U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ENERGY EDUCATION AND WORKFORCE DEVELOPMENT

The BEAM Project: Building Efficient Architectural Models

Grades: 9-12

Topics: Buildings, Energy Efficiency and Conservation

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Owner: ACTS

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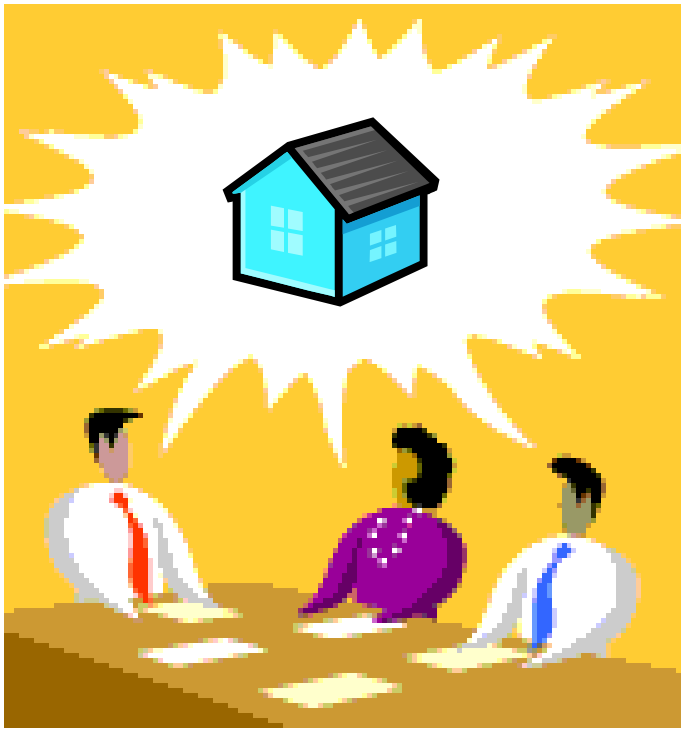
EDUCATIONAL MODULE

The B.E.A.M. Project

Building Efficient Architectural Models



Matthew Brown
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TITLE: The B.E.A.M. Project

AUTHOR: Matthew A. Brown

GRADE LEVEL/SUBJECT: 11^{th} – 12^{th} Science & Technology Education

CURRICULUM STANDARDS: (from the National Science Education Content Standards)

Science as Inquiry Standard A:

Use appropriate tools and techniques to gather, analyze, and interpret data; Develop descriptions, explanations, predictions, and models using evidence; Think critically and logically to make the relationships between evidence and explanations.

Physical Science Standard B:

Transfer of energy – energy is a property of many substances and is associated with heat, light, and electricity. Energy is transferred in many ways.

Science and Technology Standard E:

Identify a problem or design an opportunity - Students should be able to identify new problems or needs and to change and improve current technological designs. Propose designs and choose between alternative solutions - Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes. Implement a proposed solution - A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials--such as wood, metal, plastics, and textiles. Solutions can also be implemented using computer software.

Evaluate the solution and its consequences - Students should test any solution against the needs and criteria it was designed to meet. At this stage, new criteria not originally considered may be reviewed. Communicate the problem, process, and solution - Students should present their results to students, teachers, and others in a variety of ways, such as orally, in writing, and in other forms--including models, diagrams, and demonstrations.

OVERVIEW:

This activity allows students the opportunity to explore materials used in architectural engineering and gain an understanding of their insolating properties. Students will research, design, build, test and improve a structure as to achieve the highest energy efficiency possible. Structures will be tested outside on a sunny day for eight hours with temperature changes being recorded each hour. Students will gain an understanding of how the combination of building location and orientation along with building design and materials can greatly affect the energy efficiency of a building.

PURPOSE:

To increase the students awareness of energy use and efficiency in homes

To apply knowledge of energy use and efficiency to real life situations

To compare different building materials and techniques to achieve the most efficient outcome

LEARNING OBJECTIVES:

Students should be able to discuss what factors affect energy efficiency in homes and how using different materials can affect a homes energy performance.

VOCABULARY:

Energy	climate	passive solar
energy efficiency	energy transference	shading
fuel	Laws of Thermodynamics	solar gain
Energy Star label	BTU, solar mass	

RESOURCES AND MATERIALS:

Resources:

B.E.A.M. design brief handouts, computers for web research of energy efficient homes, LEED certification, etc.

Materials: *Students may bring materials from home: they must be safe for the classroom & this project.*

1/2" plywood bases for the structures to be mounted (20'x20"), different types of insulation (cotton balls, hay, clay, and shredded paper), cardboard, and overhead projector films for windows.

Tools:

Assorted methods for fastening (wood glue, hot glue, screws, nails), hammers, screw drivers, utility knives (safety version, self-retracting), tape measures, plywood (assorted sizes), 12"-18" thermometers (one for each team).

PREPATORY ACTIVITIES AND PREREQUISITE KNOWLEDGE:

Students should understand the Laws of Thermodynamics and how this affects building materials.

Energy exists in many forms, such as heat, light, chemical energy, and electrical energy. Energy is the ability to bring about change or to do work. Thermodynamics is the study of energy.

First Law of Thermodynamics: Energy can be changed from one form to another, but it cannot be created or destroyed. The total amount of energy and matter in the Universe remains constant, merely changing from one form to another. The First Law of Thermodynamics (Conservation) states that energy is always conserved, it cannot be created or destroyed. In essence, energy can be converted from one form into another.

The Second Law of Thermodynamics states that "in all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state." This is also commonly referred to as entropy. A watch spring-driven watch will run until the potential energy in the spring is converted, and not again until energy is reapplied to the spring to rewind it. A car that has run out of gas will not run again until you walk 10 miles to a gas station and refuel the car. Once the potential energy locked in carbohydrates is converted into kinetic energy (energy in use or motion), the organism will get no more until energy is input again. In the process of

energy transfer, some energy will dissipate as heat. Entropy is a measure of disorder: cells are NOT disordered and so have low entropy. The flow of energy maintains order and life. Entropy wins when organisms cease to take in energy and die.

Students should also have an understanding of positioning so the home can make the most of the south facing wall.

ACTIVITY TIME PERIOD:

This activity will take 10, 45 minute class periods or 5 block class periods.

B.E.A.M. *Building Efficient Architectural Models*

This module is designed for a 45 minute class period. For a block schedule just combine two days.

TEACHER SCHEDULE:

DAY ONE

1. PowerPoint presentation on Laws of Thermodynamics and passive solar
2. Review what uses energy in a home.
3. Break students into groups of two to four. Hand out the design brief. Have students put their name on the front cover and all the names of the members of their team on the instructor test data sheet. Assign due dates and have the students fill them into the appropriate spaces. Carefully go through the requirements, specifications and restrictions. Students do not write on the grading rubric on the last page (teacher does). Make sure that everyone understands that deviating from or misinterpreting these requirements **will** affect their final grade.

DAY TWO

1. Students should then begin to answer the research questions in Part 1.
2. Students can begin working on their individual designs for Part 2.
3. Students should come to the next class with the fist page of Part 2 completed. (Design 1 & 2)

DAY THREE

1. Students meet in their groups to discuss the final design. Each student should bring two unique designs to the table.
2. Once the team has decided on a final design each member must add this to their design brief.

Check point 1 - No group may progress beyond this point without this step being signed off by the instructor.

DAY FOUR

1. Each student will then begin writing construction steps and safety procedures for Part 3. Each student will create their own steps and the team will decide which ones will be combined to use for the construction of the final structure.
2. The team should pick the instruction that they wish to use and justify.

Check point 2 - No group may progress beyond this point without this step being signed off by the instructor.

3. Team members begin organizing materials and tools to begin constructing their structure next class

DAY FIVE - EIGHT

1. Teams begin the construction phase, completing their design brief as appropriate.
2. Teams begin testing their structure and making changes as necessary. Parts 5 & 6.
3. Teams prepare for final testing.

TESTING: A hole should be placed at the base of the north facing wall (out of direct sunlight) so that the temperature reading will be taken at floor level inside the structure. The hole can be sealed by the team with a material that won't permanently affect the thermometer. The thermometer must be able to be read from the outside of the structure. All structures should start at room temperature inside the classroom and an initially recorded temperature, before going outside.

Alternative Testing – If you are limited to working inside, you can place a hand warmer or cold pack inside the structure to simulate heating or cooling to test efficiency in an otherwise constant temperature environment . Do not allow the thermometer to come into contact with the heating or cooling device as this will skew the results.

DAY NINE

1. Teams meet before first hour to setup their structure.
2. One member takes readings each hour for eight hours. 8:00-3:00 (Student must get record sheet from instructor each hour) (If the school has electronic data recorders, the students can program them to take readings automatically.) (Further explain the "record sheet?"
3. Teams collect their structure after the last class of the day and record instructor's results.
4. During class time students should be completing unfinished sections of the design brief.
5. Design brief is due next class period. Each team will prepare 3-5 minute presentation on their structure and the results of their testing.

DAY TEN

1. Teams present their structure and results (If still testing, initial results and predicted results).
2. Students turn in the design briefs.

"BEAM"

Building Efficient

Architectural Models

Alternative Energy

Statement of the Problem

Design, build, test and evaluate a structure that will maintain an even interior temperature over a period of eight hours using a heating or cooling device.

IDEAS (IMAGINING) * DEVELOPING * BUILDING * TESTING

EVALUATING * REDESIGN/REBUILD/RETEST

to

SUCCESS

NAME:_____

DATE STARTED:_____ DATE DUE:_____

OVERALL ACTIVITY GRADE:_____

Requirements

1. You will work in teams of two to four and complete complete your design brief.
2. This activity will be due _____ for instructors final test.
3. Your completed brief is due _____.
4. You must conduct and record as many tests as necessary, then chart and graph the results.
5. Redesign, modify, & retest your design solution until it has achieved the highest efficiency.
6. Complete all work asked for and answer all questions in this breif booklet.
7. Write your name, etc. on the Assessment Rubric and Peer Presentations Review forms .
8. Review the Assessment Rubric to know all grade requirements. Be sure they are all satisfied

Specifications

1. The structure must not exceed max exterior dims of $18"^3$ & min. interior dims of $12"^3$.
2. The structure will consist of exterior walls & ceiling only. No interior walls will be
3. Wall & ceiling thickness will not exceed a thickness of 1/2" at any point.
4. There must be 80 - 100 square inches of window space included in your structure.
7. The heating or cooling device provided must be the only source of heating or cooling.
5. You may use any safe materials in the construction of the device.
6. The instructor's final test readings will be taken every 1/2 hour for a period of 8 hours.

Restrictions

1. All structures must be built on the slab provided. No additional flooring is permitted.
2. Only the structure itself may be submitted for testing. No forms of mechanical assistance.
3. Changing or altering the structure once final testing has started will not be permitted.

PART ONE : Research (idea development)

List the steps you take to get the information. that will lead you to your final design solution Include what you expect to find out with each step and where you will find it. Indicate what you will do and what your partner will do to solve the problem (team strategy).

1

2

3

4

PART ONE cont'd: Research Questions

Provide 5 insightful answers to the research questions below concerning the information you will need to gather leading to the solution of this design problem.

1. Will you use more than one factor to manipulate the interior temperature? If so, how many and what are they?

2. What will cause the air temperature to change inside the structure? How can it be controlled?

3. List the criteria you will use to determine the possible materials for your container.

4. Should one material or several be used? How will they be combined if several are used?

5. How will you test the performance of the material/s identified?

6. What is the temperature range that you predict your structure will achieve? Why?

PART TWO : Ideas & Visual design Possibilities

After rough sketching (visual brainstorming) as many possible design solutions as you can think of on scrap paper, place your BEST 2 possible solutions, neatly drawn with measurements, below. Compare your solutions with your teammate's (NOT COPIED), then agree on the team's final design choice.

You can take the best parts of what you see (four possibilities), then add up all the ideas to ma the final design

Design # 1

Materials Used: _____

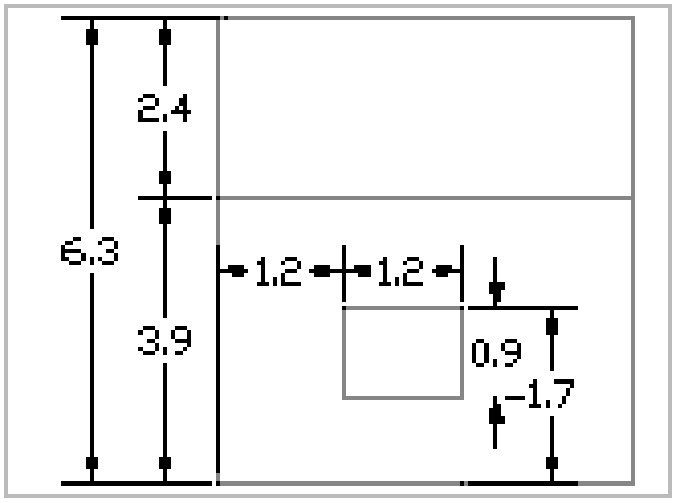
Design # 2

Materials Used: _____

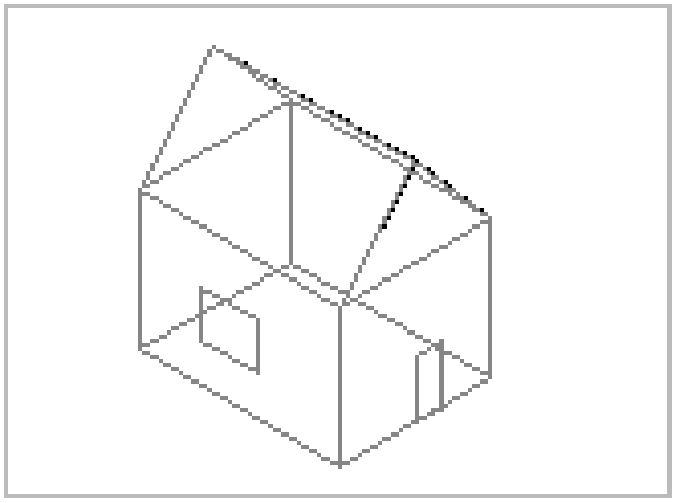
PART TWO cont.: Final Design

This sketch with dimensions, should show the size shape, and any other important information associated with your team's finished device structure. Consider drawing a front, top, and side views with perhaps a section and/or isometric view, to show the necessary detail.

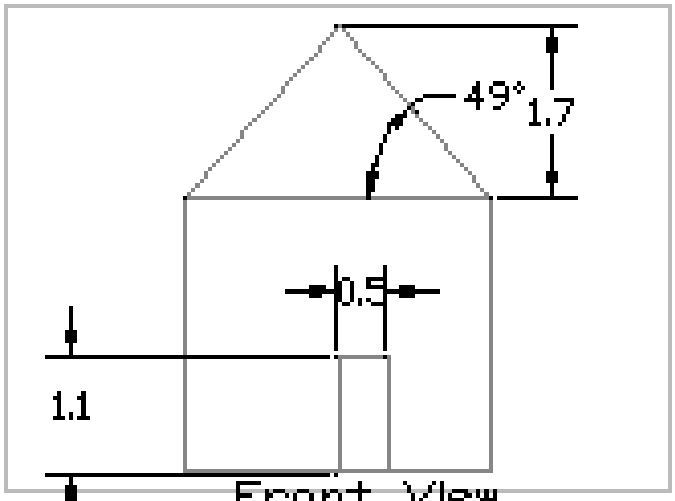
Example:



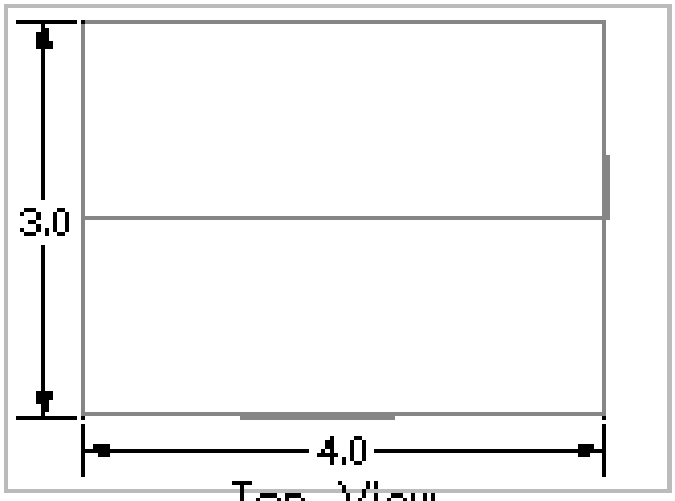
Side View



Isometric View



Front View



Top View

***With NO reference to time**, just list the step by step procedure you will follow to build your design. Be as detailed as possible. Anyone should be able to pick this sheet up and build your design with very little help. Each student must create their own instructions. The group will decide which instructions will be used.*

Attach a materials list typed on a separate piece of paper. This must include material dimensions.

(If more room is required, insert additions with the appropriate heading)

Describe any personal & property safety precautions you will take during work or testing sessions. If there are none, write "NONE". (Think carefully about this and be specific!)

Work:

Testing:

PART FOUR : RESOURCE USAGE

*These are the **SEVEN RESOURCES of TECHNOLOGY**. How have you used these resources to complete your B.E.A.M. Project?*

PEOPLE

Name	*Briefly describe how each helped you*

TOOLS & MACHINES

Tools used	*Briefly explain how each extended your abilities*

INFORMATION

Where did you find and/or how did you acquire information needed to reach your goals?

Place/Event	*Briefly describe the information you acquired*

ENERGY

The energy form	*Application - What did the energy source affect?*
Mechanical	
(potential, kinetic)	
Thermal	
Radiant (Solar)	
Electrical	
Chemical	
Nuclear	

MATERIALS and CAPITAL($)

List any materials that you used to complete this activity, then calculate the total cost

Materials Used	*Quantity*	*Unit Price*	*Total $ Amount*

Total $ Spent:

THE TIME RESOURCE

Describe when and how you used your time to complete this activity

Date	**TIME SPENT**	**NATURE OF ACTIVITY**

PART FIVE : Design Data Collection Log

In the boxes below, describe and/or sketch each change or modification you make on your structure design. It takes many changes for a good functional design to evolve into a success. By showing and evaluating each change in your design, you will have a permanent record that will lead you to your goal more quickly.

# 1 (describe and/or sketch)	*From the 1st one tried, explain why you changed the design or material.*
Changes in structure materials used:	

# 2 (describe and/or sketch)	*better same worse (circle one)*
Changes in structure materials used:	(Explain your choice)

# 3 (describe and/or sketch)	*better same worse (circle one)*
Changes in structure materials used:	(Explain your choice)

# 4 (describe and/or sketch)	*better same worse (circle one)*
Changes in structure materials used:	(Explain your choice)

PART SIX : Preliminary Student Testing

The boxes below can be used to record your completed scale model tests over any length of time up to 12 hours. Place the starting temperature inside the first box and record the temperature at the end of every hour you can conduct that test.

Test #	Start Temp.	1st Hr.	2nd Hr.	3rd Hr.	4th Hr.	5th Hr.	6th Hr.	7th Hr.	8th Hr.	9th Hr.	10th Hr.	11th Hr.	12th Hr.
1													
2													
3													
4													

SEE YOUR MODELS PERFORMANCE BY GRAPHING THE RESULTS

75° F												
70° F												
65° F												
60° F												
55° F												
50° F												
45° F												
40° F												
35° F												
30° F												
	1st Hr.	2nd Hr.	3rd Hr.	4th Hr.	5th Hr.	6th Hr.	7th Hr.	8th Hr.	9th Hr.	10th Hr.	11th Hr.	12th Hr.

Use Different colored lines to indicate different tes Test #1 color: _____ Test #2 color: _____

Test #3 color: _____ Test #4 color: _____

OTHER TESTING PROCEDURES AND RESULTS

Describe any other testing (materials, structures, etc.)you or your teammates performes. Attach testing results (numerical data, tables, graphs, etc.), or copies, for any tests performed. If there are none, write "NONE".

PART SEVEN : Activity & Student Assessment

Describe a problem that you had to solve during the design and/or construction of your solution.

What is the best feature of your final design solution (most imaginative)?

State two scientific principles that apply to the designing, building, and/or testing of your solution.

Was the preliminary testing your team performed adequate and useful in predicting the final outcome? (Compare your test data with the final test data, then explain)

Describe your feelings about the performance of your team's model in the instructors final test.

If you had a 2nd chance to solve the problem, would you change anything? Explain why you would not make any changes or describe how you would change the container and why.

PART SEVEN cont'd: Student Assessment

Did you understand what you had to do? Yes - No - With Help (Circle one). Explain how:

Which of these describes the research you did? Sufficient - Not Enough - Enough to Get By (Circle one) Explain your answer:

Did the design brief guide you to do a better job? Yes - No - To some degree (Circle one) Explain your answer:

Was the activity challenging? OK - Very Hard - Too Easy (Circle one) Explain in what way:

Was the activity interesting? Yes - No - Could be Better (Circle one) Explain why:

Was this activity relevant to the course? Yes - No - OK (Circle one) Explain why or why not:

Rate your effort on the following graphs

Research

The Design Brief

Describe something new that you learned from this activity beyond building of an insulated container.
The more information you can provide the better - be specific!

What is the grade you expect to get for the work you did? _____ *forever optimistic*

Instructor's Final Testing Data

Test #	Start Temp	1st hour	2nd hour	3rd hour	4th hour	5th hour	6th hour	7th hour	8th hour	9th hour	10th hour
Final											
120° F											
110° F											
100° F											
90° F											
80° F											
70° F											
60° F											
50° F											
40° F											
30° F											
		1st Hr.	**2nd Hr.**	**3rd Hr.**	**4th Hr.**	**5th Hr.**	**6th Hr.**	**7th Hr.**	**8th Hr.**	**9th Hr.**	**10th Hr.**

Activity Notes
(Use this space for any necessary notes)

Teammates:

_____ **Ph# :** _____ _____ **Ph# :** _____

_____ _____

(Responsible for) **(Responsible for)**

_____ **Ph# :** _____ _____ **Ph# :** _____

_____ _____

(Responsible for) **(Responsible for)**

Assessment Scale:

6 = Exceptional - Your work shows brilliance and extreme high quality.

5 = Mastery - your work demonstrates excellence in this portion of the activity.

4 = Accomplished - Your work fulfills all of the objectives of this portion of the activity.

3 = Acceptable - Your work is minimally acceptable or needs minor revisions.

2 = Minimum - Your work is either incomplete or requires major revisions.

1 = Not Addressed - Your work did not address or include what was asked for in the rubric.

0 = Not Turned In - Some portion of the activity was not turned in leaving nothing to score.

Points are awarded to each of the sub-categories (left margin), then their average is put as the total of the main category (right margin). The average of all the main categories will become the overall grade for the activity.

Design - **Total _____**

_____ Originality of design (not copied)

_____ Originality in how materials were used

_____ Able to determine the criteria & constraints to determine the best solution

_____ A logical strategy was outlined to obtain ideas and information for a solution

_____ Answers to research questions were insightful, clear, detailed and complete

Construction - **Total_____**

_____ Overall work performed showed neatness and quality

_____ Container constructed matched the final sketch

_____ Demonstrated a degree of measuring skill with the sketch and final construction

_____ Safety precautions were documented for using handtools and machines

_____ Windows were constructed within the size specifications

_____ The finished structure was within the size specifications

Test & Evaluation - **Total_____**

_____ Accuracy of student prediction based on preliminary testing

_____ The highest level attained for the instructor's final test

_____ Safety precautions were documented and followed

_____ Student preliminary tests were used to optimize the final solution

_____ Students could make connections between their work and the real world

Design Brief - **Total_____**

_____ Part One: Extent of research performed (people & information utilized)

_____ Part Two: Quality of sketches were clear, detailed and complete

_____ Part Three: Construction procedures were clear, accurate and complete

_____ Part Four: Resource pages were clear, detailed and accurate

_____ Part Five: The data Collection log was clear, accurate and complete

_____ Part Six: Preliminary Testing recorded & graphed neatly, accuratly and completely

_____ Part Seven:Activity & Student Assessment: Neat, complete and insightful

Team Work - **Total_____**

_____ Acted as a responsible member of the team during work and testing

_____ Acted efficiently during work and testing sessions (time)

Activity Total Average_____

Grade Legend

A+ = Above 5	B+ = 4 to 4.4	C+ = 3 to 3.4	D = 1.5 to 2.5
A = 4.5 to 5	B = 3.5 to 3.9	C = 2.5 to2.9	F = 0 to 1.4

Instuctor Comments: On reverse side