Research

In

Engineering and Technology Education

ncete™

NATIONAL CENTER FOR ENGINEERING AND TECHNOLOGY EDUCATION

This material is based on work supported by the National Science Foundation Under Grant No. ESI-0426421

Learning Effects and Attitudes of Design Strategies on High School Students

Robert Wicklein & John Mativo
University of Georgia
November 5, 2009
Final Report

Purpose/Background

The purpose of this research project was to use an experimental design research methodology to compare learning and attitudinal effects of two different design instructional strategies on randomly selected and assigned 11th and 12th grade students. Through the use of a common technological based problem (see Appendix A), students were guided through a design sequence that utilized two different instructional approaches (a) predictive analysis and (b) trial & error. At the completion of a five-day (15 hour) learning activity a standardized engineering design test was administered to the students to evaluate differences in engineering design capabilities. Additionally, students completed an attitude inventory related to their perceived confidence and belief in solving technological problems.

Goals

The following research questions were used to guide this study.

1. Is there a significant difference in engineering design learning ability for students who participated in a predictive analysis based engineering activity when compared with a trial and error based engineering activity?
2. Is there a significant difference in learning attitude for students who participated in a predictive analysis based engineering activity when compared with a trial and error based engineering activity?

Description of the Project

The following activities and actions took place during the development and research phases of this project:

1. Identification of School Partners – Fall 2008
2. Selection of Participants – Spring 2009
3. Random Assignment of Participants – Spring 2009
4. Selection of Instructional Topic and Preparation for Instructor Training – Fall 2008 & Spring 2009
5. Selection and Training of Instructors – Spring 2009
6. Preparation of Classroom and Laboratory Facilities – Spring 2009
7. Conducting of Research Experiment – June 15-19, 2009
8. Data Collection and Analysis – Summer/Fall 2009

Identification of School Partners. The target population for this research was 11th and 12th grade level from Oconee County High School in Watkinsville, Georgia.

Selection of Participants. A total of 40 high school students (11th and 12th graders) were randomly selected for this project. During April of 2009 a letter was distributed to all qualified 11th and 12th grade students from Oconee County High School inviting them to participate in a special program during the summer of 2009. Qualification of students were based on academic standing (GPA 2.5 or higher) and parent/guardian permission to participate in the study. A total of 43 students volunteered to participate in the study and appropriate permission forms were signed and returned.

Random Assignment of Participants. From the total pool of participants the students were randomly assigned to either the experimental group (predictive analysis group) or the control group (trial & error group). Each group had a total of 20 participants.

Selection of Instructional Topic and Preparation for Instructor Training. A specific topic of focus was selected for the instructional program. The topic was the design and development of a functional soda can crusher (see Appendix A) The topic of focus was designed to be completed in 5 days of 3 hours per day sessions.

Selection and Training of Instructors. Two technology education teachers were selected to participate in this study. Each teacher was a veteran of the classroom (5+ years of teaching experience at the high school level) and had prior knowledge of the design process. They underwent training in the objectives of the research study and training regarding the instructional topic and the instructional methodology that they would be using during the program of instruction (experimental group=predictive analysis and control group=trial & error). Teachers were supplied with all appropriate laboratory supplies and written materials needed for their instructional programs. Instructors were required to follow a strict instructional regiment that aligned with their assigned instructional methodology.

Preparation of Classroom and Laboratory Facilities. The research was conducted at Oconee County High School within the technology education classroom. Arrangement and organization of the classroom/laboratory facility were identical for both the experimental and control groups. Instructional materials were prepared by the research staff and supplied to the teachers.

Conducting the Instructional Programs. During the designated 5-day period in June 15-19, 2009 the instructional program was implemented. Instruction for the experimental group took place from 9:00am to 12:00pm and instruction for the control group took place from 1:00pm to 4:00pm. The selection of the two different times was done to prevent cross-talk among the student participants. At the completion of the instructional period all students were administered a standardized test (*Engineering Design Test*) that measures capability to understand and apply a comprehensive engineering design process. The *Engineering Design Test* (see Appendix B) has been in development for the past three years through a mini-grant of NCETE and is currently being tested and revised for validity and reliability. Additionally, an attitude inventory instrument (see Appendix C) was used to collect data regarding student attitudes regarding their confidence and belief in solving technological problems.

Data Collection and Analysis. Data was collected from the student participants at the completion of the 5-day program period (June 19, 2009). All data were quantitative and based on student responses on the *Engineering Design Test* and the *Attitude Inventory Assessment*. Collected data were entered into the SPSS statistical software and appropriate descriptive and non-parametric analysis procedures were conducted to compare the design methods (predictive analysis vs. trial & error analysis).

Findings

The findings from this research yielded a non-significant statistical difference in the in design group scores as measured by the *Engineering Design Test* (Table 1). However, the trial & error group scored approximately 3 points higher overall suggesting that there may be conflicting influences on what and how students acquired design knowledge during this instructional program.

Table 1
t-test for Engineering Design Test (n=40)

	M	*SD*	*df*	*t*	*p*
Predictive Analysis Group	20.65	4.48	38	-2.097	0.605
Trial & Error Group	23.30	3.43			

$p < 0.05$

Likewise, there was no-significant difference found between the participants in the design groups and their scores on their attitude related to Confidence in Solving Technological Problems (Table 2) and Belief in Solving Technological Problems (Table 3).

Table 2

t-test for Attitude of Confidence in Problem Solving (n=40)

	M	*SD*	*df*	*t*	*p*
Predictive Analysis Group	3.90	0.38	38	0.974	0.853
Trial & Error Group	3.77	0.42			

Table 3

t-test for Attitude of Belief in Problem Solving (n=40)

	M	*SD*	*df*	*t*	*p*
Predictive Analysis Group	3.58	0.39	38	1.781	1.0
Trial & Error Group	3.36	0.39			

Conclusion/Recommendations

The goal of this experimental research study was to help describe the effects of predictive analysis with respect to engineering design problems. However the findings from the research yielded less than desirable results. Several factors may have added to the neutral effects from the two different design strategies. First, the amount of time dedicated to the instruction program was very short and limited. A total of 15 hours was devoted to instruction with the final 3 hours used for testing and evaluation purposes. It would be very difficult for any educator to build a knowledge base for students regarding the skills and techniques utilized in mathematical predictions for solving technological problems in this limited amount of time. Further research is needed to provide opportunity for greater math skill development in order to evaluate the engineering design process effect on students. Second, the engineering design process should be integrated within normal learning experiences of students in order for students to have a more established understanding of solving technological problems by using this methodology. Without a formal preparation of the engineering design process which utilizes predictive analysis, students default to trails & error practices. Lastly, the limitations of the small numbers of student participants assigned to each group may have been a factor in the minimal differences between design methodologies. Further research needs to be done with larger numbers of students where random selection and assignment can be accomplished with samples from more complete populations.

Dissemination

The results from this study will be further refined and analyzed prior to presenting them in formal arenas. Application for presentation from this research has been submitted to CTTE and has been accepted for the 2010 ITEA conference in Charlotte, NC.

APPENDIX A

Can Crusher Design Challenge

SODA CAN CRUSHER CHALLENGE

You may be an environmentally conscious person. You have noticed that your family buys and drinks significant amounts of soda. Your family may prefer to buy soda in regular 16 oz. or 280 ml aluminum cans. Here are some interesting facts about aluminum: Huge earthmover vehicles extract bauxite from the earth. The bauxite is then mechanically crushed to separate it from impurities before being transported to a smelting plant where high energy is used to melt and extract aluminum. The aluminum is then sent to factories for stamping and extruding to create the can that soda is placed in. Assuming the energy spent in this manner to develop a soda can is 100%, recycling would use only 5% energy to develop the same can. Recycling aluminum cans makes a lot of sense because it saves valuable energy.

YOUR CHALLENGE:

To help improve the process for recycling aluminum soda cans you and your team are to design, construct, and test a wall mounted soda can crusher that will reduce a standard size and shape 16 fl. oz. soda can to one and one half inch (1 ½ ") in height. This reduction in height will aid in storing more cans in recycling bins and collection sites.

Design Specifications:

Design and product must address the following:

1. must be safe to operate
2. must be able to be operated with 5 lbs. of force
3. should be aesthetically pleasing
4. should be functional (reduce 16 fl. oz. aluminum can to 1 ½ inch in height)
5. should be reliable (be able to crush 10 cans in 2 minutes)
6. must fit within the following dimensions: 24" (height) X 6" (width) X 6" (depth)

Constraints/Limitations:

1. produced from teacher supplied materials
2. produced using available laboratory tools
3. produced within the allotted time limit

Evaluation of Assignment:

Evaluation Criteria	Points Value
Size Limitation of Product (24” X 6” X 6”)	5
Safe Operation of Product	10
Reliability/Durability of Product (10 can in 2 minutes)	15
Detailed Documentation of Design Process	20
Operation - Force Applied (5 lbs. force)	25
Functional Product (can reduced to 1 ½ ” height)	25
TOTAL	**100**

Materials List:

All products must be constructed from the following list of materials:

Material	Size	Quantity
Wood Screws	1 ½”	20
Wood Screws	1”	20
Board	2” X 4” X 45”	1
Board	1” X 6” X 3’	1
Plywood	¼” X 2’ X 4’	1
Dowel Rod	3/8” X 4’	1
Wood Glue	Capacity	Capacity
Thumb Tacks	Normal	5
Rubber Bands	¼” X 2”	4

Tool Use:

Tools used to construct the product must be done under the direct supervision of the instructor or research staff.

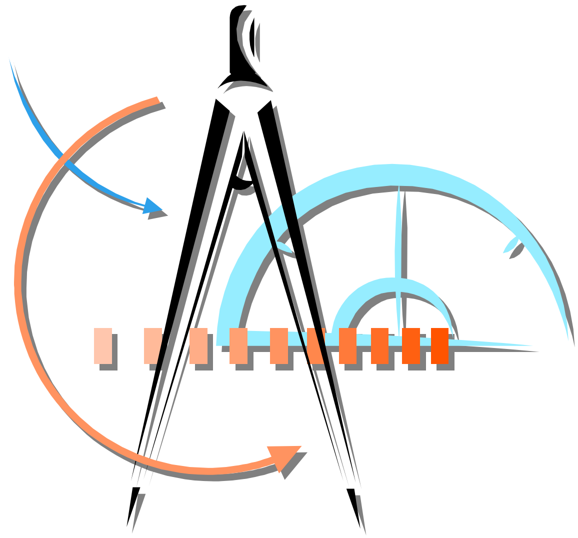
Evaluation Rubric

Evaluation Topic	Below Standard	At Standard	Above Standard	Specific Comments
Size Limitation of Product (24" X 6" X 6") 5 pts. Maximum	Product not completed	Product constructed within size limitations	Efficient utilization of materials to construct product	
Safe Operation of Product 10 pts. Maximum	Product functioned in an unsafe mode	Product functioned safely	Product functioned safely and efficiently	
Reliability/Durability of Product (10 cans in 2 minutes) 15 pts. Maximum	Product not able to perform required amount of processing within time period	Product able to process required amount of processing within time period	Product able to process required amount of processing prior to time period ending	
Detailed Documentation of Design Process 20 pts. Maximum	Use of engineering design notebook was inadequate and not complete	Use of engineering design notebook was adequate and complete	Use of engineering design notebook indicated superior understanding of documentation process	
Operation – Force Applied = 5 lbs. 25 pts. Maximum	Force needed to operate product exceeded 5 lbs. of force	Force needed to operate product was within operating force parameters (5 lbs. + 0.25 lbs. force)	Force needed to operate product was less than 5 lbs. force	
Functional Product (Can crushed to 1 ½ inch height) 25 pts. Maximum	Crushed can exceeded the 1 ½ inch height criteria	Crushed can was within the 1 ½ inch height criteria (1 ½ inch + 0.25 inches)	Crushed can was less than the 1 ½ inch height criteria	

APPENDIX B

Test of Engineering Design

Test of Engineering Design



The test consists of three problem sets that are focused on different components of the engineering design process. Each set contains a series of questions associated with the scenario that is proposed.

The questions are presented as multiple-choice options. There is only one correct or best response for each question. Indicate your answer choice by checking "√" the box next to the option you believe is correct. Scores will not be corrected for guessing.

Please answer each of the 36 questions presented on this test. Do not dwell on one problem for too long a period of time. When you have completed the test, check over your responses to ensure that you have marked the answer you consider correct.

Design Issues in the Community - Traffic & Transportation

Scenario: Your engineering firm has been hired to re-design a traffic intersection for a county road (*See Figure 1*). Your client, a county transportation official, states the following when asked what the problem is:

> *"This intersection becomes very congested during the afternoon, and many drivers become frustrated with the long wait at the stop sign. The county has received many complaints. We would like your firm to re-design this intersection to alleviate these traffic conditions and provide more efficient traffic flow for the college and retirement community. But at the same time, the County Transportation Department has a limited budget to designate to this project. It is also very important that the project is completed before the beginning of the school year, so that construction doesn't disrupt the college's normal operations during the school year"* – DIRECTOR OF TRANSPORTATION DEPARTMENT

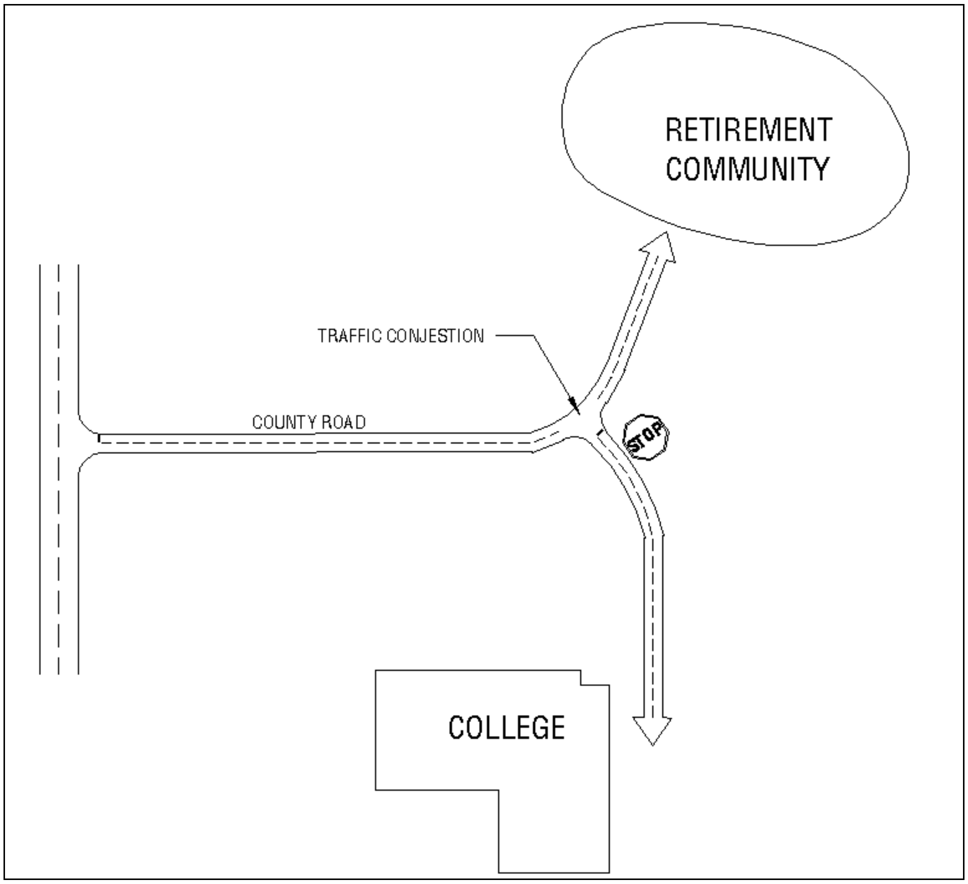


Figure 1. Schematic Drawing of Existing Intersection

1. Of the following choices, which best describes people or groups of people whom you will need to consider in your firm's re-design of this traffic intersection (stakeholders)?

- ☐ Ultimately just the Director of Transportation Department because he is the client and will be paying our firm.
- ☐ The college, the retirement community, the transportation department, the overall county.
- ☐ Our firm can determine the best solution by using our expertise and resources, therefore we do not need to consider other peoples input.
- ☐ The college and the retirement community.

2. You are assigned project manager for this job. As you begin to work on this project, which of the following is something you would ***NOT*** do?

- ☐ You question and interview officials from the college and retirement community.
- ☐ You request records from the county regarding the complaints that have been filed.
- ☐ You interview the Director to obtain more detailed information regarding the problem.
- ☐ You begin drafting alternate intersection configurations that might solve the problem.

3. Before you begin to design a solution you:

- ☐ Gather information regarding the number of homes in the retirement community and the number of students attending the college in order to estimate the amount of traffic that will drive through the intersection.
- ☐ Conduct a site visit to the intersection, taking notes and photographs to document the problem.
- ☐ Verify that your firm has the latest edition of "American Association of State Highway and Transportation Officials – Geometric Design of Highways and Streets", the national standard used in intersection design.
- ☐ All of the above

4. Based on the following statement from the Director, what should you further question him about in order to obtain data to help you in your design:

"This intersection becomes very congested during the afternoon, and many drivers become frustrated with the long wait at the stop sign"

- ☐ Ask him if he has become frustrated at the intersection
- ☐ Essentially this sentence provides all the information I need at this time.
- ☐ Ask him at what time(s) during the afternoon the intersection becomes congested and how long drivers have to wait at the stop sign on average.
- ☐ Ask him if he knows anyone that lives in the retirement community.

5. After you have clearly understood the problem your next step is to determine some of the design constraints that will need to be considered. You remember that the Director said the county has a limited budget for this project so you:

- ☐ Know that the re-design will have to be cheap.
- ☐ Know that the re-design may not be the safest design due to concessions that will be made in order to keep costs under budget.
- ☐ Ask the Director for the actual budget amount allotted for this project.
- ☐ All of the above

6. Take time to re-read the statement provided by the Director. How many design constraints are known from his statement?

- ☐ One
- ☐ Two
- ☐ Three
- ☐ No constraints are given

7. Now that you have defined the problem, assembled important information and resources, and identified constraints, your next step would be to:

- ☐ Design several alternative intersection configurations to be considered.
- ☐ Design the intersection based on what has worked on past projects.
- ☐ Design the intersection based on what the Director think is most affordable.
- ☐ Design the intersection so that it alleviates the traffic issues.

8. Someone on your design team points out that a traffic light will be a good idea but it does not need to be considered as a possible solution because it will be too expensive. Which of the following is a correct response:

- ☐ The traffic light idea should not be considered because of the cost issue
- ☐ The traffic light idea should not be considered because one of the stakeholders said they would not like a traffic light.
- ☐ The traffic light idea should not be considered because you personally don't think it is a good idea for this site.
- ☐ The traffic light idea should be considered as a possible solution

9. What is the maximum amount of different ideas that should be considered for the design?

- ☐ After brainstorming with your design team, only 1 design should be fully explored in order to keep time and cost down.
- ☐ As project manager, it is your job to pick the 1 design that shows the most promise.
- ☐ 5 possible design solutions is the general rule of thumb for good design.
- ☐ Your team should consider as many ideas as are developed

10. Based on the information below, how should you determine which design to choose?

The following ideas have been developed by your design team:

- A traffic circle (aka roundabout)
- A traffic signal at the intersection
- A new proposed interconnection for the retirement community to direct traffic away from the problematic intersection
- Reconfiguring the lane assignments so that college traffic has the right-of-way

The following design parameters and constraints have been identified

- Cost of building
- Time to construct
- Ability for intersection to quickly pass traffic
- Ability for intersection to pass large amounts of traffic
- Vehicle and pedestrian safety

- ☐ Have a meeting to discuss with your team which is best and put it to a vote.
- ☐ Conduct research to determine which of the options has been most successful in the past.
- ☐ Use a decision matrix to determine how important each constraint is and weigh this information against each possible design solution to see which is the most favorable overall.
- ☐ Since the time construct is so crucial to the college, it is the most important factor to consider, so any designs that don't meet the time constraint should be tossed out.

11. You are analyzing the viability of a traffic-circle configuration for the intersection. Given the following data, predict at which year the traffic-circle will cease to operate at an acceptable level. ***Note: Traffic analysis is often conducted by determining the Average Daily Trips (ADT) that a street or intersection can accommodate***

Current Traffic Levels
Retirement Community = 200 ADT
College w/ 400 Students = ??? ADT
Use the following curve fit equation to determine ADT for the college: ADT = 2.229(x) – 439.995, where x is number of students.

Future Year Traffic Levels
Traffic at the Retirement Community is expected to grow at a 5% annual rate (compounded)
Traffic at the College is expected to grow at a 15% annul rate (compounded)

The traffic-circle can safely function at 1000 ADT. During which year will the traffic-circle begin to fail?

- ☐ 2011
- ☐ 2012
- ☐ 2013
- ☐ 2014

12. The following are items that may possibly be discussed while the results of your design process are being presented to the stakeholders. Which of the following is ***MOST*** important to be presented to the stakeholders?

- ☐ To present what the final design solution looks like.
- ☐ To present why you think the final design solution will be cost effective.
- ☐ To present how you arrived at the final design solution including methods, predictions and analysis of results.
- ☐ To present a timeline for construction.

Engineering Design & Analysis – Sustainable Technology Development

Scenario: You are part of an engineering design team that is traveling to Nicaragua to develop a rainwater collection and distribution system for small rural villages (50 people or less). The area is rainy and several miles from the closest town. Your team involves a mechanical engineer, climatologist, environmental engineer, and an interpreter. Your project is being funded by a University and a non-profit organization.

13. Which would be most important to develop as you begin the design process?

- ☐ A list of equations related to this problem
- ☐ A list of potential people who have something at stake regarding this project
- ☐ A brainstorming list of possible design solutions
- ☐ A list of stated design constraints

14. As you begin to tackle this design problem, your team decides to interview some of the local villagers regarding their lack of available clean water. By interviewing them you are **ULTIMATELY** trying to:

- ☐ Obtain important quantitative & qualitative data
- ☐ Determine how they are affected
- ☐ Put yourself in their shoes in order to better understand the situation
- ☐ Define the problem

15. Which of the following pairs of terms best describe areas of information that will most likely need to be researched and investigated?

- ☐ Historical Rainfall Data and Physics
- ☐ Historical Rainfall Data and Climate
- ☐ Climate and Dynamics
- ☐ Native Vegetation and Mathematics

16. As you collect information and other pertinent data, the proper way to keep track of all the information is:

- ☐ Each team member should keep an individual engineering design notebook and follow the appropriate record keeping guidelines
- ☐ The team leader should keep an organized master file with all of the team members' data and research. All information should be dated, in ink or print, and loose leafed.
- ☐ An engineering design notebook should be used by each student for sketches and scratch work, which at the end of the project will be transferred to a more organized and presentable format
- ☐ Each team member is free to keep records to their preference. At the end of the project they will come together and organize their efforts into one cohesive engineering design notebook.

17. As part of your research, you interview an official from a small village that is geographically closest to the rural villages you are working at. Below in an excerpt from the village official:

    "This part of the country is too geographically remote so we do not have access to the electric grid."

    This statement provides information regarding a:

    - ☐ Design variable
    - ☐ Design factor
    - ☐ Design parameter
    - ☐ Design constraint

18. True or False, since your team is funded by a University and a non-profit organization, your team does not necessarily need to consider several limitations such as lack of electricity and availability of local materials.

    - ☐ True
    - ☐ False

19. Which of the following **BEST** describes why it is important for your team to develop several alternative design solutions?

    - ☐ In case one fails, you have a back-up design
    - ☐ You have several options to present to the villagers to see which they prefer
    - ☐ You can systematically determine which is the best design
    - ☐ You can build multiple prototypes and test them all to see which one works the best

20. Someone on your team proposed a possible water collector and purifier that requires a small amount of electricity in order to operate. What should be done with this possible design alternative at this point?

    - ☐ It should not be further considered since this area has no electricity
    - ☐ It should not be further considered because this technology is not indigenous to this area
    - ☐ It should be considered as one possible design alternative to be tested and compared against others
    - ☐ It should be considered a strong contender because electricity can be provided by batteries

21. In analyzing one potential design, you are attempting to predict how many gallons of water this particular collection device will yield on average during this time of year. Use the following given information to determine how many gallons of water can be collected using this design on average, during the rainy season?

Given:

This proposed collection system is a 10 foot diameter watertight material placed in the village to collect rainwater. The material is propped up and contains a small hole at the center which functions as the collection point, with a barrel beneath.

The following is rainfall data collected during the rainy season:
March = 2.1 inches
April = 3.2 inches
May = 2.9 inches
June = 2.5 inches

The average water loss per month due to evaporation is 1.2 inches/per month.

How many gallons of water per month can be collected using this design during the rainy season, on average? (Hint: 1 cubic foot = 7.48 gallons)

- ☐ 55 Gallons
- ☐ 62 Gallons
- ☐ 72 Gallons
- ☐ 75 Gallons

22. In analyzing an alternative design, you are able to calculate the following information:

Given:
At the beginning of dry season, the village water collection reservoir contains 48 gallons of water.

It is estimated that an additional 32 gallons is collected every 2 weeks.

It is estimated that the villagers use 22 gallons per week.

How many weeks will it take for the reservoir supply to be depleted at these levels?

- ☐ 4 Weeks
- ☐ 6 Weeks
- ☐ 8 Weeks
- ☐ 10 Weeks

23. You are trying to determine what the pressure at the bottom of a water storage tank is in order to determine whether a valve at the bottom of the tank is adequate or will blow out and fail. The tank is 5 feet in diameter and 6 feet tall. Your team member asks you to calculate what the maximum design pressure at the bottom of the tank should be in order to purchase the appropriate valve. Additionally, you decide to use a factor of safety of 1.2 to accommodate some unknown factors contributing to the pressure.

P = ρgh = Уh

Where
P = pressure at bottom of tank in lb/ft2
У = specific weight of water (62.4 lbf/ft3)
h = height of the water column in feet

What is the design pressure to be used for the valve?

- ☐ 299.5 psf
- ☐ 300.0 psf
- ☐ 374.4 psf
- ☐ 449.3 psf

24. As your team presents the results of your research, analysis and design. Your teammates give several suggestions on items that should be included in your presentation. Which of the following items should **NOT** be included in the presentation?

- ☐ An explanation that a prototype for the chosen design concept has not been built so the actual results are unpredictable
- ☐ An explanation regarding the several different design alternatives that were considered
- ☐ An explanation regarding the actual problem your team was trying solve with their design
- ☐ An explanation on the methodology used to arrive at the conclusion

Engineering Design - Energy

Scenario: You are assigned to a team project designing a windmill to be used for electricity generation for a community of 10 homes and 3 retail businesses. You are examining the feasibility of several different windmill types and configurations. You have been asked to estimate the energy demand from the community and the energy output of the windmill.

25. Of the following, what is the first step to developing a solution to this problem?

- ☐ Determine appropriate engineering science principles
- ☐ Determine appropriate mathematics equations
- ☐ Determine the capacity of a windmill for generating electricity
- ☐ Determine who are the people that have a vested interest in this project and are affected by this project is some way

26. A key component at the beginning of the design process is to:

- ☐ Define the project’s budget and scope
- ☐ Define the actual problem you are trying to solve
- ☐ Define the areas of expertise that will be needed in order to solve the problem
- ☐ Define conceptual solutions to the problem

27. In an effort to further understand the problem, what would be the next logical step?

- ☐ Brainstorm with friends and relatives about windmills
- ☐ Ask your classmates or teammates about windmills
- ☐ Search relevant windmill information in the library, online & from experts
- ☐ Build a windmill and record what it does

28. Each member of your team is using an engineering design notebook through out the design process. Which of the following is NOT a correct practice for documenting your work:

- ☐ Never tape anything into your book.
- ☐ Never erase or white out anything, if it's spelled wrong cross it out with 1 line and rewrite it. If it is incorrect, make a note as to why.
- ☐ Never remove a page from your notebook or use one page for more than one subject.
- ☐ Make sure you sign and date every page you do work on.

29. A member of your design team reminds you that consideration is to be paid as to where the location or site of the windmill will be placed. This consideration:

- ☐ Is a criteria for design
- ☐ Is a constraint for design
- ☐ Is a factor of design
- ☐ Is a principle of design

30. Further, another member of your team points out that the windmill technical system in consideration should be easy to operate by non-technical personnel. This concern is:

- ☐ Is a criterion for design
- ☐ Is a constraint for design
- ☐ Is a factor of design

☐ Is a principle of design

31. After you have gathered all pertinent information related to the design requirements of the windmill. What advice would you give your team to do next?

☐ Get materials, build a prototype and test it
☐ Develop alternative solutions and analyze using constraints and criteria
☐ Develop a decision matrix to make a selection
☐ Ask your teacher or supervisor what to do next

32. In order to select the best solution, you would:

☐ Get materials, build a prototype and test it
☐ Allow the community to select which it prefers
☐ Develop a decision matrix to make a selection
☐ Have your design team vote and document the results

33. This problem represents a conversion of

☐ Kinetic to mechanical to electrical
☐ Mechanical to electrical to kinetic energy
☐ Mechanical to electrical to potential energy
☐ Potential to kinetic to electrical to mechanical energy

34. To enable you to make the decisions on the windmill project, what would be the most critical consideration concerning the physical location in which the project is to be placed?

☐ How much you would get paid for the windmill project?
☐ What are the average wind speeds in this location?
☐ If building materials are available locally?
☐ Whether the local people will be hired for the project?

35. Your research reveals that the estimated energy required to power the average single-family residential home is 27.4 kWh/per day. And for retail use it is 30.1 kWh/per day. However, this neighborhood is installing several environmentally friendly features (Smart Energy) in the homes and retails spaces expected to cut residential energy consumption by 20% and retail consumption by 15%. What is the difference in total kWh used in the course of a month (30 days) between the regular homes vs. the smart energy homes?

☐ 8880 kWh
☐ 2050 kWh
☐ 3000 kWh
☐ 6580 kWh

36. In communicating your results, what would be considered an acceptable engineering design presentation?

☐ A windmill prototype and great drawings in an engineering book
☐ Methods of selection of the windmill including computational methods and formulas and predicting performance including free body diagrams.
☐ A PowerPoint presentation of your windmill project with nice pictures of your team.
☐ An actual windmill that works and show how it works.

APPENDIX C

DESIGN ATTITUDE INVENTORY

DESIGN ATTITUDE INVENTORY

Based on the design activity that you have just participated in, evaluate your learning attitude regarding your level of confidence in solving a technological problem and what components you believe are important when solving a technological problem.

Use the following evaluation criteria to rate your attitude. Circle the number in the box that best represents your attitude about the design concept. Be thoughtful on each item - answer all items.

1 = Strongly Disagree
2 = Disagree
3 = Undecided
4 = Agree
5 = Strongly Agree

CONFIDENCE IN SOLVING TECHNOLOGICAL PROBLEMS From what I learned in the design experience I feel confident in:	**Strongly Disagree**	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
solving technological problems.	1	2	3	4	5
identifying the basic issues within a technological problem.	1	2	3	4	5
organizing my thoughts in solving technological problems.	1	2	3	4	5
finding resources in solving technological problems.	1	2	3	4	5
applying math & science principles necessary to solving technological problems.	1	2	3	4	5
working with other people to solve technological problems.	1	2	3	4	5
predicting a solution to a technological problem based on my use of math & science.	1	2	3	4	5
solving technological problems only when I have been given all the pertinent information.	1	2	3	4	5
solving technological problems when I do not have all the pertinent information.	1	2	3	4	5
generating multiple solutions to a technological problem before testing a physical product.	1	2	3	4	5
describing a solution to a technological problem.	1	2	3	4	5
building a solution to a technological problem.	1	2	3	4	5

CONTINUE ON BACK:

Belief in Solving Technological Problems From what I learned in the design experience I believe that:	**Strongly Disagree**	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
the easiest way to solve a technological problem is working through it on paper using math & science.	1	2	3	4	5
the easiest way to solve a technological problem is to build a model or prototype to see if it works.	1	2	3	4	5
people spend too much time in evaluating solutions when they should just try a solution to see if it works.	1	2	3	4	5
time is better spent building a model or prototype to test a solution rather than working solutions out on paper.	1	2	3	4	5
solving a technological problem using a pre-planned analysis is more time effective.	1	2	3	4	5
by working solutions out on paper it is easier to make refinements and adjustments to a solution.	1	2	3	4	5
problem solving is more efficient if you think through all the design steps first prior to building a product.	1	2	3	4	5
it is more important to describe a solution to a technological problem on paper than to build a physical product.	1	2	3	4	5
the amount of time that is involved in planning to solve a technological problem is not as important as actually solving the problem.	1	2	3	4	5
if I was going to solve more technological problems I would need additional math & science preparation.	1	2	3	4	5
if I was going to solve more technological problems I would need additional technology & engineering preparation.	1	2	3	4	5