Teaching to Design, Build, and Test in Senior Projects: Learning Outcomes in the Cognitive, Affective and Psychomotor Domains

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Abstract: ABET Criterion I.C.2.b: "Technical Design Courses ---- These are courses in practice-oriented standard design applied to work in the field, such as construction, in which students acquire experience in carrying out established design procedures in their own areas of specialization. The key to this type of technical design lies in the fact that the courses would follow established design concepts developed by engineering and that there would be prime emphasis on standard design procedures and practices. Many of these design methods have already been included in handbooks or standard computer methods for various branches of engineering. These courses would require an understanding of the application of mathematics and science, for example, to such activities as [HVAC] air conditioning systems design, duct design, piping design, amplifier design, computer component and circuit design, plant layout, materials handling operations, and/or civil engineering technology applications such as road design."

Program evaluation in Engineering Technology has just ceased to be input driven. It is outcomes driven now through the ABET program evaluation criteria. Most program evaluations, however, are done with hazy and broad "outcomes statements" as "after completing this class I have acquired the necessary skills and knowledge of appropriate methods, procedures, and techniques." This paper will address the "broad outcomes level statements" like above, to crisp learning outcomes at the activity level, e.g. "By the use of project, I have **applied theory to practice**." These activity level outcomes can be measured. The changed behavior of the student, due to educational intervention and experience at the activity level will affect the behavior in cognitive, affective and psychomotor domains. Senior level research-project planning and control activities will bring about this change. These changes will be reported in perceived quality criteria that will be extracted into the design of questionnaire for the purpose of gathering such evidence.

Introduction

ABET's accreditation reform effort designed to foster effective program evaluation uses a set of criteria. This method allows programs to be flexible to many stakeholder needs. It

also allows them to innovate while still maintaining a strong emphasis on educational quality. This process accreditation philosophy encourages "student outcomes" over mere "program inputs." The outcomes philosophy encouraged constructive interaction with program stakeholders to maintain competitive quality and relevance. The stage was set for the implementation of outcome based evaluation by allowing educators, university officials, and industry representatives to examine the critical issues involved in implementing mandates for accountability and continuous quality improvement.

Five years have now passed in this implementation process. Questions are being raised to address some serious concerns, for instance "What is the effect of outcomes-based evaluation on the quality of educational process." In order to gauge the progress made, to identify on-going and new issues and challenges with implementation, and to gather input for future directions, various proposals and researches to address the following have been proposed.

Purpose of the paper is to explore and answer the following important questions that have been raised frequently by all stakeholders of an educational program.

1.   What evidence is there at the university/college/department level that outcomes-based accreditation is fostering an environment of innovation and continuous program improvement?
2.   How are institutions/programs sustaining the use of assessment in quality educational processes?
3.   What evidence is there, that outcomes assessment and the implementation of quality processes are producing innovation in educational programs?
4.   How has the change in accreditation standards effected graduates' preparation for the workplace? What evidence is there that they are better prepared for a changing work environment?

This paper will address Outcomes Based Program Evaluation and Review Technique using projects with definite learning objectives. Using an effective student project development from inception to implementation, the evidence will be shown that, "outcomes assessment and the implementation of quality processes using student projects as outcomes are producing the desired innovation in educational programs."

Outcomes Defined

Defining outcomes of a project-based learning must be identified at the very outset of the program design. This will consist of:
1. The student will identify an engineering problem
2. The student will write the goals and objectives of the project or investigation
3. The student will develop completion and performance criteria of the project
4. The student will demonstrate knowledge of theories to best apply to the project
5. The student will write the specification of assessment methods for each phase of the project

6. The student will conduct and manage proper peer evaluation of the project in class with the help of the instructor
7. The student will collect feedback of evaluation from the peer and instructor to continuously improve the project till completion
8. Finally, the student will publish for the class the final evaluation resulting in the cognitive, affective and psychomotor outcomes as suggested by the following instrument.

The outcomes in the higher-level cognitive, affective and psychomotor domains are to be written by the student after the completion of each phase of the project using the criteria defined below (example: My evaluation of my learning outcomes from the study phase of the project was **precise   5   4   3   2   1   Imprecise**)

Learning from Project Rubric– Outcomes of Quality Criteria for Project Evaluation

The lessons learned from the project was **precise**   **5   4   3   2   1   Imprecise**
The application aspect of the project was **decisive**   **5   4   3   2   1   Indecisive**
The project   **applies theory fully**   **5   4   3   2   1   Does not apply fully**
The project **experience was coherent**   **5   4   3   2   1   Incoherent**
The project **lessons were well prepared**   **5   4   3   2   1   Not well prepared**
The project **lessons were well organized**   **5   4   3   2   1   Not well organized**
The project **development steps were very clear**   **5   4   3   2   1   Not very clear**
The project **development steps were easy to apply**   **5   4   3   2   1   Not easy to apply**
The lessons learned from the project were **motivating** **5   4   3   2   1   Not motivating**
The project made me **feel confident**   **5   4   3   2   1   Not confident**
I really **enjoyed** the lessons learned from the project **5   4   3   2   1   Did not enjoy**

Examining Learning Outcomes from The Project: Design of a database for HVAC system load parameters

Introduction

In 16 weeks, the student applied the four phases of project design e.g., concept, study, design, and implementation with definite learning outcomes. These four phases of the systems design problem have been enunciated by Angus.[1]

Problem Identification Stage

The HVAC system of a modern university building does not operate on optimal condition of cooling and ventilation. The cost of non-optimal operation is disastrous in fiscally troubled times. To alleviate this uneconomical operation an effort was made to understand and apply improvements to the system on a 16 weeks' project duration. A database program MS Excel 2000 was used in this project for collecting the load parameters of a university's air conditioning system, from which intelligent prediction for

optimal usage could be made. This project report introduces the proper steps involved in the implementation this project. An Excel database containing the sampled load parameters for a specific period was generated. Load-prediction curves based on these sampled data were obtained as an experiential learning exercise to learn and apply forecasting and prediction methodologies. The evaluation of the project tested on student outcomes that correspond with TAC of ABET criteria.

Anticipated outcomes: The student will integrate his **knowledge** of thermodynamics and control circuits and forecasting techniques.

A. Initial concept Map

Concept phase The initial concept map for this project was to build a shared database that collected data from HVAC, fire system, lighting system and elevator system and make them available to each other. However, considering the following difficulties anticipated, this initial concept was not deemed feasible.

1. Time: There is no enough time to fulfill such a big project. The allowed time is only 12 weeks, effectively.
2. Manpower resources: To implement such a big project, software designer, the programmer, data collecting, facilities maintenance personnel are all necessary simultaneously. Unfortunately, all those needed resources are not fully available at the time the project was developed.
3. The facilities adoption: In order to implement this concept, not only access privileges to all the facilities (such as HVAC system, fire system, elevators, etc.) is necessary during the weekdays and weekends, but also some special measuring equipment and management software packages are also required. For example, the data from the HVAC and fire system are normally from two completely separate systems, so in order to make their data sharable, either a certain data converting software was to be developed, or we had to find some commercial software package. Neither of them was available and feasible.
4. The cost: Since this is a student project, there is no budget for it. Commercial software mentioned in item 3 and the manpower were out of question.

    The conclusion from this brainstorming exercise was to implement just the nuts and bolts of what the project promised.

B. Final Concept

Measure the load parameters of the designated HVAC system in Computer Lab, and build a database for the parameters measured. This database is to serve as a practical tool for the facility planners to optimize the HVAC system operation for the purpose of optimal operation.

For this class project, the emphasis was on the load data collection and analysis. The methods concerning the energy saving by optimizing the HVAC system operation were

not included in this study—this protracted goal is abandoned at this stage due to resource limitations.

Study Phase

The purpose of this study was to develop and evaluate ways to measure the parameters and establish the database. The objective of the study phase was to produce an effective and practical method to implement the design phase, the emphasis being on evaluating the concept developed in the previous phase, and on selecting the proper tools and locations to implement the concept. There are several activities involved in this phase, including evaluation of the database tools, data sampling methods etc.

Anticipated outcomes: The student **will research and investigate new advances** in the knowledge of thermodynamics and control circuits and forecasting techniques.

A. Main tasks

1. Identify the target area in the building for load parameters measuring – Computer Lab

2. Determine the relevant parameters to be measured – the temperature in computer lab and airflow in the tube. Select the feasible database tool – MS Excel 2000.

B. Data collecting methods analysis

For the HVAC project, it was decided to measure the three parameters: average room temperature, tube-air temperature, and the airflow rate. After obtaining these three data, the load parameter of the computer lab can be calculated by the following formula.

L = (T1-T2)*1.08*CFM   where,
L = sensible heat added or removed from the air (Btuh);
T1= Tube air temperature (ºF)
T2=Average room temperature (ºF)
Air coefficient =1.08
CFM- Airflow rate (cfm)

(Note: This formula is only used to calculate the "sensible" heating load, which does not take into account the humidity factor)

Data collecting methods have been of two categories e.g., automatic and manual. The automatic data collection is done by the intelligent control system itself. For an HVAC control system, the above three data are the most pertinent concerning the control of quality[2]. Every control system is designed to collect these data. The control system will use different sensors to sample the three data and make them available to the facility

personnel by transferring them to the computer monitor by a feedback. This is the fastest, the most efficient way to get the data with the lowest cost.

Another way to collect data is the manual method. Comparing with automatic collection method, manual collection is often used as an auxiliary method when those required data cannot be measured by the control system, and it is not fast and it is also not effective. So in this project, we use the automatic collection method to collect the data, since all these data are already collected by the HVAC control system studied.

C. Database tools analysis

Many database tools are currently available on the market. They are different in prices and applications. For this project, it is neither possible nor necessary to use a very complicated and expensive database tool. The general commercial database tools are roughly divided into three categories according to their application areas.

- Oracle, the Large scale database
  Complicated, not necessary for this project, and also programming is needed.

- Sybase the Middle scale database
  Complicated, not necessary for this project, and also programming is needed.

- Access, Excel the poor man's database tool
  Easy to use, simple, nearly no programming is needed.

Evidently, for this project, MS Excel 2000 was selected as the database platform. MS Excel 2000 has plenty of built-in function tools, which are suitable for most common applications. It is also practically the most often used data collection and analysis tool in HVAC control systems today[3].

D. People and cost analysis

Since this is an active learning course by project, the student and the professor are involved, and there is nearly no other cost outlay to consider except for measuring instruments which were loaned by the physical plant.

E. Establish a rough timeline and roadmap

The roadmap is the best way to control the project, no matter how large or small it may be. In this project roadmap was developed and referred to rigorously, in the study phase itself.

Conception Phase	Study phase	Design Phase			

Format DB. Understand and apply formula to load params

Measuring parameters on a regular basis. Calculate load variations. Store in DB with time stamp

Data processing, Document preparations

8/31/02   9/13/02   9/20/02   9/27/02   10/27/02   12/12/02
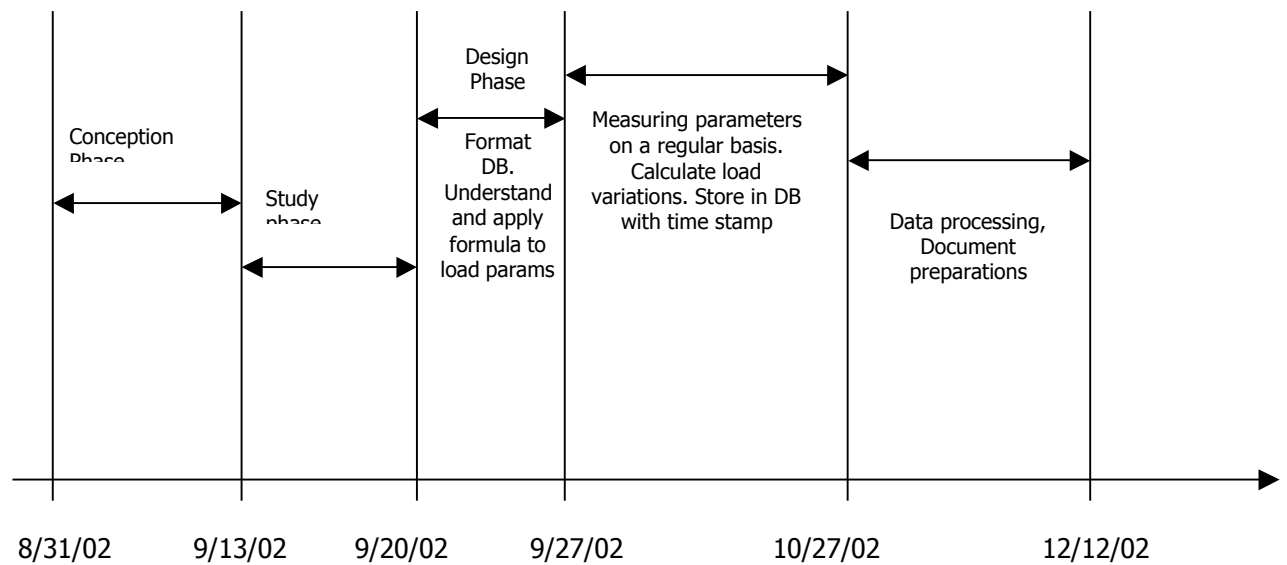
Design Phase

During this phase, a database tool, based on MS Excel 2000 was developed for input, which provided both the tabulated representation of the sampled data and the visualized representation of those sampled data. A detailed discussion on this tool is presented in the next section.

Besides the database tool, another key issue that is important to the design phase is how often the data are to be measured[4]? Considering the cost, manpower issues related to this project, daily measurements were limited to three times, which were scheduled at 11:00AM, 3:00PM, and 7:00 PM. The basic idea for this decision was the notion of adhering to the typical load distributions in the morning, afternoon and the evening. After the data were collected according to the scheduled time sheet, they were input into the database for data processing and analysis. The predicted load calculation, data tabulation, and visualization tasks were incorporated into the software and implemented by the database tool.

Anticipated outcomes: The student **will apply the research and investigation in new advances,** to his present knowledge of thermodynamics and control circuits and forecasting techniques.

Implementation Phase

The final phase of this project was the implementation phase. In this phase, the only task remaining was is to collect the required data, input the data and process them. This phase was scheduled from the end of design phase to culmination of the semester. As a result of effort of this phase, a completed database together with the collected data is shown in the display. Based on these collected data, various prediction model curves were plotted

as shown. They were compared with the actual data distribution curve, and their efficacies evaluated.

Anticipated outcomes: The student **will apply and build his design** to represent his knowledge of thermodynamics and control circuits and forecasting techniques.

DATABASE ON MS EXCEL 2000

The database tool in this project is a key element of learning outcomes. Although the Excel 2000 itself is a very powerful tool for data handling and processing, some work must be done to fit into the special needs in this project, including the data input, data storage, data representations, and predictions.

The MS Excel 2000 provides a built-in Visual Basic editor, which supports all the functions of Excel built-in functions, and a standard Visual Basic grammar. A Virtual Basic program to collect and categorize the data the data was written by the student to understand the process involved. Then the student wrote the program to process the data using built-in functions in the program.

Tasks of the Database Tool

The tasks of this database tool were targeted to:
1. Provide a data input box for the users
2. Sort the data in a date-ascending sequence
3. Use the Excel 2000 built-in pivot table to manipulate the input data
4. Give the tabulated data representation
5. Give the visualized data representation
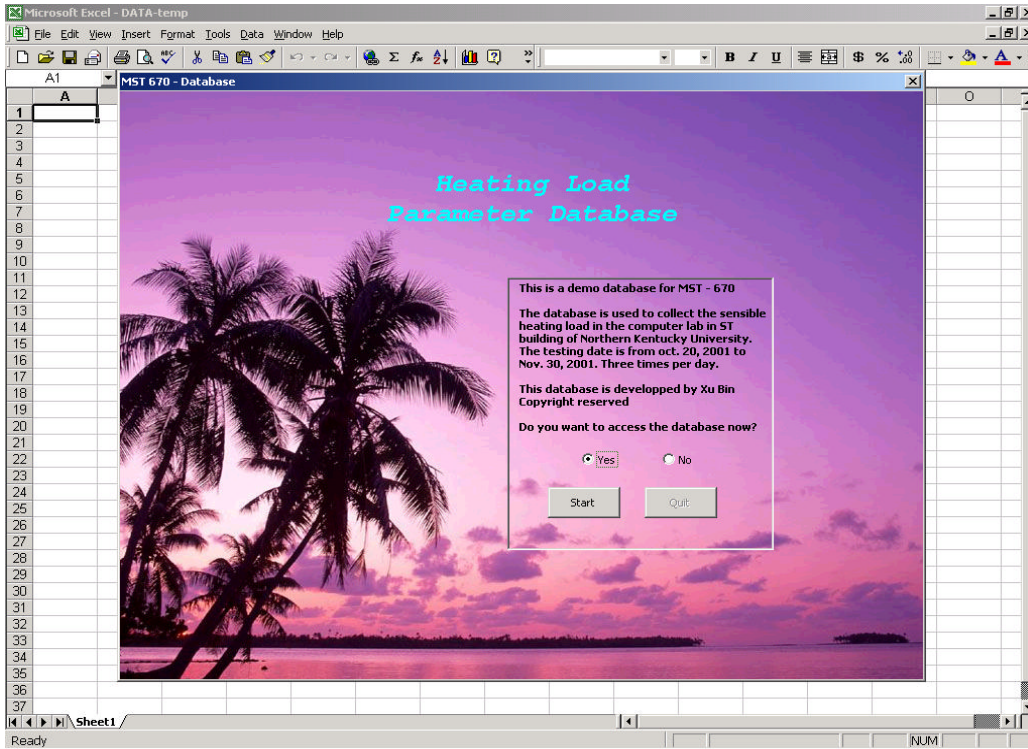
Figure 1- Greeting Screen

Figure 2 – Data Input Box
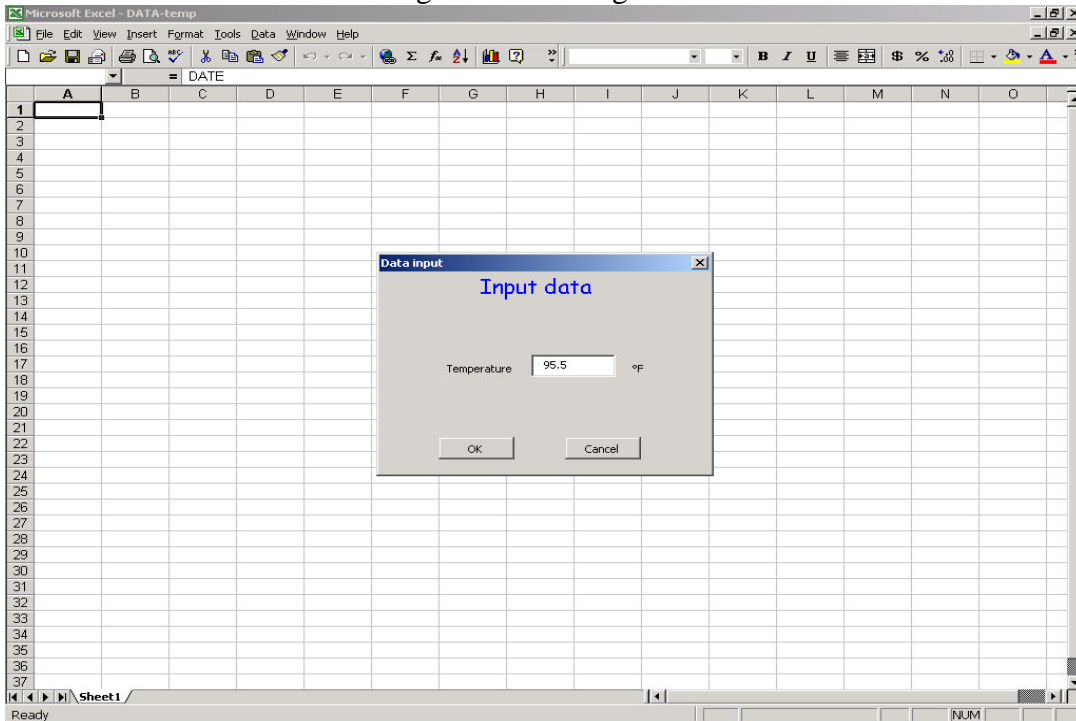
Figure 3 – Data Table

The data table (not the pivot table) above shows the data are stored according to their input date. The item named "TIME" means at which scheduled point in a given day the data were collected.

Figure 4-- Pivot Table

Figure 4 above is the pivot table that shows the recorded data at a certain scheduled time point (in this example 11:00 AM) in a given day. However, Pivot Table provides a function of "summarizing" all the collected data in every column and row with a "Grand Total," as a built in function. This function cannot be removed from the Pivot Table although it is not a useful feature in this particular project, pivot tables have been used with more enhanced adoption of this feature for analysis.
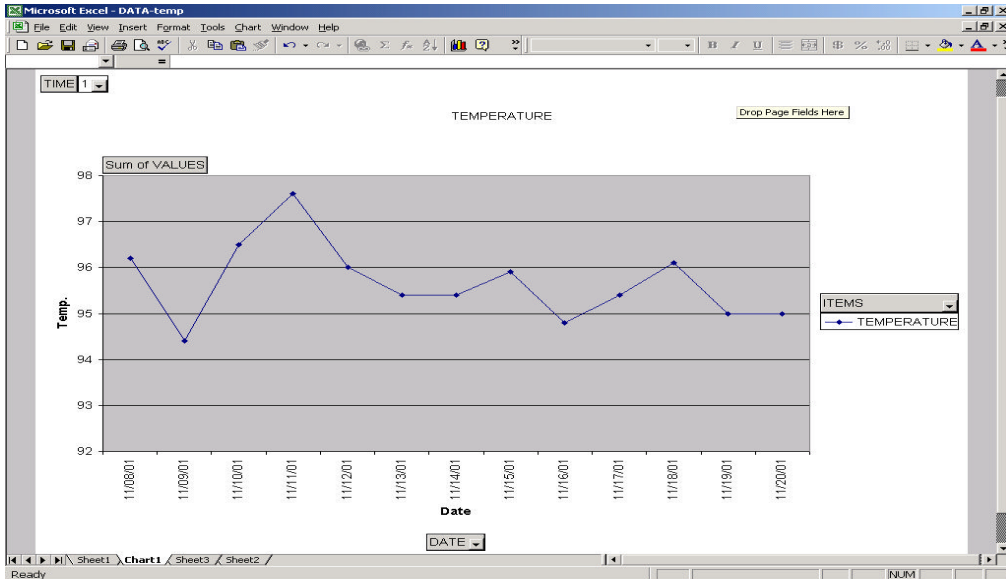
Figure 5 – Visualized data

Figure 5 above is the visualized data representation. Each dot represents an actual value being measured.

Data Prediction

This section is the most important part of learning in this project report, which deals with the statistical prediction of the "next step" data. The source data were collected daily three times per day at three scheduled time points (11:00 AM, 3:00 PM and 7:00 PM).

Statistically, data prediction (using simple to advanced forecasting methods) has been implemented with various mathematical models. Each has its own advantages, and applications with limitations. In this project, the student employed four statistical methods to perform and graph the prediction equations. The results are shown for each method.

A. LINEAR REGRESSION MODEL

Linear regression analysis is often used in data forecasting. This prediction model was created for a population of measurements that was generally unknown to the experimenter, and two variables are involved with the assumption that within the

population, the variable of interest (Y) is linearly related to an independent variable (X). The basic idea to implement this model is to find a best-fitted line so that the summary of distance of each interested variable to this line is the minimum. This best-fit line is called least squares line. Figure 6 shows the result of this model.

The predicted data is given by:

$$y = a + b * x$$

Where

$$a = \overline{Y} - b\overline{X}$$

$$b = \frac{n\Sigma xy - (\Sigma x)(\Sigma y)}{n\Sigma x^2 - (\Sigma x)^2}$$
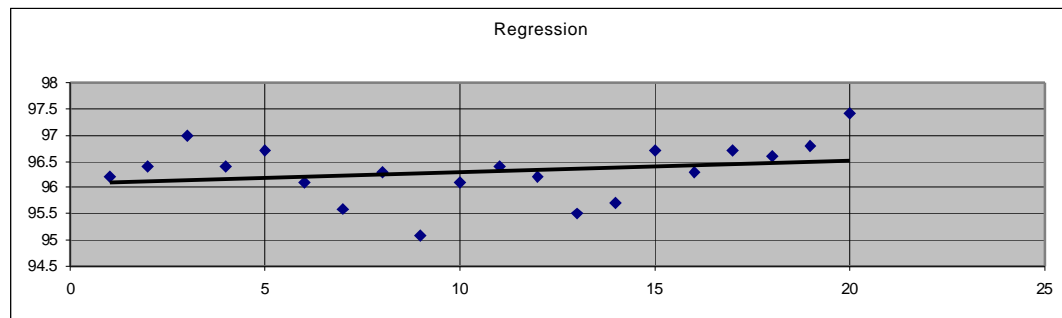
Figure 6

x is the independent variable, and y is the dependent variable; x-bar and y-bar are the sample means of x and y. The prediction result as obtained by this prediction model is attached in Appendix III with the Mean Squire Error **MSE = 0.26**. According to this model, the predicted value for the next step is **96.54**.

B. MOVING AVERAGE FORECASING MODEL

The second prediction method used in this project for comparison was Moving Average Model. This validity of this method is based on the average value of the variable over a specific number of preceding periods. The result is given by:

$$F_{(t+1)} = \frac{1}{N} \sum_{j=1}^{N} A_{t-j+1}$$

where,

- N is the number of prior periods to include in the moving average;
- A_j is the actual value at time j;
- F_j is the forecasted value at time j
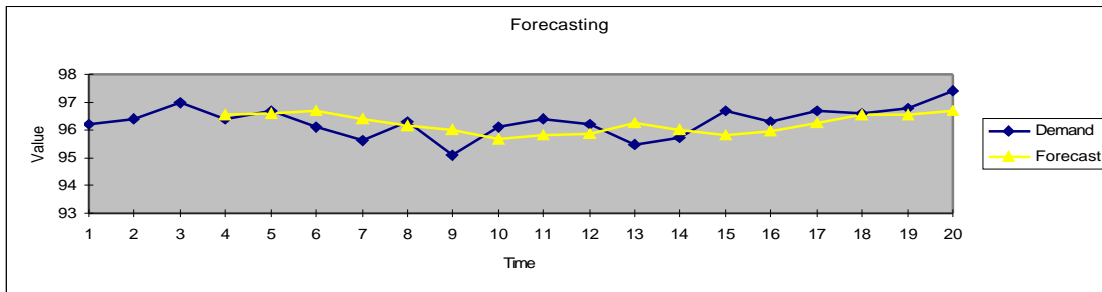
Figure 7

Figure 7 shows the prediction curve as compared with the actual variable curve. Yellow dots curve represents the prediction. The prediction result as obtained by this prediction model is attached in Appendix III with the Mean Squire Error **MSE = 0.28**. According to this model, the predicted value for the next step is **96.93**.

C. WEIGHTED MOVING AVERAGE MODEL

The Weighted Moving Average Forecasting Model is a modified Moving Average Forecasting Model, which gives weight to each variable according to its "importance" in the variables' series. The summary of all weights is always equal to one. In this project, the student used 0.33 as the weight value for each of the first two obtained variables, and use 0.34 for the last one, closed to the predicted time.
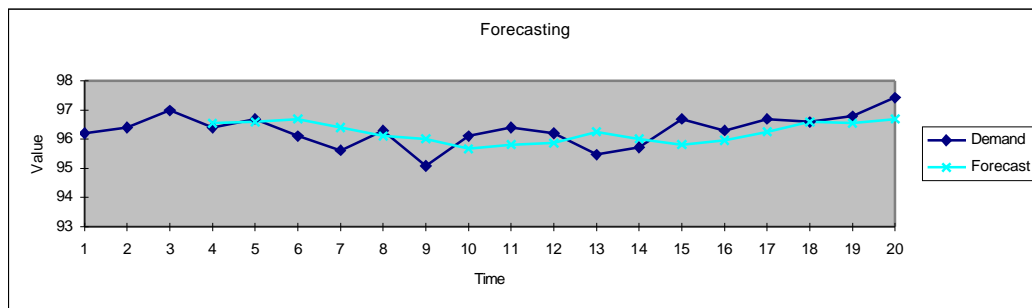
Figure 8

Figure 8 shows the prediction curve as compared with the actual variable curve. Light blue dots curve represents the prediction. The prediction result as obtained by this prediction model is attached in Appendix III with the Mean Squire Error **MSE = 0.28**. According to this model, the predicted value for the next step is **96.94**.

D. EXPONENTIAL SMOOTHING MODEL

The last statistical prediction method employed in this project was Exponential Smoothing Model. This analysis tool and its formula predict a value based on the forecast for the prior period, adjusted for the error in that prior forecast. The tool used

the smoothing constant *a*, the magnitude of which determines how strongly forecasts respond to errors in the prior forecast. The result is given by:

$$F_{t+1} = F_t + a(A_t - F_t) = F_t + (1 - dampFact)(A_t - F_t)$$

Where,

- F_t represents the forecast at time *t*
- F_{t+1} represents the forecast at time *t+1*
- A_t represents the actual value at time *t*

Values of 0.2 to 0.3 are reasonable smoothing constants. These values indicate that the current forecast should be adjusted 20 to 30 percent for error in the prior forecast. Larger constants yield a faster response but can produce erratic projections. Smaller constants can result in long lags for forecast values. In this project, the student chose 0.3 as the value for the *a*.
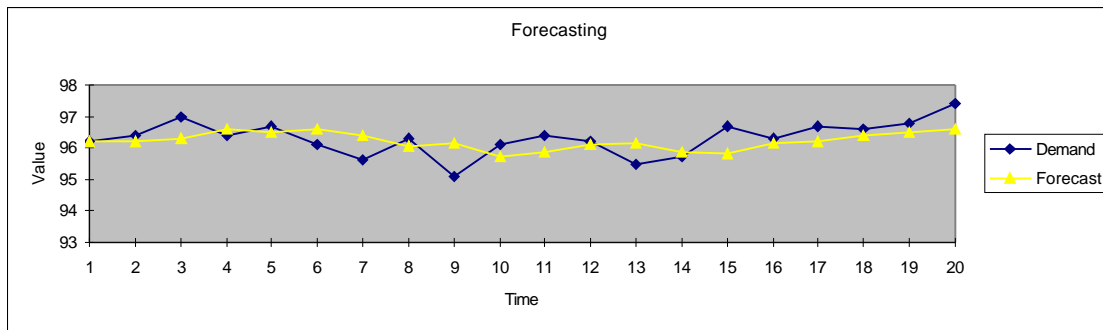
Figure 9

Figure 9 shows the prediction curve as compared with the actual variable curve. Yellow dots curve represents the prediction. The prediction result as obtained by this prediction model is attached in Appendix III with the Mean Squire Error **MSE = 0.28**. According to this model, the predicted value for the next step is **96.93**.

Actually this prediction mechanism can be generated to predict all the variables that are involved in the HVAC control system, such as the humidity, the airflow rate, the water volume in the water circulation system etc. Based on these predictions, the HVAC control system will apply the controls to each of them.

E. <u>STUDET NOTES ON AIR CONDITIONING SYSTEM</u>

As mentioned in the "objective" part, the purpose of this project was to provide information to the HVAC system to optimize the operations of the system. Based on the collected data (load parameter), the control system will predict the approximate

load of the next day at the same time point. For example, if in the past three days the loads were X Btuh, Y Btuh and Z Btuh, then, according to a certain prediction algorithm used, the control system may predict "tomorrow at that same time, the load to be Q Btuh". According to this prediction, the control system may open more hot water valve, speed up the fan to give more heat to the room just shortly before the scheduled time point, or the system may do something in the opposite direction "to obey and to optimize".

The actual load may be different from the predicted one at the scheduled time: this difference can be compensated by the control system by slightly adjusting the relevant valves or related components. The key point is that the prediction algorithm had already set a certain load range for the scheduled time point according to the "old load parameters" obtained before, so the variance in load will not be so significant to the system as to compel it to start another air conditioner or stop one in order to make the compensation.

By looking at the load formula: $L = (T1-T2)*1.08*CFM$, it was found that there are actually two parameters that can be directly controlled by the control system[2]. The T1 and the CFM. Both of them will affect the load. Problems of how to decouple these two parameters and make them controllable separately by the control system were not the topics of this project, and will not be studied further[4].
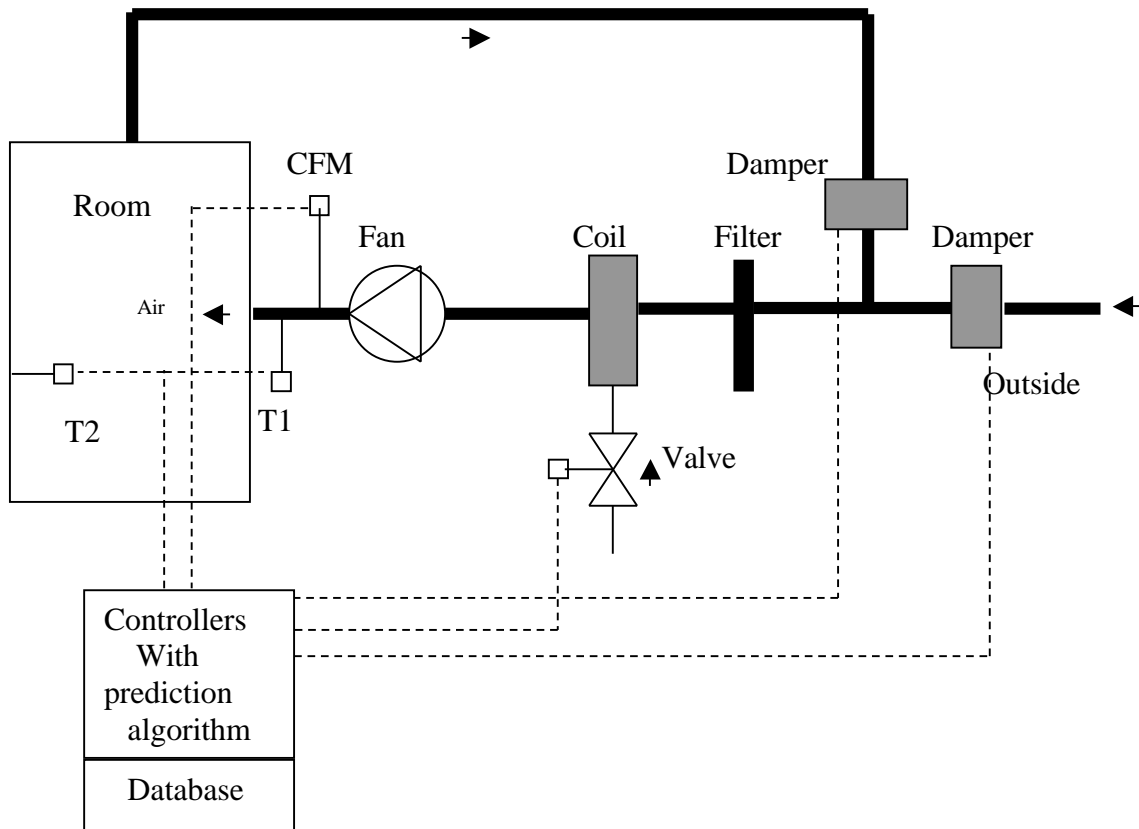
Figure 10– Diagram of Air Conditioning System

Figure 10 shows a typical air-handling unit in a certain area of the building. All dotted lines connected to controllers are the control paths through which the controllers perform the control algorithm and collect real time data. All the load data mentioned in this paper are to be used by the controllers to perform the prediction.

Summary

This project lasted sixteen weeks, wherein the student broke the projects down to four significant learning compartments consisting of conceptual phase, study phase, design phase and implementation phase. The main purpose of this project was to build a database of the load parameters of the HVAC system. Based on the acquired data, the HVAC control system could predict the load of the next day at the same time point[5]. Thus, the control system will be capable of optimizing the operations of the HVAC system by adjusting the water valves, starting/stopping the fans, running the heating exchangers as needed, in a proper order and sequence and within a proper time period. Since the prediction will give the predicted data based on the "long term and experience" intelligently[6]. Theoretically the actual variance at the time point of the next day does not expect to be very large compared with the actual value, which can be handled properly by the control unit with least effort. Then, the energy will be saved considerably[7].

A database tool on MS Excel 2000 has been developed for the data collection. This database tool can process the acquired data both by tabulated manner, and by visualization graphs as shown by the templates designed below[8].

XU BIN'S REGRESSION FORECAST MODEL

Forecasting — Regression/Trend analysis

Data / **Error analysis**

Period	Demand (y)	Period(x)		Forecast	Error	Absolute	Squared
11/08/01	96.2	1		96.10	0.10	0.10	0.01
11/09/01	96.4	2		96.13	0.27	0.27	0.08
11/10/01	97	3		96.15	0.85	0.85	0.73
11/11/01	96.4	4		96.17	0.23	0.23	0.05
11/12/01	96.7	5		96.19	0.51	0.51	0.26
11/13/01	96.1	6		96.21	-0.11	0.11	0.01
11/14/01	95.6	7		96.23	-0.63	0.63	0.40
11/15/01	96.3	8		96.26	0.04	0.04	0.00
11/16/01	95.1	9		96.28	-1.18	1.18	1.39
11/17/01	96.1	10		96.30	-0.20	0.20	0.04
11/18/01	96.4	11		96.32	0.08	0.08	0.01
11/19/01	96.2	12		96.34	-0.14	0.14	0.02
11/20/01	95.5	13		96.36	-0.86	0.86	0.75
11/21/01	95.7	14		96.39	-0.69	0.69	0.47
11/22/01	96.7	15		96.41	0.29	0.29	0.09
11/23/01	96.3	16		96.43	-0.13	0.13	0.02
11/24/01	96.7	17		96.45	0.25	0.25	0.06
11/25/01	96.6	18		96.47	0.13	0.13	0.02
11/26/01	96.8	19		96.49	0.31	0.31	0.09
11/27/01	97.4	20		96.52	0.88	0.88	0.78
Intercept	96.08			Bias	MAD	MSE	
Slope	0.02				0.39	0.26	
Next period	96.54	21			Correlation	0.24	

Figure 11--Regression forecasting results

XU BIN'S MOVING AVERGE FORECAST MODEL

Forecasting   Moving averages - 3 period moving average

Data | | | **Error analysis** | | | |
Period	Demand	Period #	Forecast	Error	Absolute	Squared
11/08/01	96.2	1				
11/09/01	96.4	2				
11/10/01	97	3				
11/11/01	96.4	4	96.53	-0.13	0.13	0.02
11/12/01	96.7	5	96.60	0.10	0.10	0.01
11/13/01	96.1	6	96.70	-0.60	0.60	0.36
11/14/01	95.6	7	96.40	-0.80	0.80	0.64
11/15/01	96.3	8	96.13	0.17	0.17	0.03
11/16/01	95.1	9	96.00	-0.90	0.90	0.81
11/17/01	96.1	10	95.67	0.43	0.43	0.19
11/18/01	96.4	11	95.83	0.57	0.57	0.32
11/19/01	96.2	12	95.87	0.33	0.33	0.11
11/20/01	95.5	13	96.23	-0.73	0.73	0.54
11/21/01	95.7	14	96.03	-0.33	0.33	0.11
11/22/01	96.7	15	95.80	0.90	0.90	0.81
11/23/01	96.3	16	95.97	0.33	0.33	0.11
11/24/01	96.7	17	96.23	0.47	0.47	0.22
11/25/01	96.6	19	96.57	0.03	0.03	0.00
11/26/01	96.8	19	96.53	0.27	0.27	0.07
11/27/01	97.4	20	96.70	0.70	0.70	0.49
			Total	0.80	7.80	4.84
			Average	0.05	0.46	0.28
				Bias	MAD	MSE
					SE	0.57

Next period   96.93

Figure 12--Moving Average Forecasting Result

XU BIN WEIGHTED MOVING AVERAGE PREDICTION MODEL

Forecasting   Weighted moving averages 3 period moving average

Data | | | **Error analysis** | | | |
Period	Demand	Weights	Forecast	Error	Absolute	Squared
11/08/01	96.2	0.33				
11/09/01	96.4	0.33				
11/10/01	97	0.34				
11/11/01	96.4		96.54	-0.14	0.14	0.02
11/12/01	96.7		96.60	0.10	0.10	0.01
11/13/01	96.1		96.70	-0.60	0.60	0.36
11/14/01	95.6		96.40	-0.80	0.80	0.64
11/15/01	96.3		96.13	0.17	0.17	0.03
11/16/01	95.1		96.00	-0.90	0.90	0.82
11/17/01	96.1		95.66	0.44	0.44	0.19
11/18/01	96.4		95.84	0.56	0.56	0.32
11/19/01	96.2		95.87	0.33	0.33	0.11
11/20/01	95.5		96.23	-0.73	0.73	0.54
11/21/01	95.7		96.03	-0.33	0.33	0.11
11/22/01	96.7		95.80	0.90	0.90	0.81
11/23/01	96.3		95.97	0.33	0.33	0.11
11/24/01	96.7		96.23	0.47	0.47	0.22
11/25/01	96.6		96.57	0.03	0.03	0.00
11/26/01	96.8		96.53	0.27	0.27	0.07
11/27/01	97.4		96.70	0.70	0.70	0.49
			Total	0.80	7.79	4.83
Next period	**96.94**		Average	0.05	0.46	0.28
				Bias	MAD	MSE
					SE	0.57

Figure 13--Weighted Moving Average Forecasting Result

XU BIN'S EXPONENTIAL SMOOTHING MODEL

Forecasting — Exponential smoothing

| Alpha | 0.4 | After trying .3, .4, .5,.6, .7, .8, .9, it is determined that ..4 is the best smoothing factor for prediction. |

Data			Error Analysis			
Period	Demand	Period #	Forecast	Error	Absolute	Squared
11/08/01	96.2	1	96.20			
11/09/01	96.4	2	96.20	0.20	0.20	0.04
11/10/01	97	3	96.28	0.72	0.72	0.52
11/11/01	96.4	4	96.57	-0.17	0.17	0.03
11/12/01	96.7	5	96.50	0.20	0.20	0.04
11/13/01	96.1	6	96.58	-0.48	0.48	0.23
11/14/01	95.6	7	96.39	-0.79	0.79	0.62
11/15/01	96.3	8	96.07	0.23	0.23	0.05
11/16/01	95.1	9	96.16	-1.06	1.06	1.13
11/17/01	96.1	10	95.74	0.36	0.36	0.13
11/18/01	96.4	11	95.88	0.52	0.52	0.27
11/19/01	96.2	12	96.09	0.11	0.11	0.01
11/20/01	95.5	13	96.13	-0.63	0.63	0.40
11/21/01	95.7	14	95.88	-0.18	0.18	0.03
11/22/01	96.7	15	95.81	0.89	0.89	0.80
11/23/01	96.3	16	96.16	0.14	0.14	0.02
11/24/01	96.7	17	96.22	0.48	0.48	0.23
11/25/01	96.6	18	96.41	0.19	0.19	0.04
11/26/01	96.8	19	96.49	0.31	0.31	0.10
11/27/01	97.4	20	96.61	0.79	0.79	0.62
			Total	1.82	8.45	5.31
			Average	0.10	0.44	0.28
				Bias	MAD	MSE

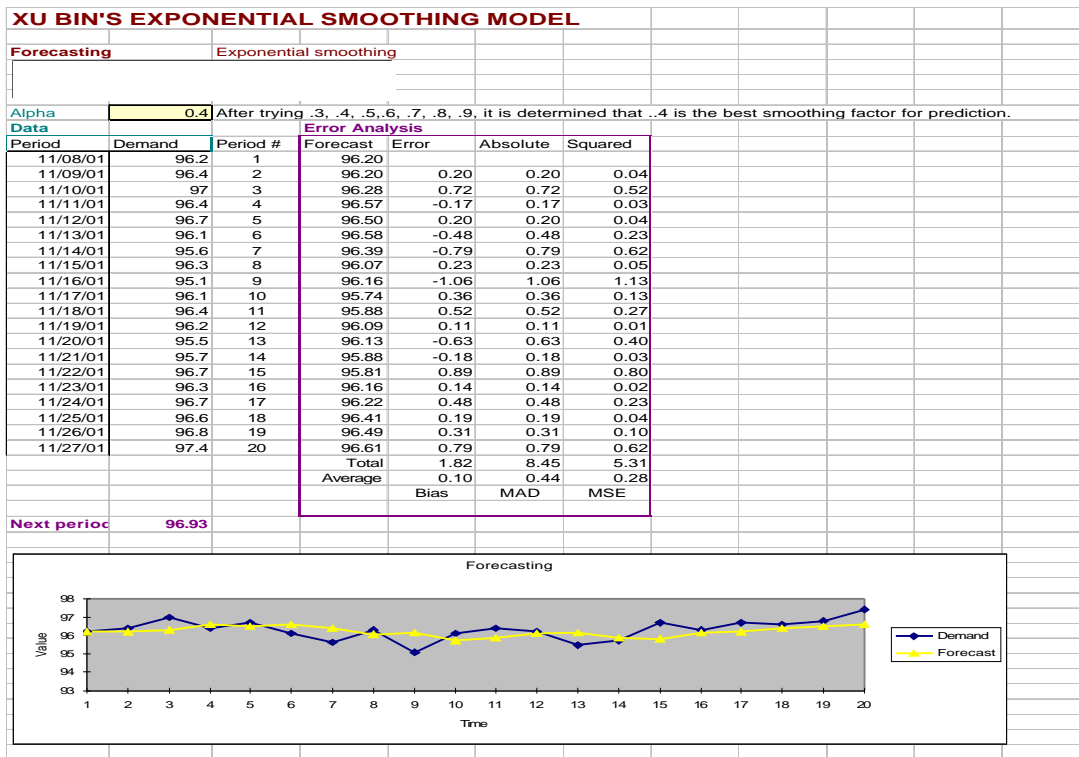| Next period | 96.93 |

Figure 14--Exponential Smoothing Model

Evaluation of Learning Outcomes

This student-project was evaluated by student, peers and the faculty member who was in charge of supervision of the project. In determining the comprehensiveness, time frames, complexity, reliability and validity of the project for leaning outcomes questions were designed from the activity level outcomes, which are enumerated below. These results of peer and instructor evaluation were tabulated after the student presented what he learned, and how he learned, and to what extent he thought the project was helpful in applying the concept using the project guidelines. The highlighted responses indicate the median responses to the behaviorally anchored question.

Peer and Instructor Evaluation of Student Projects
N (number of students)=10

SA = Strongly Agree = 5; A = Agree = 4; U = Undecided = 3; D = Disagree = 2; SD =Strongly Disagree =1 (Medians of outcomes are highlighted in red)

A. PROJECT CONTENTS (SUMMATIVE) EVALUATION

1. The overall contents of the project in all the phases were excellent

SA A U D SD

2. The student writes and explains problem identification statement clearly

<p style="text-align: right;">SA A U D SD</p>

3. The student writes and explains conception phase clearly

<p style="text-align: right;">SA A U D SD</p>

4. The student writes and explains study phase clearly

<p style="text-align: right;">SA A U D SD</p>

5. The student writes and explains design phase clearly

<p style="text-align: right;">SA A U D SD</p>

6. The student writes and explains Implementation phase clearly

<p style="text-align: right;">SA A U D SD</p>

7. The student's overall quality of work accomplished is excellent

<p style="text-align: right;">SA A U D SD</p>

8. Benefits (of learning outcomes) of this project are clear

<p style="text-align: right;">SA A U D SD</p>

B. LEARNING OUTCOMES EVALUATION

(Outcomes at the <u>Activity Levels</u> of Cognitive (C) Affective (A) and psychomotor (P) quality criteria / domains indicated as C A or P. Medians of outcomes are highlighted in red)

The lessons learned from the project was **precise**	(A)	**5**	4	3	2	1	**Imprecise**
The application aspect of the project was **decisive**	(P)	5	**4**	3	2	1	**Indecisive**
The project **applies theory**	(C)	5	**4**	3	2	1	**Does not apply**
The project **experience was coherent**	(C)	**5**	4	3	2	1	**Incoherent**
The project **lessons were well prepared**	(A)	**5**	4	3	2	1	**Not well prepared**
The project **lessons were well organized**	(A)	5	**4**	3	2	1	**Not well organized**
The project **development steps were very clear**	(C)	**5**	4	3	2	1	**Not very clear**
The project **development steps were easy to apply**	(P)	5	**4**	3	2	1	**Not easy to apply**
The lessons learned from the project were **motivating**	(A)	**5**	4	3	2	1	**Not motivating**
The project made me **feel confident**	(A)	5	**4**	3	2	1	**Not confident**
I really **enjoyed** the lessons learned from the project	(A)	**5**	4	3	2	1	**Did not enjoy**

Reference:

1. Angus, R.B. (2001). Planning, Performing, and Controlling Projects, Prentice Hall, Upper Saddle

2. Mull, T.E. (1998). Introduction to heating, ventilation and air conditioning, ASME Press

3. ASHRAE (1999) Handbook of Fundamentals, ASHRAE CRC pub.

4. Sauer, H. J., Gidh Y (1999). ASEE Conference Proceedings, Building energy analysis software

5. Forsberg C. H. (1999). ASEE Conference Proceedings, Use of computer in undergraduate HVAC design.

6. Kim H. W, Kamal A. K. (1999). ASEE Conference Proceedings, Desiccant dehumidification in air conditioning for a large commercial building.

7. Swedish, M. J., (2000). ASEE conference Proceedings, Development of a psychometric test chamber.

8. MS Excel 2000. 24 hours programming. Microsoft Office Handbook, 2000.

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