questions regarded student opinions of the content that was taught. Questions prompted participants to respond to knowledge gained from the VisTE curriculum. None of the questions were considered specific to the unit, but asked about Energy and Power Technologies and Medical Imaging in general. Individuals were asked to how much he or she agreed with the following statements, and to check the box that matched his or her choice. Question *f*, *I think that knowing the material that I learned from this VisTE unit will help me do better in my other classes*, was only given on the post-test. The mode was taken for each individual survey question with an average calculation if there was more than one mode.

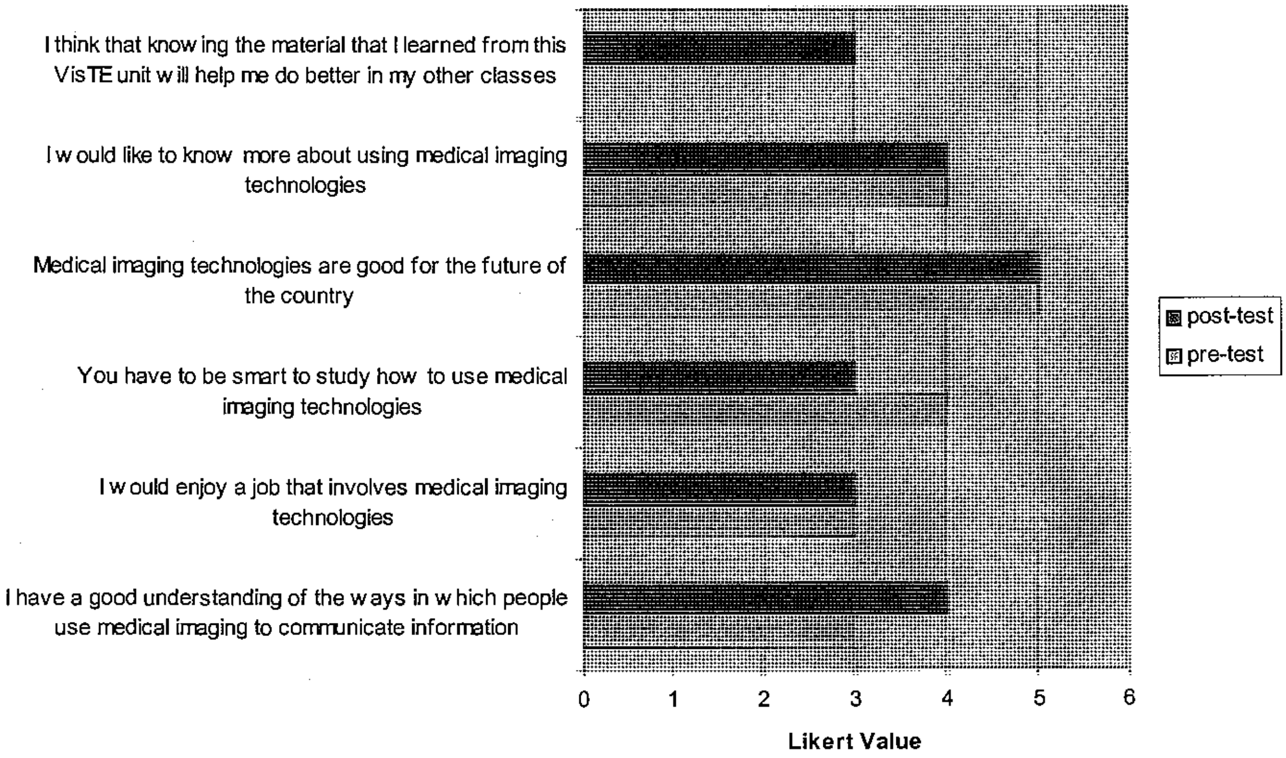
Figure 3: Student Interest in Energy and Power Technologies



Note: Likert values 1= disagree, 2=tend to disagree, 3= neutral, 4= tend to agree, 5= agree

The Energy and Power Technologies class expressed no feelings toward applying knowledge from the unit to other classes *(Figure 3)*. Two out of five survey questions indicated no increase or decrease of opinion. These questions included student perceptions of whether or not one must be smart to learn energy and power technologies and enjoyment of a job involving energy. There was a 10% decrease in curiosity of the subject material and a 20% decrease in understanding of how energy and power technologies are used. This made up two of the five questions. Students tended to agree that energy and power technologies as are good for the future of the country on both the pre- and post-test.

Figure 4: Student Interest in Medical Imaging



Note: *Likert values 1= disagree, 2=tend to disagree, 3= neutral, 4= tend to agree, 5= agree*

The Medical Imaging class demonstrated no feelings toward applying knowledge from the unit to other classes *(Figure 4)*. Three out of five questions establish no change in students' willingness to learn more of the subject matter, their thoughts of medical imaging being good for the future, and whether or not they might enjoy a job in this field. One question indicated a 20% increase in understanding how imaging is used to communicate information. There was a 20% decrease in one question: if one must be smart to study medical technologies.

The third set of questions included in the survey instrument was specific to each VisTE unit that was piloted. There were twenty questions total with a maximum score of 100%. *Table 3* displays the results from the post-test. The post-test was included as a test grade in the classes that participated in the pilot and was distributed after four introductory activities were completed from the VisTE curriculum. The questions asked were very specific to content that was taught with the level of questions varying from knowledge recall to analysis and application of information. The majority of the questions asked were directly related to the materials covered in the pilot. The mean gain was calculated from the point gain per student according to each unit that was taught.

Unit	Pre-test score M	Post-test score M	Mean Gain
Energy and Power Technologies Unit	36.8	52.9	20 points
Medical Imaging Unit	39.7	74.2	34.7 points

Table 3: Results of pre-and post-tests.

Tables 4 and *5* show the point gain distribution for each pilot class.

Point gain	Frequency of students (n=14)	Percent
0	1	7.1%
5	1	7.1%
10	2	14.3%
15	2	14.3%
20	3	21.4%
25	1	7.1%
30	1	7.1%
35	2	14.3%
40	1	7.1%

Table 4: Energy Unit pre- and post-test score gains.

Point gain	Frequency of students (n=19)	Percent
10	1	5.3%
20	1	5.3%
25	2	10.5%
30	3	15.8%
35	5	26.3%
40	2	10.5%
45	3	15.8%
50	2	10.5%

Table 5: Medical Imaging Unit pre- and post-test score gains.

Conclusions and Recommendations

According to the data, students' opinions of technology in general showed no increase after the pilot study. The Energy and Power Technologies Unit showed an increase of opinion in three statements and a decrease in two statements. Both of these differences were only by one Likert value. The Medical Imaging Unit had an increase in two questions, a decrease in three. Once again, the difference was only in one Likert value. Four statements included in the survey instrument showed no difference in opinion in both classes.

There were a few similarities between the two pilot groups. Two survey statements had an increase in both groups: Everyone needs technology and Technology has brought more good things than bad. The common decrease was: You have to be smart to study technology. There was no change in the statements of Technology being good for the future of the country and that Technology is important in life.

There was a change in students' opinions of general technology; however these findings were not significant because the increases and decreases occurred in so few questions. For example, when an increase did take place it was only by 20%. There are three attributes that might explain the students' responses and why there was so little change. First, these middle school students might have been too young to make a decision on what kind of job they will be choosing in the future. Second, the statement regarding if one must to be smart to study technology seemed inappropriate for this type of survey. Most students have a different definition of what smart may be, or consider themselves bright in one area but not another. Another possibility is that this assertion may have made participants feel like the survey encouraged him or her to only pick one particular answer. A question stating, " How difficult or easy is it for you to learn technology?" using a rating scale of very difficult to very easy may have encouraged students to select a different answer.

The limited amount of change in opinion could also be credited to the fact that the students involved in the project already agreed with the majority of the statements on the survey instrument. The survey from the Energy and Power Technologies answered eight out of nine questions as agree or strongly agree on the post-test, while the Medical Imaging group responded to six out of nine questions as agree or strongly agree. After reviewing this data another conclusion drawn is that students agreed with the majority of the survey.

The material taught showed a very slight decrease in participants' interest of Energy and Power Technologies. Out of the six statements, there was a decrease in two statements and both showed a decrease by only one Likert value. Three statements demonstrated no change. The premonition of this data was that the students in this group were very indifferent to the content. Four of the six questions were scored as neutral on the post-test. Included was the comment of whether or not the VisTE material is applicable to other subjects, tallied as neutral.

The Medical Imaging unit established no change in student interest of the subject. There was one statement with an increase in the subject interest, another with a decrease. Both of these changes were by just one Likert value. Three of the statements on the survey instrument showed no change in interest of the subject. Once again, the comment of whether or not the VisTE material is applicable to other subjects was tallied as neutral. After reviewing the data one can conclude that students in this group were impassive to the VisTE material that was taught. Of the statements on this survey half were marked as neutral on the post-test.

The increases in post-test scores conclude an increase in middle school students understanding of both the subjects, though gains varied significantly for each unit. The Energy and Power Technologies class began with a mean score of 36.8; the post-test mean score was 52.9. The mean gain was 20 points and was calculated by averaging the point gain per student. The VisTE curriculum did increase understanding of energy and power Technologies in middle school students.

The Medical Imaging Technologies unit showed an even greater gain. The pre-test mean score was 39.7, the post-test mean score 74.2. The mean gain was 34.7 points and was calculated by averaging the point gain per student. This was a significant increase in test scores. The VisTE curriculum did increase student understanding of Medical Imaging Technologies. Though the purpose of the study intended to determine how the VisTE units affected student understanding of two particular subjects, inferences were also drawn that explained the gap in the gain between the two units.

First, the Energy and Power Technologies curriculum was in its first pilot year. The writers of the unit had not had a chance to receive any feedback regarding the unit or student opinions of the material. Second, there were six test questions that were not directly related to the activities that the students completed. Identification of the components of an alkaline battery and how the oxidation and reduction processes occur were included in the objectives and resources but there was no application of this knowledge. An additional example of not implementing learned content was recognizing components and their function in a photovoltaic cell. The frequency of questions marked incorrectly is shown in Table 6.

Table 6: Frequency of Questions Marked Incorrect on the Energy and Power Technologies Post-Test

Question	Frequency of students who marked post-test incorrectly (n=14)	%
4. Which component of an alkaline battery is responsible for conducting the electricity within the cell to the outside circuit?	13	92.9%
8. What is the name of the process in which the anode loses electrons?	8	57.1%
11. What is the name of the process in which the cathode gains electrons?	8	57.1%
13. What does the term "energy gap band" refer to in a photovoltaic (solar) cell?	8	57.1%
17. The major difference between different types of batteries is:	8	57.1%
19. Which component of an alkaline battery is responsible for facilitating the movement of ions within the cell?	9	64.3%
21. Which of the following is considered a type of kinetic energy?	14	100%
22. In which part of a photovoltaic (solar) cell does the creation of the electron current occur?	11	78.6%

Table 6 denotes which test questions were most frequently missed on the Energy and Power Technologies unit post-test. *(All questions displayed in the table were missed by over 50% of the students in the class.)*

The majority of students in the class recorded questions 4, 8, 11, 13, 19, and 22 as incorrect. As indicated in *Table 6*, the majority of the questions marked wrong either dealt with the parts and function of an alkaline battery or photovoltaic cell.

The third reason for the greater increase in test scores in the Medical Imaging class was that the curriculum was in its second pilot year. The writers had a chance to revise student and teacher materials to support student success in the unit. The gap in the pre- and post-test scores between the two units can also be accredited to the fact that each learning objective was applied in the student activities. For example, features of a sine wave were applied to Project 2: Students will develop an understanding of the behaviors of electromagnetic waves through an interactive Excel worksheet. All instruction given to the students allowed the opportunity for them to exercise and apply the information.

One recommendation for future pilot studies involving the Medical Imaging unit is that the pre-and post-test should not include questions that pertain to recalling average measurements for types of dog skulls. 13 out of 19 students marked both test questions 18 and 19 on the Medical Imaging post-test incorrectly. The inquiry presented students with a chart of the facial width and length of three dogs. Students were asked to identify the skull type of two dogs, recalling from Project three the average measurements for each skull type. Each question was equally missed. A suggestion is that the two questions should include two dog skull scans with measurements from the E-film Lite software and a table displaying the average measurements for Brachycephalic, Dolichocephalic, and Mesaticephalic skull types. The students would study the CT scans and reference the table, inferring the correct dog skull type. If these types of analysis inquiries were used, there would be an even greater increase in pre- and post-test gains.

There are quite a few solutions that would support a greater increase in the Energy and Power Technologies Unit pre- and post-test scores. The first is to create an activity where students would generate a visualization of how a battery or photovoltaic cell works amid each devices' respective components. If this were required as Project two or Project four in the unit, it is possible that the majority of students would be more likely to apply and retain the knowledge related to these two energy transformations. Students can create animations, slide shows or other media visualizing the chemical reaction that takes place inside a battery. A second possibility is that students could create their own solar cells or batteries and experiment in class. As long as the assessment expects students to know about these two energy supplies, the VisTE unit and its resources need to provide activities where students apply content knowledge that is learned.

A third suggestion for the Energy and Power Technologies unit is to fabricate an activity that is more applicable to students' lives. For instance, instead of designing an energy transfer device, students could come up with ways to improve the energy consumption in their homes and visualize their solution, or visualize energy transformations that take place inside their homes. An alternate topic for Project four is to create a presentation for the general public illustrating the United States' over-consumption of energy or renewable energy sources and their benefits.

After a thorough review of the data, one can conclude that the VisTE curriculum does not change student opinions of technology in general. The material taught slightly decreases student interest of energy and power and medical imaging technologies. The VisTE curriculum does increase middle school students understanding of energy and power technologies and medical imaging according to pre- and post-test scores. The increase in comprehension and visualization can be attributed from the activities VisTE has synthesized.

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The Effects of Direct and Problem-based Learning Instruction in an Undergraduate Introductory Engineering Graphics Course

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Introduction

This study used a teaching pedagogy of problem-based learning (PBL) to compare any significant change in knowledge, skills, and attitude in comparison to the traditional teaching of engineering graphics. The quasi-experimental study sample comprised forty-eight (N = 48) students in a Foundation of Graphics course at North Carolina State University, and involved a pre-test / post-test control group, using single control and single treatment groups of 24 persons per group.

The independent variable was pedagogical strategy, and the dependent variables of knowledge pre-test and knowledge post-test measured graphic content knowledge, which allowed for direct gain comparisons of engineering graphics to the control and treatment groups. Other dependent variables comprised a CAD skill evaluation that measured students' skill in creating a three-dimensional CAD model and an attitude survey (MSLQ) to compare attitude associated with traditional versus problem-based learning pedagogy. The main pedagogical PBL treatment was a series of 20 in-class exercises, where students worked in small groups to complete small-problem scenarios, including reverse engineering of parts.

To determine whether groups differed on more than one dependent variable, an ANOVA was used to analyze data and investigate difference and gain between traditional-instruction and problem-based learning for knowledge, skills, and attitude. Each ANOVA investigated if any significant difference or gain ($p < 0.5$) existed between groups and was used to determine gain between dependent variables. In addition, statistical means on pre- and post-tests measured if the two groups were significantly different in their prior knowledge and skill. A comparison of the means and an ANOVA of the MSLQ survey score revealed no significant differences in attitude. The result of hypothesis #1 (knowledge), $F(19, 23) = 2.12$, $p = 0.24$, indicated no significant gain. The result of hypothesis #2 (skill), $F(1, 23) = 0.03$, $p = 0.85$, indicated no significant difference, and the result of hypothesis #3 (attitude), $F(21, 527) = 1.57$, $p = 0.50$, indicated no significant difference. Further studies were recommended using similar or other variables to determine if more benefits can be attributed to problem-based learning within the teaching of engineering graphics.

The Problem

Problem-based Learning and Engineering Graphics

The factors toward problem-based learning in engineering graphics were (a) cognitive, (b) motivational, and (c) functional. Cognitive research deals with comprehension and learning, and research on traditional learning indicates that rote learning may be effective in the short term for routine tasks and tests but is ineffective for deep understanding and retention of complex problem solving (Cognition and Technology Group at Vanderbilt [CTGV], 1992). Motivational reasons deal with incentives and attitudes and how students focus on the problem, issues, questions raised, and the teacher's assessment, nurturing, and support. It was found that attitudes are difficult to gauge, but, if measured with care, they indicate that specific support can create a more positive attitude toward a given issue than when not supported. Lambros (2000) points out that PBL goes beyond this, with group dynamic elements as a social and intrapersonal side to learning. Although attitude studies are often associated with change and like or dislike, Lambros indicated that many traditional education students move up through an academic climate of competition where success is grounded in how clearly they set themselves apart from the rest of the group and where students' attitudes and their motivational conditions of acceptance and self-awareness are often focused on themselves rather than on others in a team. Functional research looks at how closely the problem is aligned to a students needs, and if it simulates a real-world concept, and that it helps prepare students toward technology, communication, and presentation skills arising out of the problem.

In the application of this to engineering graphics, comprehension, and learning can be achieved by connecting problem-based learning via graphical problem solving using visualization and other techniques. To illustrate a graphics study for example, we can create visuals as sketches, drawings, concept ideas, charts, diagrams, clusters, or chunks of information so space in short-term memory does not impede a problem-solving process. Cognitive psychologists agree that, for information to be retained in long-term memory, learners must construct a memory link between the new information and some inert-related information already stored in long-term memory (Gagné, 1985). For example, sketching and drawing 2-D and 3-D visual images adds short-term ideas to our long-term memory to produce new internal memory visualization.

Nevertheless, to apply this concept to engineering graphics, we can connect the visualization process to the flow of ideas as ideation, communication, and documentation and produce two-dimensional sketches of a three-dimensional model to eventually produce working, final assembly or toleranced drawings. An engineering graphics PBL question for example, might connect ideation and communication to a scenario where a single rough dimensioned pictorial sketch is provided. The initial question could prompt for an explanation of the pictorial and its use in graphics and how students might sketch new views to show the parts in more detail to an engineer supervisor, including what and where dimensions would be placed, and to what engineering standards, and what geometry would be needed to sketch the parts? The final part of the PBL question could then move into prompting for the rough visual steps to model the part in CAD. Team members could swap a response with other groups, who would create the parts in CAD as a visualization check and present it to the class.

An alternative PBL scenario is to produce and modify real parts using Vernier calipers and engineering sketch pads; in the process small teams reverse-engineer dissimilar assemblies into a series of ANSI-dimensioned sketches complete with modifications. In turn the parts can be shared throughout the collaborated teams according to complexity then individually produced in the parametric modeler, before being assembled and checked for interference. Some parts can then be sent to a three-dimensional prototyping printer as a 3-D model, which as part of the PBL solution, can demonstrate the technology learned and help to communicate the process into a final presentation model as students present their solution.

Research Focus

The major research focus for this study was: Does the use of problem-based learning have any effect on knowledge, skills, and attitude when compared to students enrolled in traditional engineering graphics courses? Significant research questions were

1. Will there be a significant gain in knowledge scores between the traditional lecture group and problem-based learning group?
2. Is there a significant difference in CAD skill performance scores between the traditional lecture group and problem-based learning group?
3. Will there be a significant difference in attitude scores between the traditional lecture group and problem-based learning group?

The study was a quasi-experimental design (see Table 1) using statistics to explore gain among variables (Campbell & Stanley, 1969). Pedagogical strategy was the independent variable treatment. The dependent variables were (a) knowledge pre- and post-test to compare knowledge gain; (b) CAD skill, a comparison of a CAD lab test; and (c) MSLQ attitude survey. Table 1 shows the quasi-experimental research design.

Table 1
Quasi-experimental Research Design

Group	Pre-test	Treatment	Post-test
Treatment	O_1	X	O_2, O_3, O_4
Control	O_1	--	O_2, O_3, O_4

Note. O_1 = knowledge pre-test, week 1. X = problem-based learning treatment, week 1 through 10. O_2 = knowledge post-test, week 10. O_3 = CAD skill evaluation (timed), week 11. O_4 = MSLQ attitude survey, week 12.

Control Group and Treatment Group Difference Summary

The syllabus for the engineering graphics course, tools, resources, and activity worksheets between the control and treatment groups started out as similar, yet what made the 12-week treatment different in this study was the PBL pedagogy and teacher facilitation. Explicitly what made the pedagogy different was the PBL treatment and instructor facilitation process (as shown in Table 2).

Table 2
Control and Treatment Group Pedagogy

Control	Treatment
Research consent form	Research consent form
Graphic pre-test	Graphic pre-test
Demographic survey	Demographic survey
GC 211 syllabus	GC 120 syllabus
PowerPoint or web-based lectures[a]	--
Individual sketching exercises[a]	20 PBL group & individual exercises[a]
Furniture design project[a]	Vernier reverse engineering problems[a]
No group interaction[a]	Group interaction[a]
Individual reading[a]	PBL group & individual reading[a]
Individual homework	PBL & individual homework[a]
CAD tutorials	CAD tutorials
Class web page	Class web page
--	PBL group work outside of class[a]
Mid-term quiz	Mid-term quiz
Graphics post-test	Graphics post-test
CAD skills test	CAD skills test
Post-MSLQ survey	Post-MSLQ survey
Individual CAD projects	Individual CAD project w/assembly[a]
100-question final exam	100-question final exam

[a] Indicates pedagogical differences.

PBL classroom work was crucial to this study, and the PBL treatment group used both paper-and-pencil exercises to follow the PBL graphics and live group student–to–teacher interaction and student–to–student interaction. The PBL group & individual exercises followed the syllabus and was broken down into 10 units (as shown in Table 3)

Table 3
Project and Problem-based Learning Activity Design Summary

#	Unit type from syllabus	Task time (week)	Graphics format
1	Engineering & Metric Instruments	1	Hand sketching
2	Applying Engineering Geometry	1	CAD/hand-sketching
3	Engineering Standards/Multiviews/Geo.	1	CAD/ hand-drawing
4	Lines/Drawings with Geometry	1	CAD/ hand-drawing
5	Missing views - Eng. Drawings w/Geo.	1	CAD/ hand-sketching
6	Engineering Practice – Metal Lab Tour	1	Written paper
7	Projecting Engineering Dimensions	1	CAD/ hand-drawing
8	Projecting Engineering Sections	1	CAD/ hand-sketching
9	Projecting Auxiliary Projections	1	CAD/ hand-drawing
10	Engineering Project & Assembly	3	CAD/ hand-drawing

Probing PBL Questions and Differences in Pedagogical Activities and Materials

Due to the standard syllabus, the control group and the treatment group had to use similar activities such as, sketching, orthographic projection, CAD, geometry, sectioning, dimensioning, etc. A few examples of the many differences between pedagogical activities and PBL material sheets is shown next.

Sketching In the first instance, both the control and treatment groups used sketching, but in different formats. The control group used sketching exercises from the textbook, whereas the treatment group used questioned scenario sketching (LeMaster, & Matthews, 1996) which is partially shown in

Figure 1, and shows a part graphic from an orthographic sketching activity for the PBL treatment group. To this end, a variety of PBL sketching scenarios were used, and included probing PBL treatment questions such as: What are the names of each of the views shown on this sketch sheet? What is line weight? What is the difference between a centerline and a center mark? Why is this line thicker on the outside of this sketch, and what is the difference between these lines? In turn, these questions led the PBL facilitator to then ask: What is the alphabet of lines? Why do we layout drawings using multiviews? What is a multiview? Can you sketch a correct profile in the correct multiview location? As a further sketching option prior to CAD work, students would also be asked to sketch and visualize the steps on grid paper before putting them into the CAD system?

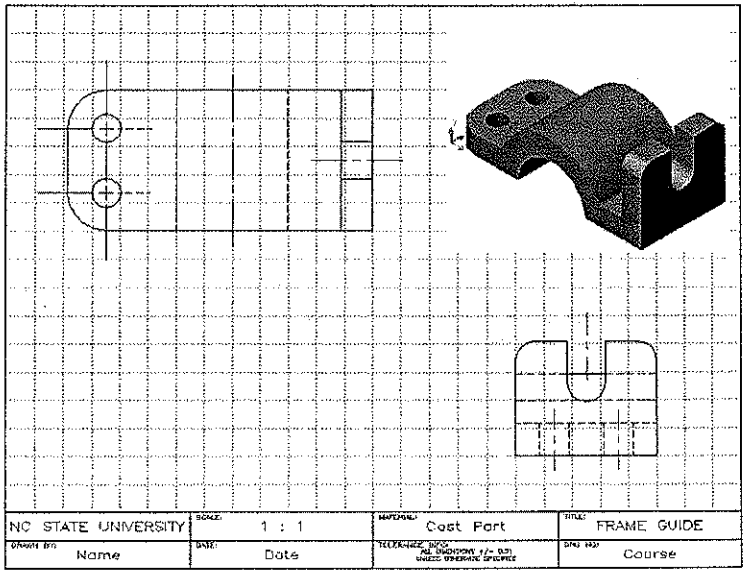

Figure 1. A treatment group orthographic sketching example.

Nevertheless, sketching for the control group on the other hand did not use probing questions or a facilitation format. After a lecture by the instructor, the control group used sketching examples from the class text as listed on the class web site. Two control group sketching examples are shown in Figure 2. The class web site simply instructed students to create two pictorial sketches of each of the following objects in their sketchbooks:

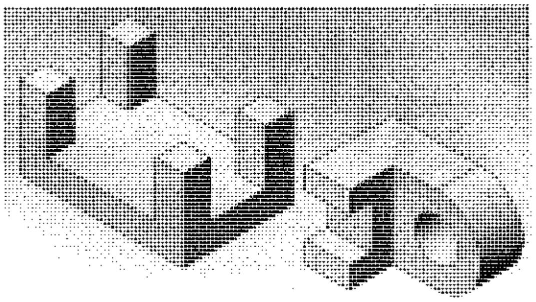

Figure 2. Two examples from a control group pictorial sketching exercise.

Geometry and CAD The control and treatment groups also used geometry throughout the study. The control group used 2-D sketching and 2-D CAD geometry exercises. The purpose was to learn how 2-D geometry is closely connected to CAD as an electronic drawing tool. The class would sketch the geometry, list the relationships, then create the part in CAD. The class web site instructed students to sketch the Rod Guide and identify the geometric relationships present. The CAD geometry sketching example for the control group is shown in Figure 3.

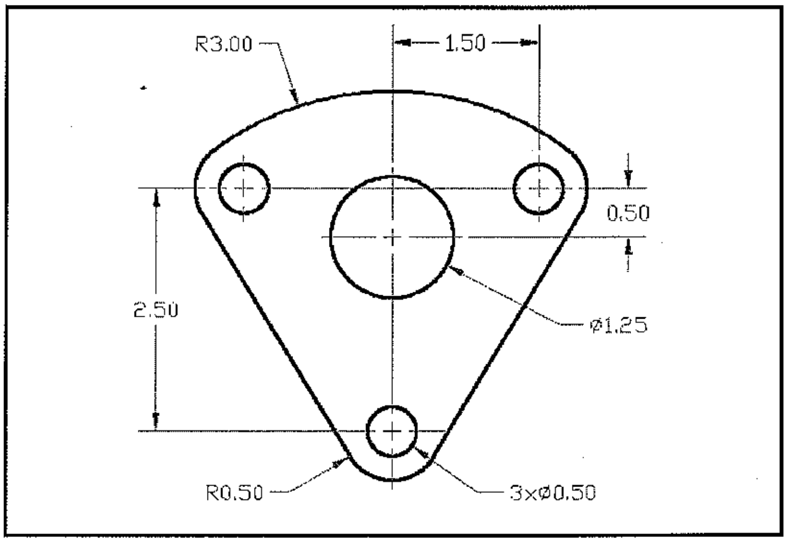

Figure 3. A control group 2-D CAD geometry exercise.

Nevertheless, in the treatment group, to learn how 2-D and 3-D geometry, sketching, and measurement are interconnected with engineering and CAD, the treatment group used reverse engineering of a C-clamp and other geometric activities, as shown in Figures 4 and 5.

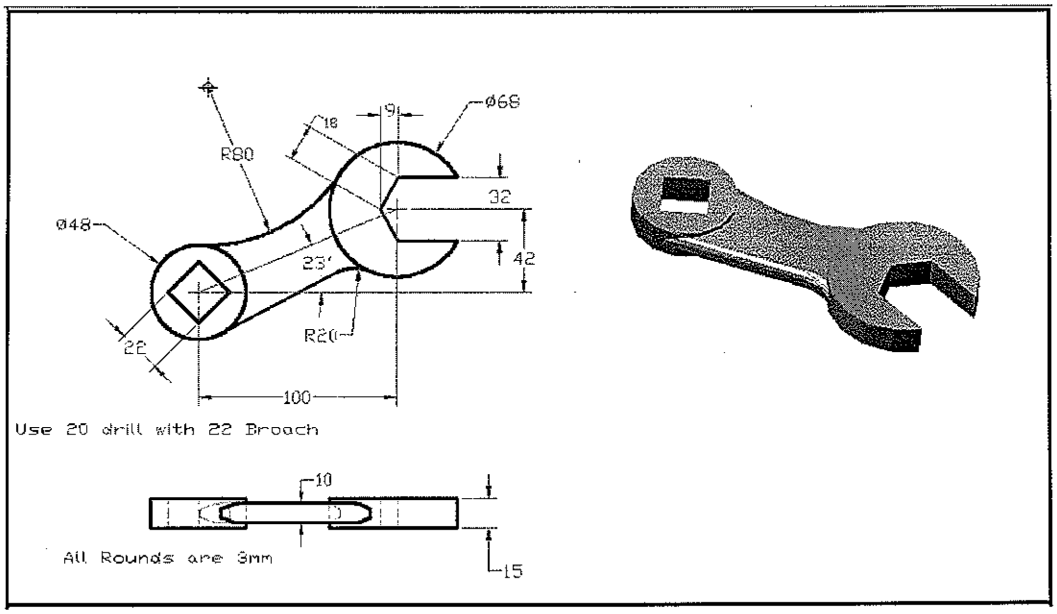

Figure 4. Treatment group 2-D and 3-D CAD geometry problem.

Figures 4 and 5 show treatment-group graphics. PBL treatment group questions to subjects for these examples included: Are all the profiles of each view correct? Can you sketch and describe how you would create the part in CAD? Do the views show correct centerlines and center marks to ANSI standard? What is the difference between a centerline and a center mark? Is the line weight correct for each of the views? What is line weight? Are the hidden lines correct? What is a fillet? Do the profile views show the correct hidden lines to ANSI standard? Are all views needed to show the part—are any views redundant?

These questions led the PBL facilitator to further ask: Why would we use a fillet or round in the design of the part? How does a fillet or round affect the design and strength of the material? If the part is a casting, what would happen if it was cast without fillets or rounds? Why do we apply tolerances between parts, and where would we find or place tolerance references in the text? Figure 5 shows part of a case study where treatment students would start with a paper drawing, which would be sketched in millimeters, then produced in CAD. This drawing would also be used to introduce correct multiviews, dimensioning, and the use of hidden lines, centerlines, and center marks, as used within CAD documentation.

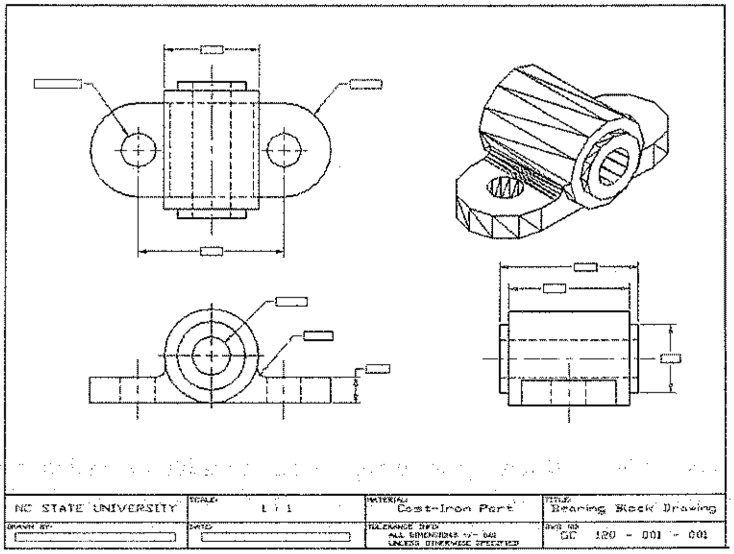

Figure 5. Treatment group 2-D and 3-D CAD geometry and ANSI problem.

The control group on the other hand used a different technique and different models, such as the Bearing Block and Tool Holder. The Bearing Block for the control group is shown in Figure 6. The class web site instructed students to work on modeling procedures of the tool holder and the bearing block.

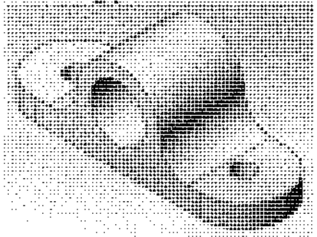

Figure 6. Control group bearing block for 2-D and 3-D CAD geometry.

Sectioning Other control group drawings included a section of the Tailstock. For the control group this Tailstock exercise was created as a preformatted step-by-step tutorial; the completed drawing of which is shown in Figure 7.

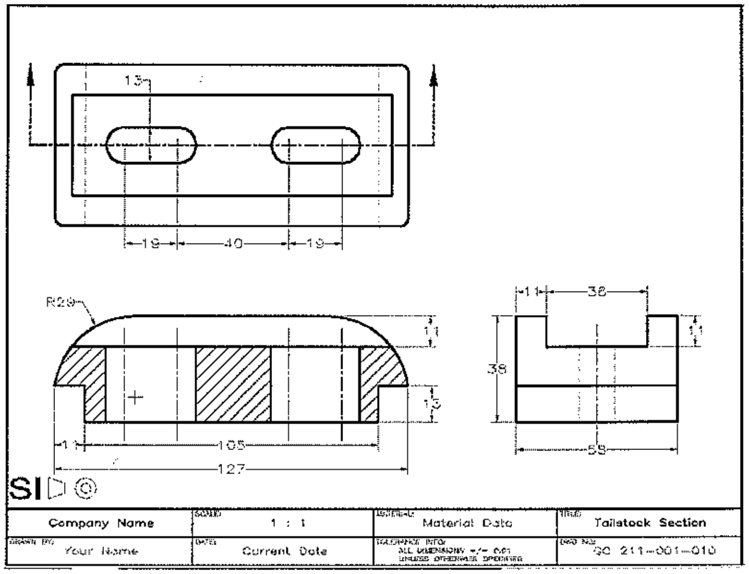

Figure 7. Control group Tailstock drawing to create a full section.

Whereas, to create sections in the treatment group, subjects used multiple case study sheets. The section sheets were also used for dimensioning, multiviews, object lines, hidden lines, centerlines, and center marks. One such example was the full-section view of the Bearing drawing as shown in Figure 8. Case problem parameters attached to this drawing included:

1. Produce a full section of the drawing.
2. Place dimensions on the detail drawing.
3. Place counterbore dimensions on the simple part.
4. Are any of the views shown below redundant. If so, why and which one?

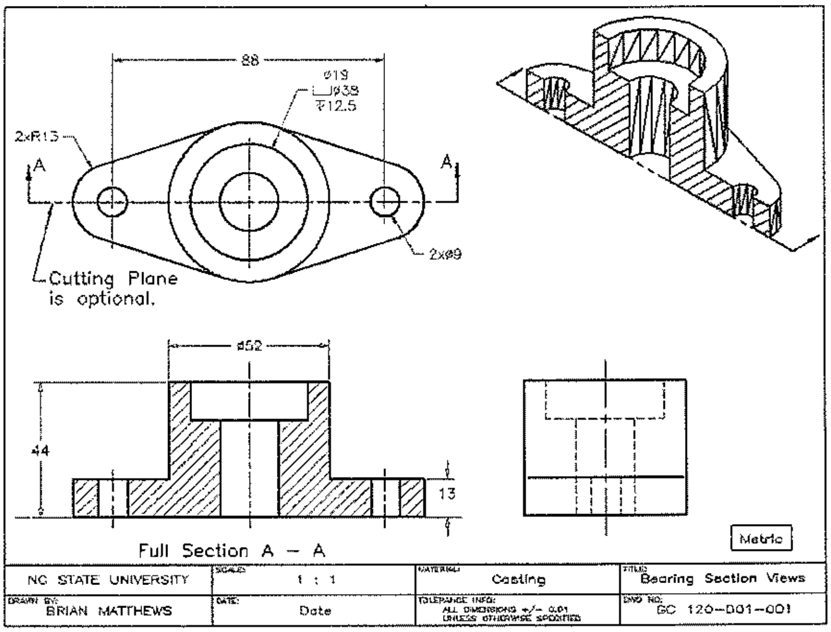

Figure 8. Treatment group full section of Bearing drawing.

Graphic Instrumentation and Treatment and Control Analysis Design

The various instruments compared knowledge, skills, and attitudes, comprising pre- and post-knowledge tests, timed CAD skill evaluations, and an attitude survey. Simple graphic instruments were used to determine knowledge, as both pre- and post-tests were graphic tests that included missing views of a single engineering object. The CAD instrument was an in-class modeling exercise, as outlined in the syllabus, and the attitude instrument was the MSLQ survey, (Matthews, 2004).

To make the control exercises consistent and unbiased to departmental graphic and academic standards, the paper exercises were also reviewed by a minimum of two other faculty in the department. To confirm or reject hypothesis #1, the pre-test and post-test scores were designed from the equations shown below and in Table 4.

(H1a) Gain score of treatment group to gain score of control group
$[(O_2T - O_1T) - (O_2C - O_1C)]$.

(H1b) Pre-test score of treatment group to pre-test score of control group $(O_1T - O_1C)$.

Table 4
Treatment and Control Analysis Design

Quasi-experiment	Pre-test	Treatment	Post-test
Treatment Group	O_1T	X	$O_2T,\ O_3T,\ O_4T$
Control Group	O_1C	–	$O_2C,\ O_3C,\ O_4C$

The attitude score was obtained using the 31-item MSLQ survey, administered in the 12th week, to measure student attitude, with the subjects responding to scales from the learning questionnaire. The MSLQ is a 7-point (1 = *totally disagree* to 7 = *totally agree*) Likert-type self-report questionnaire designed to measure students' motivation and use of learning strategies. The researcher selected intrinsic goal orientation, extrinsic goal orientation, task value, and self-efficacy to serve as indicators of student motivation (Pintrich, Smith, Garcia, & McKeachie, 1993).

Analysis of Research Questions and Hypotheses

Out of a possible score of 100 for the control and treatment groups, the initial range of pre-test raw data varied from 35 to 99 and from 0 to 90, and the range of post-test raw data varied from 10 to 98 and from 50 to 100 respectively. For hypothesis #1a, the ANOVA scores were compared as gain score for the treatment group to the gain score of the control group.

Mean scores for the control and treatment groups were also compared. The means of the scores for the control group pre- and post-tests indicated a gain in learning from pre-test to post-test. The means of the scores for the treatment group pre- and post-tests also indicated a gain score in learning from the pre-test to post-test. Table 5 displays mean and standard deviation scores for the pre- to post-tests for the control and treatment groups.

Table 5
Comparisons of Pre- to Post-Test Mean Scores by Group

Knowledge achievement scores	N	M	SD
Control group pre-test	24	51.95	23.32
Control group post-test	24	58.75	15.19
Treatment group pre-test	24	54.08	22.20
Treatment group post-test	24	69.45	15.36

Note. N = 48. Highest possible score = 100.

To measure hypothesis #1a as a dependent variable, the gain score of the treatment group was compared to the gain score of the control group and analyzed by an ANOVA. The measure was a direct comparison of the treatment group gain score to the control group gain score. The research hypothesis indicated there would be no significant difference in knowledge gain between groups. The ANOVA findings, $F(19, 23) = 2.12$, $p = 0.24$, supported the null hypothesis that there would be no significant difference in knowledge gain between the response scores of the traditional lecture (control) group and the problem-based learning (treatment) group. Table 6 illustrates the ANOVA results of these gain score analyses.

Table 6
ANOVA of Knowledge Gain Score

Knowledge achievement scores	SS	df	MS	F	p
Treatment group to control group					
Between groups	7406.00	19	389.78	2.12	0.24
Within groups	729.33	4	182.33		
Total	8135.33	23			

The results showed no significant difference between the control and treatment groups in knowledge gain between the response scores of the traditional lecture (control) group and the PBL (treatment) group. Consequently, the researcher failed to reject the hypothesis.

Hypothesis #1b—Pre-test to Pre-test

To test for equality of prior knowledge between groups, hypothesis #1b as a dependent variable compared the pre-test score of the treatment group to the pre-test score of the control group. Table 7 lists the comparable means of these pre-test scores.

Table 7
Comparison of Knowledge Achievement Scores for Pre-tests by Group

Knowledge achievement scores	n	M	SD
Pre-test to control group	24	52.25	23.55
Pre-test to treatment group	24	54.33	22.39

Note. N = 48. Highest possible score = 100.

For hypothesis #1b, an ANOVA was used to compare the treatment pre-test score to the control group pre-test score. The result, F(17, 23) = 3.32, p = 0.07, indicated no significant difference between the treatment group and the control group. Table 8 shows the ANOVA result, which supported null hypothesis #1b, that the pre-test score of the treatment group when compared to the pre-test score of control group would have no significant difference in knowledge gain between the response scores.

Table 8
ANOVA Results for Pre-tests

Knowledge achievement scores	SS	Df	MS	F	p
Treatment pre-test to control pre-test					
Between groups	10431.83	17	613.73	3.32	0.07
Within groups	1107.50	6	184.58		
Total	11539.33	23			

$p < 0.05$.

Null Hypothesis #2—Skill Performance

Hypothesis #2 stated that with the control and treatment groups there would be no significant difference in CAD skill performance scores between the traditional lecture group and the problem-based learning group. Hypothesis #2, as a measurable dependent variable, compared the timed CAD skill scores of the control group to the treatment group.

Table 9 shows the comparison of CAD skill scores in which subjects created a CAD drawing under laboratory conditions and presents the mean and standard deviation values between groups.

Table 9
Comparison of CAD Skill Scores by Group

CAD skill performance scores	n	M	SD

Control group	24	93.04	8.38
Treatment group	24	91.58	3.23

Note. N = 48. Highest possible score = 100.

To determine skill performance for the control and treatment groups, an ANOVA was also used to analyze differences between the two groups. The hypothesis stated that there would be no significant difference in CAD skill between group performance scores of the control and treatment (problem-based learning) groups. The ANOVA results are listed in Table 10.

Table 10
Analysis of Variance for CAD Skill Scores

Skill performance scores	SS	df	MS	F	p
CAD score					
Control group	0.37	1	0.38	0.03	0.85
Treatment group	239.45	22	10.88		
Total (n - 1)	239.83	23			

$p < 0.05$.

Results of the ANOVA for group skill performance scores, F(1, 23) = 0.03, p = 0.85, indicated that for CAD skill, where the subjects created a CAD drawing under laboratory conditions, there was no significant difference in skill performance scores between groups. ANOVA results for group skill performance, as a measurable dependent variable, indicated no significant difference in skill performance scores between groups. Consequently, the researcher failed to reject the null hypothesis, that with the treatment and the control groups there would be any significant difference in skill response scores between the control group and the treatment group.

Null Hypothesis #3—Group Attitude

The variations between the MSLQ subscales 1, 2, 3, and 5 used to test subject attitude in the study are explained in this section (subscales 4 and 6 were not used). Subscale summaries and results for each of the subscale analyses are presented in Tables 11 and 12. Table 11 lists the means and standard deviations of the scores for subscales 1, 2, 3, and 5 used in the MSLQ, and Table 12 summarizes the ANOVA results. Hypothesis #3, as a measurable dependent variable for group attitude was based on the short version of the MSLQ and its subscales. The subscales used were intrinsic goal, extrinsic goal, task value, and self-efficacy. Hypothesis #3 stated that for the treatment and control groups there would be no significant difference in attitude scores between the control and the treatment groups. To analyze attitude data with the treatment and control groups, an ANOVA was used between the two groups. Specifically, the subscales in the MSLQ survey were listed as (a) intrinsic goal, (b) extrinsic goal, (c) task value, and (d) self-efficacy. All question values were grouped into summary tables (see Tables 11 and 12) in order to support or reject findings for null hypothesis #3.

Table 11
Comparison of Scores for MSLQ Subscales by Group

Subscale	n	M	SD
Value component: Intrinsic goal orientation			
Control group	24	4.74	1.49
Treatment group	24	4.97	1.59
Value component: Extrinsic goal orientation			
Control group	24	4.86	1.86
Treatment group	24	4.93	1.65
Task value component			
Control group	24	5.34	1.33

Treatment group	24	5.19	1.58
Self-efficacy–Learning performance			
Control group	24	5.64	1.22
Treatment group	24	5.23	1.29
Overall MSLQ summary (1, 2, 3, and 5)			
Subscale: control group	24	5.18	1.52
Subscale: treatment group	24	5.07	1.54
Total MSLQ: control group	24	5.09	1.61
Total MSLQ: treatment group	24	4.97	1.65

Note. N = 48.

Table 12
Overall and Subscale ANOVA Analyses for the MSLQ

MSLQ subscales	SS	df	MS	F	p
Intrinsic goal (1)					
Between groups	18.11	3	6.04	2.49	0.06
Within groups	222.79	92	2.42		
Total (n - 1)	240.90	95			
Extrinsic goal (2)					
Between groups	6.11	3	2.04	0.95	0.42
Within groups	196.37	92	2.13		
Total (n - 1)	202.90	95			
Task value (3)					
Between groups	6.97	5	1.39	0.54	0.74
Within groups	353.58	138	2.56		
Total (n - 1)	360.55	143			
Self efficacy (5)					
Between groups	25.74	7	3.68	2.29	0.03*
Within groups	294.71	184	1.60		
Total (n - 1)	320.45	191			
Overall summary: MSLQ					
Between groups	73.02	21	3.48	1.57	0.05
Within groups	1116.45	506	2.21		
Total (n - 1)	1189.48	527			

*$p < 0.05$.

Summary

Research indicates that active-learning and small-group teaching, both significant features of PBL, are two deeply interrelated concepts, (Albanese, & Mitchell, 1993). They represent two different types of theories. Activeness is one theory about how we learn, which in effect is a learning theory. Small-group teaching, a pedogogical theory, relates to how we can encourage and support learning in others, (LeMaster, & Matthews, 1996). To this end, this study used the independent variable of pedagogical strategy to measure traditional lectures and compared it to problem-based learning in engineering graphics. Research also indicates that both industry and government reports suggest broad changes in the engineering curriculum to include problem-solving, active-learning, and visualization techniques, (Matthews, 2004). They also invite engineering education to include the foundation of successful practice, effective teaching, and relevant research in engineering design. Problem-based learning connects visualization to engineering graphics by associating problem solving with visualization in a number of ways. It allows us to process and retain form to creative ideas during problem solving and to connect two-dimensional spatial concepts to three-dimensional solutions. Henderson and Jordan (1995) argued there is a self-evident skill or link in visual cognition with engineering culture and technology. From conception to production, we see engineering documents intrinsically linked to visual thinking. Until recently, engineering graphics still operated in a 2-D environment, where machinists translated 2-D drawings into 3-D form, which resulted in problems in production, assembly, sales, and marketing, and where part of the team often had difficulty with the product and 2-D drawings. Part of this articulation can be rectified by the changes that engineering graphics is undergoing as 3-D solid modeling, problem solving, and visualization in both the industrial and educational environments. The key for combining some of these suggestions may be through problem-based learning in engineering.

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Color Preferences in Web Design

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Abstract

This study analyzed and documented color preferences on the Internet by an online survey from a sample population of male and female students in the age of 18 to 24. In addition to the survey data, available resource materials were researched and reported on concerning information in Internet color preferences, color calibration of monitors for color preference testing, the use of color space for the Internet, and existing research on color science and color conception thinking. This information was compiled and cross-referenced with the data found in the survey of the sample population, to verify if there was any comparable color preferences in data obtained and those previously observed, or are there different color preferences on the Internet?

Introduction

Hume and Reid, (1997) identified the Internet as one of the fastest growing technologies in the United States. The quantity of companies, teaching institutions and individuals accessing the Internet has grown daily. Beyond academic uses, many web sites are developed and designed to lure the consumer or web surfer into his or her domain (Freeman, 1996). Billions of dollars have been invested in developing the technology associated with the Internet (Anderson, Chandrasekar, Motta & Stokes, 1996). Consumers have purchased the computer hardware required for getting online at a rate that surpasses the purchases of color television (Hume & Reid, 1997). Companies and advertisers on the Internet have designed and distributed numerous online web sites for this new communications tool. For these web developers, it may be important to understand what variables determine how individuals utilize the Internet and what are some of their preferences. One of these variables may be determined through a preference of color usage in the web page design.

Purpose of Study

This study explored color preferences and variables associated with color theory principles from existing research. The purpose of this study was to determine if there are preferences for color usage in Internet web page design. The study included persons of various ages and backgrounds to determine if there do exist color preferences within those groups and if those preferences were identical to traditional color theory. A web page color survey was designed and distributed among a convenient sample and information was obtained.

Problem Statement

Research on color issues, usage and perceptions has been documented in numerous studies. There has been an abundance of scholarly literature and psychological studies produced on color and color association. Studies of color theory and the psychology of color have taken on two different assumptions. One direction deals with the standardization of color preferences through the result of mass testing. The other direction for study involves the individual's association with color. Both types of research involved sampling, observation and documentation (Sidelinger, 1985).

Electronic media, like the Internet, use image display monitors to produce colorimetric color-space, the area of color display, by combinating red, blue and green (RGB) outputs (Cowan, Jolicoeur, & Olds, 1999).

The problem of color management on the Internet has been broad and debatable. There is a growing need for consensus on some sort of Internet standardization in the industry.

Resources and time have driven the Internet industry in the pursuit of standardization of RGB color-space and the calibration of equipment for color usage on the Internet (Anderson, Chandrasekar, Motta, & Stokes, 1996). Color on the Internet and how we perceive that color will depend on the quality of the equipment and if the color is calibrated properly (Cowan, Jolicoeur, & Olds, 1999). The ability to standardize color on the Internet has yet to be accomplished.

Purpose Statement

There is an abundance of information about the psychology of color preferences, the physical properties and science of color and how we see color, and research into the calibration of color imaging equipment as we would see color on the Internet. Preliminary research on available information about color preferences and web design has located a minimal body of knowledge on underlying color preferences and web page displays. Presently research on color and the Internet have primarily concerned itself with management of color calibration, and there has yet to be any standardization of color space. The purpose of this study is to deliver a survey of a conventional sample population and determine from the results if there are any color preferences for web design on the Internet and compare this research to existing and collaborating research on color preferences.

Research questions

With so many resources of new technology, some fundamental questions about web design may be taken for granted by web site developers.

1. Beyond what is already known of the principles of the science of color and color preferences, are there any additional differences in our color preferences on how that color is displayed than from traditional print media and the psychology of color preference.
2. Are there any identifiable preferences of color in web page design on the Internet, and can those preferences be documented?
3. For the graphic designer, web page designer, or a marketing professional of small businesses or large corporations, the insight to color preferences by segments of population may prove beneficial. Does traditional color usage in print media and related color preferences transfer to web page design?
4. It is probable that within certain populations, that there exists possible preferable color usage and combinations. Without the standardization of color-space on the Internet and monitor calibration will it be possible to find trends in color preference on web pages and document those results?

Significance of study

It is probable that within certain populations, that there exists possible preferable color usage and color combinations. If it is possible to determine if there are detectable color preferences in web design, the web developers would be able to apply this knowledge to the design of websites.

Limitations

The information about color preferences determined from this study was limited to college students both males and females.

Delimitations

For this research persons participating in the online questionnaire utilized any available equipment that will access the Internet. The researcher suspected that inconsistencies in monitor color calibration and non-standardized color-space on the Internet, may have made it difficult to ascertain any specific color preferences. Because of this limitation, the questionnaire is designed to ask participant's opinions of color usage versus a selection of online color samples.

A secondary delimitation is that this online survey can only be viewed and accessed by Internet Explorer.

Results from Research

An online survey was available to all persons on the World Wide Web at [**blueboyzpage.tripod.com (2001)**]. This online survey was created in Microsoft's Frontpage software because of the program's ability to create an active server page that could create a questionnaire with the function of collecting data and transmitting that data via email to a Hotmail account, (blueboyzpage@hotmail.com 2001). A total of 120 emails were received from participants in the online survey. Of the 120 emails received, 99 emails were found to be viable. The 21 surveys received that were unusable were either only partially filled out or the data was not sufficiently transmitted.

A preliminary study of all those who submitted color preferences found that the top three preference combinations of background and font color were:

1. 33% preferred white background with black text
2. 13% preferred black background with white text
3. 9% preferred white background with blue text

A second sample was drawn from the population of students from primarily the Graphic Arts and Imaging Technology program in the Department of Technology at a university on the Southeastern United States. From the total 99 usable emailed results, 69 were identified as students, with 36 being male and 33 being female. As a total group of students, the top three preferences were identified, and statistically were the same as the total group:

1. 33% preferred white background with black text
2. 13% preferred black background with white text
3. 9% preferred white background with blue text

Within the sample of students of 36 males and 33 females the top six (6) preferences were identified as:

Female Students

1. 26% preferred white background with black text
2. 23% preferred white background with blue text
3. 9% preferred black background with white text
4. 9% preferred yellow background with white text
5. 6% preferred blue background with white text
6. 6% preferred black background with blue text

Male Students

1. 31% preferred white background with black text
2. 15% preferred black background with white text
3. 14% preferred blue background with white text
4. 11% preferred white background with white text
5. 5% preferred black background with blue text
6. 3% preferred white background with blue text

Other Findings

The additional results from the sample of students, beyond the questions of color preferences are:

1. Age Range of Students

83%	18-24
10%	25-30
6%	31-40
1%	41+

2. How they use the Internet

44%	Information Gathering
30%	Entertainment
16%	Communications Tool
6%	Educational

4%	Other

3. Hours online per day

35%	1 to 2 hours
32%	15 minutes to 2 hours
28%	3 to 5 hours
3%	10 hours or more
1%	6 to 10 hours
1%	other

4. From where they go online

57%	Home (dorm)
38%	School
4%	Other
1%	Work

5. Platform Preference

70%	PC
30%	Macintosh

6. Browser Preference

74%	Internet Explorer
22%	Netscape
3%	Other
1%	None

7. Use of Pictures as Background

61%	Yes
39%	No

8. Use of Animation

94%	Yes
6%	No

When the survey asked for what was considered their best preference in web design (In your opinion of the following aspects of Web page construction, which has the highest significance to its appearance?), the survey offered the following suggestions: Use of frames, Non use of frames, Color combinations, Use of readable text, Use of pictures, Time it takes to load, Ease of navigation, and Other (Where they were able to type in a different preference.) The results of this question were:

22%	Use of pictures
20%	Ease of navigation
16%	Readable text
16%	Time it takes to load
13%	Use of frames
12%	Color combinations
1%	Other

When the survey asked for what was considered their least preference in web design (In your opinion of the following aspects of Web page construction, which has the lowest significance to its appearance?), the survey offered the following suggestions: Use of frames, Non use of frames, Color combinations, Use of readable text, Use of pictures, Time it takes to load, Ease of navigation, and Other (Where they were able to type in a different preference.) The results of this question were:

74%	Use/Non-use of frames
13%	Color combinations
6%	Use of pictures
4%	Time to load
3%	Ease of navigation

Conclusions

The results show that regardless of gender within the group, that persons prefer web pages with lighter backgrounds and darker text. They use the Internet for information gathering, entertainment, and as a communications tool. This group goes online from 15 minutes to 2 hours a day and goes online at home and school. Within this group, the preferred platform is a PC and the preferred online browser is Internet Explorer. This group also likes to see pictures as a background or used in the background. This group almost unanimously likes animation in web design. This group is split on preferences of highest significances as to the use of pictures, ease of navigation, readable text, aud time it takes to load, yet this group almost unanimously agrees as a group and gives low significance to the use of frames and don't agree as a group in nonuse of frames.

Concurring Studies

One study by Whattananarong (1991), University of North Texas, presented a cross-cultural study of color preferences on a computer screen between Thai and American students. The color combination most preferred by the students was white text on a blue background.

In a similar research project by Dolsky (1993) of the University of Alberta, Canada, for the purpose of examining adult (persons of 20 years or older) preferences for combinations of four colors presented on a color display using a gray background, the most popular combination of colors was blue, red, purple and black; and the least popular from the sample was yellow, green, orange and red.

In an additional study by Chen (1998), on color and human-computer interaction, the researcher investigated the role of color preference in computer-user performance. Nearly 50% preferred personalized colored screens, and 35% preferred a combination of personalized and recommendations by the color assistant, and 85% were willing to interact with the color assistant prior to customizing their screens. The results of the experiment concluded that those participants who customized their screens, either with or without consultation, out performed those using screens composed of random colors (Chen, 1998).

Recommendations

Studies by Chen (1998), Dolsky (1993), and Whattananarong (1991), on human color preferences and computer displays have recommended that additional research should be conducted before color standards can be created.

Summary

The predominate research of color preferences has dealt with human preferences as they relate to psychological and physiological studies conducted through print and projected color media. A majority of the research for color preferences has been conducted for printed applications. Research into the areas of color and the way we perceive color by the means of the TV and computer screen may offer some new insights. Most of the studies that have been conducted in the area of color research and computer displays state that there is a significant lack of research and attention to the methods by which color is displayed. These same studies also reveal that there is a need for additional research in this area to determine if there are changes in color preferences over time and what factors determine those preferences. This area of research has many possibilities as to the depth of study and application of those results. Its benefits will provide a better understanding of how to make computer displays and the information presented more ergonomic and functional in relation to color use.

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