Session 1566

Building Undergraduate ME Student Design Portfolio: Case study on Heat and Mass Transfer Project

Z.T. Deng, Ruben Rojas-Oviedo, X. Qian, A. Jalloh and A. Mobasher

Department of Mechanical Engineering
Alabama A&M University
Normal, AL 35762
Phone: (256) 858-4142
E-Mail: aamzxd01@aamu.edu
rojaso@aamu.edu; cqian@aamu.edu; ajalloh@aamu.edu; amobasher@aamu.edu

Abstract

One of the key challenges to engineering educator today is how to provide a fast track to project and design engineering while providing the strong fundamental engineering education and solid preparation in engineering analysis and design in a four-year program. It is critical to build the skills necessary for engineering graduates to better meet industry's expectations and have successful careers.

The faculty of the Mechanical Engineering (ME) department at Alabama A&M University adopted a system approach, denoted by the acronym SEAARK, for instruction and teaching. SEAARK stands for (in reverse order) Knowledge, Repetition, Application, Analysis, Evaluation and Synthesis. It covers the learning from the basic to the complex levels. The SEAARK approach for lectures is also utilized for class projects. The ME program strongly encourage teamwork on a class project for courses in the major. This allows students to develop a design portfolio starting from the freshman year. Project training continues through their capstone design course. The projects assigned to students are often combined with on-going faculty externally funded research projects.

The faculty of the Mechanical Engineering department is currently conducting research on "investigation of energy conservation in residential hot water distribution systems" funded by Department of Energy Oak Ridge National Lab. The objective of the project is (1) to perform a feasibility analysis of the technique or devices that can improve delivery efficiency of hot water distribution system, (2) to develop simulation model to variable hot water delivery methods and (3) to perform laboratory tests of hot water distribution conservation techniques/devices.

This research contract provides design and analysis student projects to several mechanical engineering courses, such as Thermodynamics, Fluid Mechanics, Heat and Mass Transfer, Computer Programming, Automatic Controls, and the mechanical engineering senior design course.

This paper presents a case study on student project in heat and mass transfer class. Student project for heat and mass transfer class requires the development of a virtual residential house hot water distribution system using LabView and the development of simulation model using FORTRAN to analyze system energy loss for a given typical 24 hours. Computer programming, conduction, forced and natural convection are required knowledge elements in the project. The further development of this project may become the basis of the senior design course. This paper presents the project description, process control, evaluation and assessment as well as project impact on course contents.

I. Background about Alabama A&M University's Mechanical Engineering Program

Alabama A&M University (AAMU), is a land grant historically black university. It is located in the northeast outreach of Huntsville, Alabama, an important world center of expertise for advanced missile, space transportation and electronic research and development. Among the leading industry and government agencies located in this area are NASA Marshall Space Flight Center, the Army Aviation and Missile Command Center (AMCOM), Redstone Arsenal Testing Center, The Boeing Company, Northrup Grumman, Lockheed Martin Aerospace and many others associated with high-tech. endeavors. These industries and government agencies require large numbers of highly trained engineers, both in the areas of manufacturing and propulsion.

To respond what is important around north Alabama, the Mechanical Engineering program at AAMU was formulated into two options: Manufacturing and propulsion system.

II. Building Undergraduate Design Portfolio

A system approach, denoted by the acronym SEAARK was adopted by the faculty of the mechanical engineering department at Alabama A&M University for instruction and teaching approach that starts from the basic to the complex levels or learning. SEAARK stands for (in reverse order) Knowledge, Repetition, Application, Analysis, Evaluation and Synthesis. The implementation of SEAARK approach was discussed in an earlier paper by Dr. Ruben Rojas-Oviedo [1,2,3]. The SEAARK approach for lectures is also utilized for class projects. As part of the vertical and horizontal integration of design and project development, a project is required in each course. The ME program strongly encourage teamwork on a class project for courses in the major. This allows students to develop a design portfolio starting from the freshman year [2]. Project training continues through their capstone design course. The projects assigned to students are often combined with on-going faculty externally funded research. This aspect of program keeps the students in touch with leading-edge technology and current research activities in the real world.

III. Elements of the Heat and Mass Transfer Class

The catalog description for ME 312 Heat and Mass Transfer class reads as follows. ME 312 Heat and Mass Transfer is three credit hour lecture. It has a one credit hour Laboratory as co-requisite. The Laboratory session is three hour per week (ME 312L). ME312 is one of the key core courses that introduce design and analysis to the junior level students.

ME312 provides fundamentals of heat transfer by conduction, convection, and radiation. It also provides mass transfer by convection and basic system applications in engineering and component performance. This class requires the student to be able to solve ordinary differential equations. Students entering the class are required to have knowledge of computer programming using FORTRAN, C, MATLAB, or LabView. Computer program in FORTRAN or in C, MATLAB, LabView will be developed and used to support design and project and analysis. Parametric study for optimized component performance and trade-off analysis for system integration will be performed. Students are required to take Fluid mechanics and thermodynamics as pre-requisites.

The Heat and Mass Transfer class is designed to provide the student a basic working knowledge of heat and mass transfer processes with the inclusion of open-ended problems in the design of thermal systems. The design should consider the economics of system performance. Theoretical, empirical and practical relations for heat and mass transfer will be utilized in selected open-ended problems in the basic design of thermal systems. The student will be able to utilize computer based methods and software to identify the parameters that characterize the operation of heat exchangers and other system components. At the end of the course the student are expected to learn at a level of analysis and synthesis, i.e. beyond repetition.

Topics to be covered in the heat and mass transfer class include

1. Introduction to basic modes of heat transfer—conduction, convection, radiation.
2. The primary design of a thermal system – system requirements and project definition.
3. Steady-state conduction – One-Dimension.
4. Steady-state conduction in multi-dimension.
5. Unsteady-state conduction.
6. Principles of convection.
7. Empirical and practical relations for forced-convection heat transfer.
8. Numerical analysis methods.
9. Natural convection systems.
10. Radiation heat transfer.
11. Condensation and Boiling heat transfer.
12. Heat exchangers overall heat transfer coefficient effectiveness.
13. Mass transfer.
14. Combustion processes.
15. Instrumentation, testing, simulation and monitoring of heat transfer processes.

IV. Residential Hot Water Energy Conservation Project

Under the support of the Department of Energy Oak Ridge national Lab (ORNL), the Mechanical Engineering Department at AAMU is currently conducting investigation of energy conservation in residential hot water distribution systems. One of the research tasks is to build a simulation model of typical hot water distribution systems for residential applications. The simulation model will help researchers gain analytical knowledge on critical issues of instrumentation and data acquisition and analysis to identify energy losses associated with residential hot water distribution systems. Another task of the research is to perform feasibility analysis of the techniques and devices that can improve delivery efficiency of hot water distribution systems, and identify hot water distribution system energy loss for real houses. This research bring many student projects into class such as Thermodynamics, Fluid mechanics, Analysis and Instrumentation of Physical Systems, Heat and Mass Transfer, and Mechanical Engineering Senior design project.

Students in the ME312 class were asked to design a Virtual House Hot Water Energy Usage Monitoring System using LabView as part of the required class project. The tasks are (1). To create a three bedroom, two bathrooms, house plan. (2), Create a virtual hot-water system using LABVIEW, and (3), Calculate the energy losses of the piping system in a 24-hour period.

Students entering the Heat and Mass Transfer class have already taken Thermodynamics and Fluid mechanics. In those two classes, feasibility studies on energy conservation techniques were conducted. Table 1 shows one of the literature review results on potential energy loss distribution.

Table 1. Possible energy loss for residential hot water distribution system.

Parameters	Importance [in terms of percentages]
Standby Loss	25 %
Length of pipeline	15 %
Ambient Air temperature	10 %
Daily Draw Volume	20 %
Inlet Water Temperature	15 %
Desired Water Temp.	15 %
Total	**100 %**

The energy loss elements listed in this table gives students design constraints, i.e., students have to consider these factors in their simulation model to account for energy loss. As a result of this, the hot water tank temperature change can be simulated using the energy balance equation

$$\dot{E}_{IN} - \dot{E}_{OUT} + \dot{Q}_{IN} = \dot{E}_{ST}$$

$$\dot{m}c_P T_{COLD} - \dot{m}c_P T_{Tank} + \dot{Q}_{IN} = \rho \forall c_P \frac{dT_{TANK}}{dt}$$

The solution can be easily obtained for these ordinary differential equations. The solution was illustrated in Figure 1, where student use LabView to design a virtual house hot water distribution system and then simulate the tank water temperature change using LabView to solve the differential equations. The solution provides tank outlet water temperature if there is no conduction loss around the tank surface. However, in real situation, the tank energy does lose in the process. This loss is currently analyzed using tank energy balance including conduction loss.

The tank temperature output provides input for the pipe energy loss calculation. In the pipe calculation, convective heat transfer, conduction heat transfer, and natural convection heat transfer were introduced. The project was introduced in the very beginning of the semester. However, that time, the convection and natural convection were not introduced yet. As the semester progress, more contents were delivered to students, and the overall picture become very clears at the second half of the semester. Many black boxes were filled with real equations and empirical formulas in terms of natural and forced convections. Energy balance concepts were applied and reinforced many times during the project design process. The project is really open-ended based on the fact that different tank insulation and pipe insulation and different layout of piping plan will produce different loss patterns. Figure 2 shows the flow chart of the simulation program.

FORTRAN program was created to compute temperature history of the tank and pipe as part of the project report requirement. The program predict energy loss due to conduction in the tank, conduction, forced convection and natural convection in the pipes, for a given 24 hour. Usage profiles have to be selected before the simulation. This provided many options on the design of the system. Figure 3 shows a sample hot water usage profile on a typical two bathroom house over 24 hours period.

The simulation was performed for a given tank with selected tank and pipe thermal conductivity. In one of the design, three pipes were connected to the tank sequentially with individual hot water usage profile given. The total hot water usage profile combining the pipe faucets was given in Figure 3. The pipe length from tank to pipe #1 is assumed to be 20 meters and the rest pipe section length is assumed to be 10 meters. Pipe diameter is assumed to be 0.5 inch. Figure 4 shows the temperature change (history) in tank, and pipe #1. The ambient temperature surrounding the tank and pipe was assumed to be a constant. The simulation results on total energy loss from tank and pipes are shown in Table 2 for the aforementioned hot water usage profile.

Table 2. Calculated Energy Loss for Kitchen, Utility, and Single Bathroom House Hot Water Distribution System

Energy Loss (BTU) over 24 Hours		
TANK ENERGY LOSS WITHIN 24 Hours	110779.5	BTU
PIPE #1 ENERGY LOSS WITHIN 24 Hours	535.01	BTU
PIPE #2 ENERGY LOSS WITHIN 24 Hours	62.38	BTU
PIPE #3 ENERGY LOSS WITHIN 24 Hours	62.38	BTU

V. Project Evaluation

At the end of the semester, students are required to deliver a written project report in the format of NASA Technical report. Student project reports are graded based on quality of the design and analysis, and technical style. Students are also required to make oral presentation of the project. Other faculty and students from the ME Department were invited to attend to the presentation and provide feedback to the students. They are all required to fill evaluation forms regarding the presentation. The presentation evaluation form is shown in Appendix 1. Project grade will be given based on combination of written project report grade and oral project presentation grade. Evaluation will be discussed with the student before the final grade given. Improvement methods on presentation are recommended to each student.

VI. Conclusion and Recommendation

The Mechanical Engineering department at AAMU has utilized s SEAARK approach to develop a new undergraduate Mechanical Engineering curriculum. This allows students to develop a Design portfolio starting from the freshman year. Project training continues through their capstone design course. The heat and mass transfer project was derived from the on-going research supported by DOE-ORNL. A virtual residential hot water distribution system was created in heat and mass transfer class project and energy loss associated with hot water usage profile was computed. This aspect of program keeps the students in touch with leading-edge technology and current research activities in the real world. The results of this project will be applied towards senior design, where students are required to design a hot water distribution system in space station application. Project in each engineering class has been proved at the ME Department to strongly enhance the student design experience and help build student design portfolio.

VII. Acknowledgement

This work is in part supported by the United State Department of Energy Oak Ridge National Laboratory under contract # 4500012124.

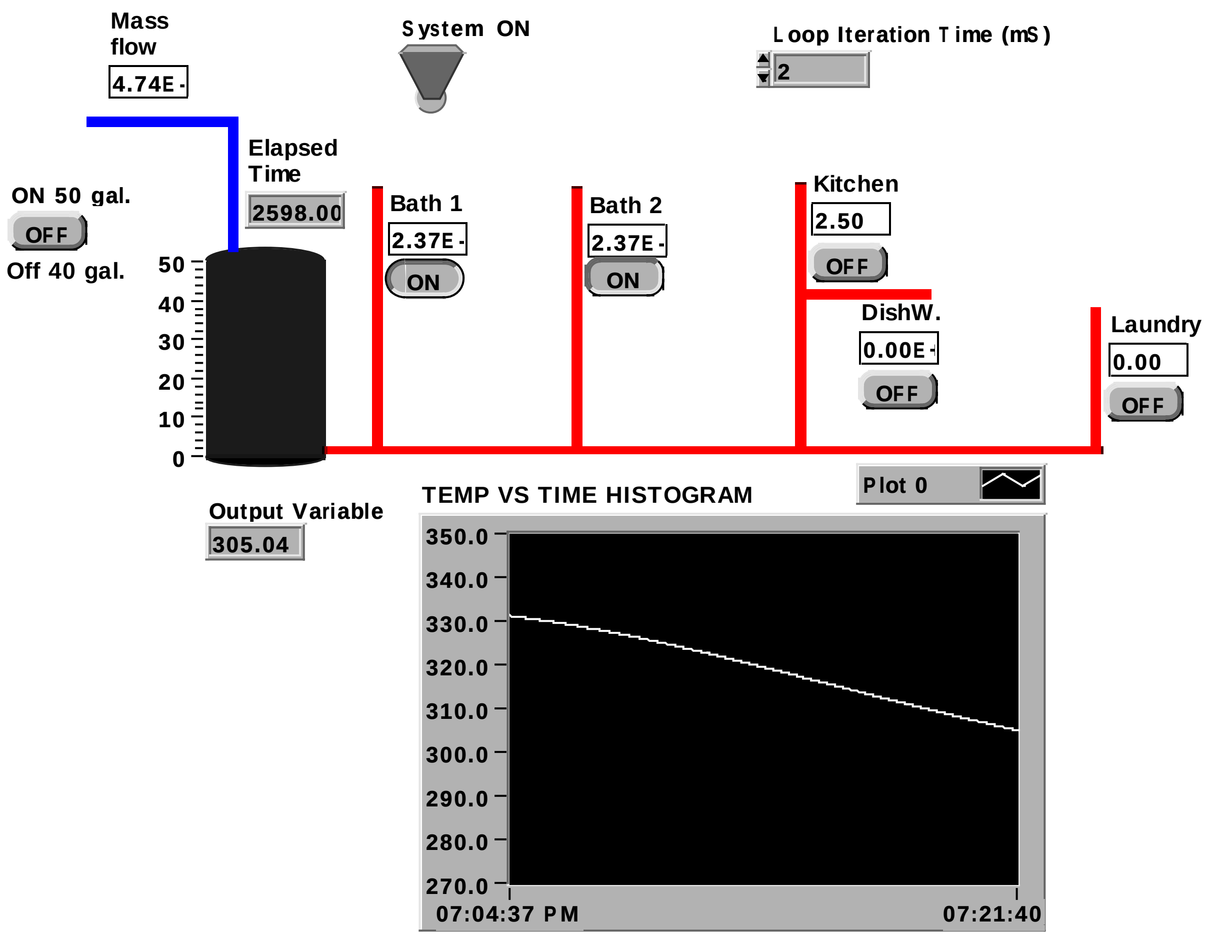

Figure 1. LabView Screen shot for hot water tank temperature history simulation.

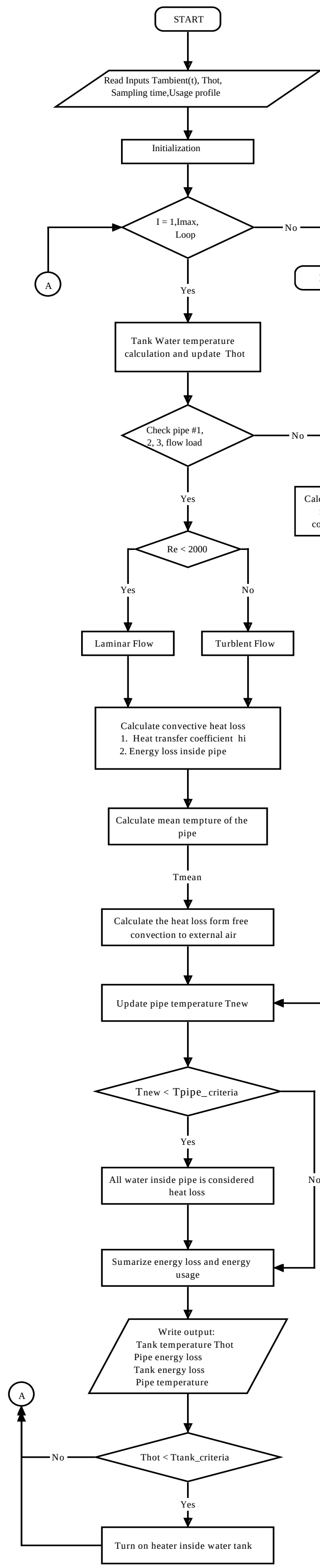

Figure 2. Simulation Flow-Chart.

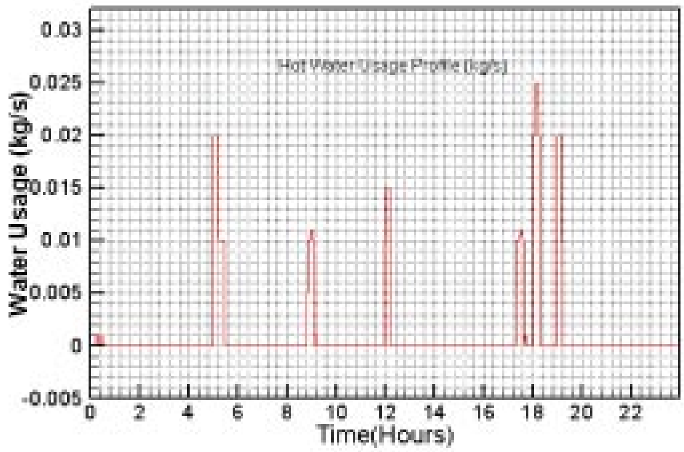

Figure 3. Typical sample hot water usage profile for a house with two-bathroom, one kitchen, and one utility room.

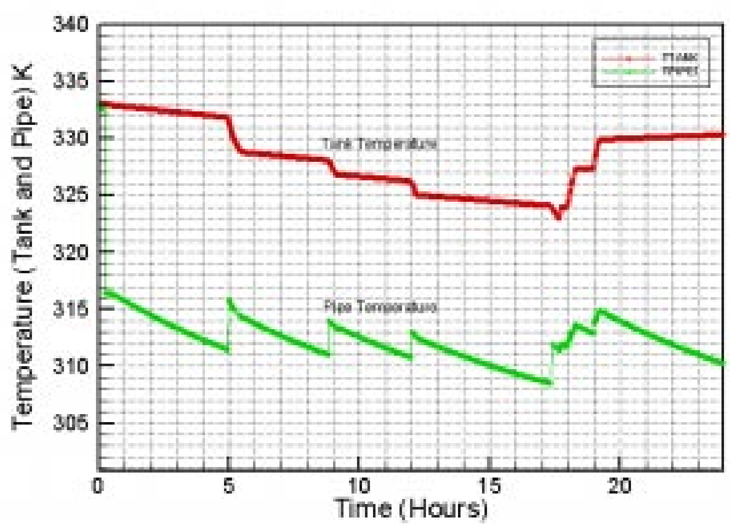

Figure 4. Temperature histories in hot water tank and pipe.

Bibliography/References:

1. Implementation of a System Approach for Curriculum Design. Ruben Rojas-Oviedo, Z.T. Deng, Amir Mobasher, A. Jalloh, Mechanical Engineering department, Alabama A&M University, ASEE Paper, Session 1566, 2000 ASEE Annual Conference and exposition, St. Louis, Missouri..
2. Development of Engineering Competencies in Freshman Courses. Ruben Rojas-Oviedo, Z.T. Deng, Amir Mobasher, A. Jalloh, Mechanical Engineering department, Alabama A&M University, ASEE Paper, Session 1566, 2000 ASEE Annual Conference and exposition, St. Louis, Missouri.
3. Synthesis of Engineering Best Practices and ABET AC2K into a New Mechanical Engineering Curriculum. Ruben Rojas-Oviedo, Z.T. Deng, Amir Mobasher, A. Jalloh, Mechanical Engineering department, Alabama A&M University, ASEE Paper, Session 2266, 2000 ASEE Annual Conference and exposition, St. Louis, Missouri..
4. Integrating the Product Realization Process (PRP) into the Undergraduate Curriculum . The American Society of Mechanical Engineers, December 1995.
5. Manufacturing Education Plan: Phase I Report. "Industry Identifies Competency Gaps Among Newly Hired Engineering graduates. Published by the Society of Manufacturing engineers and the SME Education Foundation.
6. Engineeri Criteria 2000, Third Edition, Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, December 1997.

ZENGTHAO DENG
Z.T. Deng is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Deng has an extensive background and research experience in Computational Fluid Dynamics numerical simulation in particular high speed aerodynamics/flows with heat transfer phenomena. He earned his Ph.D., Aerospace Engineering, University of Tennessee, 1991, and his Bachelor of Science, Aerospace and Mechanical Engineering, from Beijing University of Aeronautics and Astronautics in 1985.

RUBEN ROJAS-OVIEDO
Ruben Rojas-Oviedo is Chairperson and Associate Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville AL. Dr. Rojas-Oviedo has international engineering experience working both in academe and industry. He has an engineering consulting company and conducts applied research. He earned a Ph. D. In Aerospace Engineering from Auburn University, he has two Masters degrees one in Mechanical Engineering from N.C. State at Raleigh and the other in Applied Mathematics from Auburn. He earned a B.S. degree in Aeronautical Engineering from the National Polytechnic Institute – Escuela Superior de Ingenieria Mecanica y Electrica - in Mexico City, Mexico.

XIAOQING QIAN
X.Qian is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Qian earned her Ph.D. and M.S. in Mechanical Engineering from the University of Tennessee. Dr. Qian has been working at industry for five years as a Senior System Engineer. She has an extensive experience in instrumentation, measurements, numerical simulation in particular heat transfer phenomena, and system engineering.

ABDUL JALLOH
A. Jalloh is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Jalloh earned his Ph.D.in Mechanical Engineering, with a minor in Engineering Mechanics from the University of Arizona, he obtained his M.S. Mechanical Engineering also from the University of Arizona, and he holds a B.Eng. in Mechanical Engineering from University of Sierra Leone. His research interest is in areas of finite element analysis, manufacturing and reliability.

AMIR MOBASHER
Amir Mobasher is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. He holds a Ph.D. degree in Mechanical Engineering from University of Alabama in Huntsville. He has research interest in the areas of Computational Fluid Dynamics, Biomechanics, and Control and Automation.

Appendix 1. Project Oral Presentation Evaluation Form

Project Oral Presentation Evaluation Form

Class: ____________________
Presenter(s): ____________________
Team Members: ____________________
Project Presented: ____________________
Date:

	Rating:	Poor (1); Fair (2); Good (3); Excellent (4)
Technical Presentation Contents	Were the objectives and purpose clearly stated?	
	Was the problem well defined?	
	Was the project properly justified (Why?) (Scientific, economic, political, value?)	
	Was the design, analysis and modeling understood?	
	The approach taken was reached as part of a selection process?	
	Are the results technically and economically feasibie?	
	Effective conclusions / recommendations?	
	Quality of the work or design.	
Presentation Methods	The content was well organized?	
	Appropriate use of graphs, charts, board, audio-video.	
	Was the message clearly delivered?	
	Teamwork was evident in the presentation	
	Overall Score:	
Comments to improve the presentation:		