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Longitudinal Study of Factors Impacting the Implementation of Notebook Computer Based CAD Instruction

Richard F. Goosen

Western Michigan University

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LONGITUDINAL STUDY OF FACTORS IMPACTING THE IMPLEMENTATION OF NOTEBOOK COMPUTER BASED CAD INSTRUCTION

by

Richard F. Goosen

A Dissertation Submitted to the Faculty of the Graduate College in partial fulfillment of the requirements for the Degree of Doctor of Philosophy
Department of Educational Leadership, Research, and Technology
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Western Michigan University
Kalamazoo, Michigan
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LONGITUDINAL STUDY OF FACTORS IMPACTING THE IMPLEMENTATION OF NOTEBOOK COMPUTER BASED CAD INSTRUCTION

Richard F. Goosen, Ph.D.
Western Michigan University, 2009

This study provides information for higher education leaders that have or are considering conducting Computer Aided Design (CAD) instruction using student owned notebook computers. Survey data were collected during the first 8 years of a pilot program requiring engineering technology students at a four year public university to acquire a notebook computer for a class formerly conducted in a conventional computer laboratory. Data from 148 students was used to develop five metrics which are described and quantitatively evaluated: (a) student preference for notebook computer instruction, (b) student perception of learning, (c) out of class hands-on operating time, (d) economic impact of the notebook computer purchase, and (e) the severity of operational problems experienced.

The results of the study indicate that all measures evaluated did not exhibit significant variation during the period of the study. Students preferred notebook computer instruction primarily because of added flexibility and they perceived learning more in these classes relative to classes conducted in a conventional computer laboratory. Students used their computer on class related activities for 2.1 hours outside of class for each hour of in-class time. The study
uses a unique method to determine the economic impact experienced by students in obtaining the required notebook computer and establishes that students spent an average of $631 more than necessary despite identifying cost as their most significant area of concern. Operational problems, as reported by students, were found to be few in number and severity. The quantitative findings of the research are supported and expanded by student comments and a separate survey of faculty with direct experience teaching the class evaluated.

Extending upon prior studies addressing factors important to previous notebook computer implementations, this research describes the value of using similar metrics in future implementations of both student owned notebook computers as well as other new technologies. A number of recommendations for such future applications are provided for higher educational leaders.
ACKNOWLEDGEMENTS

I would like to thank my committee members, Dr. Louann Bierlein Palmer, Dr. Mark Curtis, and Dr. Brian Horvitz for their contributions as members of the dissertation committee. I would also like to thank Randy Stein and Bill Koepf for their expertise and support of notebook computer based, solid modeling instruction. The contributions of Dr. Nate Tymes and Dr. Elies Kouider of the Applied Statistics Team in reviewing the statistical analysis elements of this study are gratefully acknowledged. Finally I wish to thank Marjorie for her personal and professional support at many critical moments during this endeavor.

Richard F. Goosen
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CHAPTER 1
INTRODUCTION

Continuing improvements in notebook computer performance coupled with significant reductions in their cost have influenced a number of colleges and universities to require student owned notebook computers and integrate them into existing curricula. Beginning with the University of Minnesota at Crookston in 1995 (Sergeant & Svec, 2003), the number of schools implementing this change has grown progressively until at least 36 universities were committed to some type of notebook computer based instruction by 2003 (Finn & Inman, 2004). More recently, in 2006, at least 150 colleges and universities required students to obtain a notebook computer (Carnevale & Young, 2006) and a summary list of such institutions in 2008 numbered approximately 244 worldwide (Brown, 2008). The implementation of notebook computer based instruction has been driven by a variety of motivations and has presented a number of challenges to higher educational leadership. In addition there have been a variety of implementation strategies employed, with varying degrees of success, that must be evaluated when the faculty and administration of an institution consider making this type of change. The primary question that must be that must be of paramount importance is “Can technology strengthen the university and its faculty, or will it undermine the enterprise?” (Gregorian, 2005, p. 88).

There have been a number of motivating factors identified as influencing higher educational institutions to implement notebook computer based instruction. Originally the most common motivation identified was to enhance the image of the institution. This was the case for the pioneering University of Minnesota at Crookston
(Sergeant & Svec, 2003), as well as subsequent implementations at the University of North Carolina (Newby, 2003) and San Jose State University (Brieling, 2004). An additional motivating factor has been cost reduction. In the case of the University of North Carolina at Chapel Hill, reductions in state funding led to the elimination of existing desktop computer laboratories by replacing them with student owned notebook computers (Carnevale, 2003). This effectively shifted significant technology costs from the institution to the individual student. Institutions requiring student owned notebook computers also receive the benefit of eliminating the significant expense associated with the disposal of used computing equipment (Carlson, 2003). The educational impact of notebook computer based instruction is also frequently cited as a motivating factor. As stated by Bierling (2004), notebook computers allow “anytime, anywhere learning” (p. 47). In addition many experts feel that requiring all students to have their own notebook computer, with the purchase of required equipment supported by financial aid, levels the technological playing field (Weigel, 2002).

While there are a number of positive motivating factors that have influenced higher educational institutions to implement notebook computer based instruction, there are a number of other factors college or university leaders must consider in making the change. While computer hardware cost savings are an obvious benefit, a successful student owned notebook computer implementation often requires additional technical support. In addition, individual student notebook computers can increase network security expenses (Foster, 2004). Organizational resistance to the
use of individual notebook computers can also be problematic according to Morgan (1997):

The fact that technology has a major impact on power relations is an important reason why attempts to change technology often create major conflicts between managers and employees and between different groups within an organization, for the introduction of new technology can alter the balance of power. (p. 184)

Higher education leaders considering significant technological changes therefore must consider methods to reduce barriers. Pilot programs, restricted to a specific college or academic program, have been used to reduce conflict by providing experimental performance measures that can be accepted by institutional stakeholders as a valid indicator of future costs and benefits (Bolman & Deal, 1997). Without this means to influence faculty to incorporate notebook computers within the curriculum, the financial burden to students can become a very visible unjustified expense (Corwin, 1998).

Hardware and software factors often produce unplanned results within an institutional conversion to notebook computer based instruction. While improved classroom capacity and effectiveness can be gained by the reduction or elimination of dedicated computer laboratories (McKimmy, 2002), the constant degree of technological change and the wide variety of hardware and software requirements involved can negatively impact a notebook computer implementation. This is particularly true in more technical curriculum such as Computer Aided Design (CAD) which utilize software programs requiring higher speed graphics capability and larger
display screens. Since notebook computers have only recently reached the hardware performance levels necessary to support CAD instruction, these classes have been typically excluded from university wide notebook computer policies. More recent implementations such as the University of Oklahoma (Kolar, 2002) and Vanderbilt University (Shiavi, 2005) have, however, been successful incorporating notebook computers into their engineering curriculum.

Historically the number of desktop personal computers sold nationally has exceeded that of notebook computers. As recently as ten years ago, an evaluation of relative capability and flexibility with respect to cost for higher education found that desktop computers were a better value (Grier, 1998). This difference has been steadily decreasing, however, with notebook hardware prices dropping at a much higher rate than that of desktop computers (Sidener, 2005). Driven by a strong preference among students for the portability offered by notebook computers (Sidener), it is likely that an increasingly larger number of students will arrive on campus with personally owned notebook computers. The challenge for higher educational leadership is to effectively capitalize on this transition by planning curriculum changes to facilitate an effective improvement in the learning environment.

While there has been a continuing research interest in evaluating various aspects of these relatively new notebook computer programs within higher education, the literature review for this study reveals that the research completed to date has typically consisted of qualitative evaluations of limited duration. Since the use of notebook computers for CAD classes has lagged the initial implementation of
notebook computers in higher education, research covering this aspect of notebook computer use is extremely limited to date. This has created a lack of useful information available for evaluation by higher educational institutions and their leaders considering, or in the process of implementing, CAD instruction using student owned notebook computers. In addition, institutions which have implemented CAD instruction using notebook computers have lacked the information necessary to improve their initial implementations. Finally since new technologies can be expected to appear and impact higher education in the future, research information describing and documenting the implementation of notebook computers can be leveraged to develop strategies and timing for the implementation of other future technological advances.

Purpose

This research examines the implementation of student owned notebook computers within a CAD-based curriculum at a four year institution in the Midwest. It examines data collected during the first 8 years of an implementation tracking a number of variables over time. The research is based on a conceptual foundation of leadership and organizational theory as well as learning theory. While organizational characteristics and the leadership environment indicate that a variety of implementation strategies for the introduction of new technologies such as notebook computers can be successful, the use of appropriate metrics to plan timing and to reduce organizational resistance to change is appropriate for many institutional settings. A number of metrics applicable to facilitating institutional change are presented as part of this study. Applicable organizational systems theory is addressed
by evaluating the balance between cost and performance measures over time as a means to avoid premature and/or inappropriate implementations of new technology. While the research does not provide an objective evaluation of the impact of notebook computers on the amount of learning achieved, it includes measures that provide the means to explore whether an implementation facilitates an improvement in the educational experience according to the learning theory appropriate to the instructional environment and objectives.

Within its conceptual framework, this research is specifically focused on providing information for higher education leaders that have or are considering implementing student notebook computer based curriculum. Specifically concerned with CAD instruction using student owned notebook computers, this study provides various metrics as documented by classroom survey data collected over multiple years following the implementation of a pilot program at a four year public university. This information is analyzed with the objective of providing higher educational leaders at similar institutions with the information necessary to implement this type of technological change. In addition the research provides leaders planning a future implementation with strategic information to assist in the development of policies necessary to ensure the success of their programs.

The longitudinal aspect of this research permits the evaluation of trends in various factors critical to the implementation of new CAD-based notebook computer instruction. This information could be used to determine if a similar pilot program might be an appropriate means to help build centers of organizational support necessary for larger scale implementations. By examining the initial and evolutionary
reactions of students to the implementation, this research offers predictive insight regarding the optimum timing for launching such programs and in defining realistic institutional goals to be achieved over time. An important supporting objective is to evaluate the interrelationship between the various metrics used in the research as a means to avoid potential problems as identified by various system archetypes. A representative example of this would be the evaluation of the actual financial burden to students and the relationship between cost impact and operating performance. This analysis can assist in developing notebook computer hardware requirements that optimize cost and performance for notebook computer based classroom CAD instruction without creating the systems level problem of performance requirements beyond adequate student resources.

Competency in CAD requires a significant amount of computer time operating a specific CAD software application in order to develop mastery in accurately representing the designs to be modeled. The value of active learning and time on task for CAD instruction, dictated by learning theory, is required according to the principles of good practice for undergraduate education (McVay, 2005). Traditional instruction in computer laboratories limits this student hands-on learning to class time and open laboratory sessions. CAD instruction utilizing student owned notebook computers expands student access to a level of 24/7 availability and allows students to develop their skills at a time and place of their choosing. Given the importance of operating/practice time on skill development, this research evaluates the amount of time students spend operating the CAD software outside of class. In addition, this
research evaluates if the student perception of learning exhibits a relationship to hands-on learning as indicated by out of class operating time.

The costs associated with computing resources and their associated infrastructure is of significant importance. At the most fundamental level, the cost advantages an institution can achieve in requiring students to own their own notebook computers must be supported by having this shift of instructional expense to be within the financial resources of the institution’s student population. Over time the use of computers on campus has become widespread primarily as a result of increased capability and reduced costs of hardware and software. Notebook computers have followed this path and, consistent with the implementation histories of other technological advances, they have become a pervasive aspect of campus life ("Death of the desktop", 2007). Once student ownership is mandated, however the cost of the notebook computing hardware becomes a consideration in evaluating the acceptability of the requirement’s cost impact (Cooke, 1995). The research includes a measure of the economic impact of requiring students to obtain their own notebook computer for CAD-based classes in order to avoid a critical depletion of this resource and a systems level failure of the organization.

When implementing CAD-based instruction using student owned notebook computers, the proper operation of hardware and software could be reasonably expected to be related to the level of student acceptance of this type of instruction. On this basis, to maintain student acceptance, the computational and graphical demands of CAD software must be established to be within the capabilities of the notebook computers purchased by students. Should the notebook computer hardware available
to students be inadequate, operational problems can result and potentially impact the level of student satisfaction (Carnevale & Young, 2006). This research measures the student perceived level of operational problems experienced and relates this measure to the student expressed preference regarding notebook computer instruction.

Although the information evaluated by this research will be most useful in directing the incorporation of notebook computers for CAD instruction, it is also probable that its results will prove useful for the introduction of future technological advances into higher education. As described by Hannah (2000) there will be a continuing need to incorporate learning technologies into the strategic thinking of universities in order to provide students with increased access to relevant educational content. The concurrent changes of the decreasing cost of new technologies and the increase in its availability within education and the society overall will be of vital importance in planning the introduction of these technologies into colleges and universities.

Research Questions and Research Design

The institutional setting for the study is a four year public university of approximately 12,500 students located in the northern midwest region of the United States. The institution sponsoring the notebook computer program evaluated, referred to as the Subject University (SU), has maintained a regionally recognized position in applied technical education since 1884 including the mechanical design area of study targeted by this research. The CAD class examined in this research required all students taking the course to provide a notebook computer as part of an exploratory pilot program approved by the SU administration beginning in the 2000 – 2001
academic year. The primary motivation for the faculty (including the researcher) in implementing this change was to facilitate student access to critical instructional software and to improve student learning by increasing the opportunity for hands-on learning. The survey information evaluates the existing data base for learning impact as well as other relevant factors longitudinally from the initial implementation of the program until present.

The research evaluates eight years of existing class survey data taken from a short self-administered exit survey completed by students completing the targeted CAD class utilizing solid modeling software. An example of a typical survey is presented in Appendix A. This information had been collected as part of the program implementation and evaluation process, but was never carefully analyzed. All classes included in the survey database required each student to provide a suitable notebook computer to be used in class and for completing homework assignments outside of class. Each class consisted of students typically classified as third year and enrolled in the course as a specific requirement to complete a four year degree in Product Design Engineering Technology. A total of 148 sets of student survey data, comprising all students completing this class over the eight year period, were used in the research as shown in Table 1. For the purpose of analysis, the available data was placed into three groups: Early implementers (from the first three years of the pilot program), Intermediate implementers (from the middle two years) and Recent implementers (from the most recent three years of the program).
Table 1

Available Survey Responses by Year Group

<table>
<thead>
<tr>
<th>Survey Date</th>
<th>Responses</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>34</td>
<td>Early</td>
</tr>
<tr>
<td>2002</td>
<td>11</td>
<td>Early</td>
</tr>
<tr>
<td>2003</td>
<td>30</td>
<td>Early</td>
</tr>
<tr>
<td>2004</td>
<td>14</td>
<td>Intermediate</td>
</tr>
<tr>
<td>2005</td>
<td>19</td>
<td>Intermediate</td>
</tr>
<tr>
<td>2006</td>
<td>15</td>
<td>Recent</td>
</tr>
<tr>
<td>2007</td>
<td>10</td>
<td>Recent</td>
</tr>
<tr>
<td>2008</td>
<td>15</td>
<td>Recent</td>
</tr>
<tr>
<td>Total</td>
<td>148</td>
<td></td>
</tr>
</tbody>
</table>

The class survey data used for the research is descriptively analyzed individually for meaningful trends and characteristics and then analyzed jointly as appropriate to answer the following research questions.

Research question 1: During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in:

(a) expressed student preference for CAD classes conducted using notebook computers; (b) student's self-evaluated perception of learning in notebook computer CAD instruction; (c) active learning as indicated by out of class operating time; (d)
economic impact in obtaining the required notebook computer hardware; and (e) operational problems in operating CAD software on notebook computers.

Research question 2: During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there any statistically significant changes in the relationship between the following: expressed student preference for CAD classes conducted using notebook computers and the student’s self-evaluated perception of learning in notebook computer CAD instruction.

Research question 3: During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationships between the expressed student preference for CAD classes conducted using notebook computers and each of the following measures: (a) active learning as indicated by out of class operating time; (b) operational problems in operating CAD software on notebook computer; and (c) economic impact in obtaining the required notebook computer hardware.

Research question 4: During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationships between the student’s self-evaluated perception of learning in notebook computer CAD instruction and each of the following: (a) active learning as indicated by out of class operating time; (b) operational problems in operating CAD
software on notebook computers; and (c) economic impact in obtaining the required notebook computer hardware.

Research question 5: During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationship between the following; (a) active learning as indicated by out of class operating time and operational problems in operating CAD software on notebook computers; (b) operational problems in operating CAD software on notebook computers and the economic impact in obtaining the required notebook computer hardware; and (c) active learning as indicated by out of class operating time and the economic impact in obtaining the required notebook computer hardware.

Research question 6: To what extent, if any, did the perceptions of students taking CAD classes utilizing notebook computer based instruction changed during the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction as indicated by (a) their most commonly expressed advantages and (b) their most commonly expressed disadvantages of such instruction.

Using the survey database, variables for analysis were developed from specific survey questions and then analyzed to answer the research questions as described in Table 2.
Table 2

*Research Questions and Variable Assignment*

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Dependent Variable(s)</th>
<th>Independent Variable(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preference for notebook computer instruction</td>
<td>Year Group</td>
</tr>
<tr>
<td>2</td>
<td>Preference for notebook computer instruction</td>
<td>Perception of Learning Year Group</td>
</tr>
<tr>
<td>3</td>
<td>Preference for notebook computer instruction</td>
<td>Out of Class Operating Time Year Group</td>
</tr>
<tr>
<td>4</td>
<td>Perception of Learning</td>
<td>Year Group</td>
</tr>
<tr>
<td>5</td>
<td>Out of Class Operating Time</td>
<td>Operational Problems Year Group</td>
</tr>
<tr>
<td>5</td>
<td>Out of Class Operating Time</td>
<td>Economic Impact Year Group</td>
</tr>
<tr>
<td>5</td>
<td>Operational Problems</td>
<td>Economic Impact Year Group</td>
</tr>
<tr>
<td>6</td>
<td>Student Perceptions</td>
<td>Year Group</td>
</tr>
</tbody>
</table>

The research method used is survey based and non-experimental. Since the stated research tests the relationship between several numerically represented variables using primarily closed end questions, the selected research approach is quantitative (Creswell, 2003). The survey strategy for this research was both
convenience and purposeful in nature since all students taking the subject course were required to complete the survey instrument. The survey data is not stratified since no background information was collected as part of the survey to enable differentiation based on gender, sex or other background factors. The methodology used includes the analysis of descriptive statistics on relevant survey responses as well as trend analysis to evaluate changes occurring since initial implementation. An evaluation of correlations between variables is performed followed by an analysis to determine statistical significance as required by the research questions presented. The analysis also includes the evaluation of the interaction between variables where appropriate.

The survey instrument used for this research also offered the opportunity for students to provide a limited number of open ended responses regarding classes conducted using student owned notebook computers. These responses are presented and evaluated to provide confirmation and explanation of the quantitative findings. This methodological triangulation between quantitative measures and open ended qualitative student responses provides a limited indication of the validity of the research results (Bogdan, 2003).

In addition to the student survey instrument, a second survey instrument was developed to solicit information regarding the perceptions and observations of faculty members with direct experience teaching the subject course. Because of the small number of faculty available (2), the information obtained from the faculty survey instrument is used to enhance the understanding of the results of the student survey information but not used in the quantitative analysis of the student information. A secondary purpose of the faculty survey instrument is to provide an understanding of
the institutional motivations associated with the implementation of the notebook computer initiative.

Conceptual Framework

The conceptual framework constituting the basis for this research addresses the application of various leadership and organizational theories to the implementation of new technologies within higher education. In addition the research on the implementation of notebook computer based CAD instruction is based on various learning theories applicable to technical instruction at the post-secondary level. These theoretical foundations are of significant value in understanding the pedological basis for notebook computer based instruction as well as the nature of its implementation strategies. A descriptive conceptual framework for the study is provided as figure 1.
A number of systems level problem areas can develop during the implementation of new technologies. The competition between higher educational institutions can influence their decision to implement new technologies such as notebook computer based CAD instruction prematurely and/or without adequate preparation. Institutions which are primarily using the implementation of technology
to increase institutional prestige, such as the University of North Carolina notebook computer initiative (Newby 2003), frequently experience difficulties such as forcing the use of notebook computers in classes which are not adaptable to such a format (Hall, 2003), and negative reactions to the costs of the technology (Corwin, 1998). The competition to gain an advantage in institutional image over other institutions to the extent that it drives the improper or premature implementation of new technology is an example of the escalation archetype described by Senge (1994). A similar relationship between notebook computer implementation and systems level institutional problems can be observed when the increasing costs experienced by the students required to purchase notebook computer hardware for classes becomes excessive when added to other costs imposed by the organization. This archetype, described as a 'Tragedy of the Commons' by Senge, occurs when the amount of financial support available for students (the 'commons') reaches a critical limit as the aggregate costs imposed by notebook computers, tuition, books, student services and living expenses becomes excessive.

The need to avoid the negative effects of unjustified technology escalation as the limits of student financial capability are examined in this study by the evaluation of operating performance as reported by students and the level of discretionary spending present in the student notebook computer purchase. By measuring operating performance, an indication of the escalation of technology beyond the operational limits of the software and hardware required for CAD instruction is developed. The discretionary spending content of student notebook computer purchase was used to determine how closely the need to purchase necessary notebook computer hardware
approaches the limits of the undergraduate student budget. The longitudinal nature of this study allows an evaluation of these effects during the time period since initial implementation. By evaluating both the economic and performance factors in the study, the relationship between expenditure and performance is explored, providing valuable information for leaders in establishing requirements that define the cost performance relationship.

The nature of each notebook computer implementation must be consistent with the characteristics of the organization. Higher educational leadership must consider the context or frame of their organization as described by a number of organizational and/or leadership theorists when planning their implementation strategy. In an institution with a formal leadership environment, the decision to implement a notebook computer based curriculum can be made largely by the organization’s leaders (Bolman & Deal, 1997). In such an environment, however, it is important for the decision makers to clearly show how that decision was made by a rational evaluation of organizational goals. In organizations better described as operating in a cultural or symbolic leadership environment, it is important to carefully link the decision to implement with core institutional values (Bolman & Deal; Bush, 1995). Leaders considering implementation of technological change in organizations best described as collegial are required to take a more indirect approach. In these organizations it is important to inspire support for change by linking the change to a core belief or value embraced by the organization (Bush). One common method to do this has been to emphasize the consistency of the change with creating or maintaining a ‘leading edge’ organizational image. The most complex organizations in which to
implement technological change are those institutions which present a highly political leadership environment. In such organizations it is be necessary to build centers of organizational support. Within the context of this research, institutions implementing notebook computer programs often do so on a trial basis, using the part of the institution that is most likely to embrace the change as a trial case. This was done successfully at Vanderbilt (Shiavi, 2005) and the University of Oklahoma (Kolar, 2005) by initially requiring notebook computers only within their Colleges of Engineering. The successful results of the initial implementation can then be used as a source of political power to justify campus-wide change at a later date (Bolman & Deal).

Organizations implementing technological change are one area of focus in Diffusion Research which can evaluate how innovations are communicated over time within an organization. One of the five innovation characteristics identified by Rogers (1995) is observability which predicts that innovations with observable results are adopted more easily and quickly. Suitable metrics are needed to monitor the change process in order to provide observable results which can be used to modify the implementation process and/or to document its results. This study examines two critical elements of the subject pilot program as fundamental indicators of its results. Student satisfaction is evaluated using their stated preference for notebook computer based instruction and their perception of learning as obtained from the student survey responses. In addition, the relationship between these measures is explored over the longitudinal scope of the study. In this way an exploration of metrics likely to be of
use in implementing technological change is made available for future leadership
decision making in a variety of higher educational organizations.

The motivation to implement based CAD instruction can be based on a
number of educational theories. Notebook computer based CAD classes allow a
significant amount of student learning to occur outside the laboratory. Unlike classes
conducted within a computer laboratory, student access to the hardware and software
necessary to learn is not restricted to class periods. This unlimited availability allows
students to manage when and where they learn and allows students to expend
additional time to master concepts introduced during class or to go beyond required
course content. Requiring students to plan the way the learning is to occur prompts
the development of metacognitive thinking skills important for life-long learning
(Phelps, 2001). CAD instruction using notebook computers can encourage and
facilitate learning outside of class and create the opportunity to emphasize several
critical elements of experiential education. The theoretical elements of experiential
learning that are likely to result from a notebook computer implementation such as
described in this research include (a) a structured experience that requires the learner
to take initiative, make decisions and be accountable for results, (b) personal learning
outcomes that form the basis for future experience and (c) providing opportunity for
spontaneous learning ("What is experiential education?", 2007). The research
addresses the impact of notebook computer based instruction on these elements of
educational theory by measuring student evaluated out of class time spent operating
the CAD software used during the pilot program.
Significance of the Research

This research provides a number of benefits for higher educational leaders involved in the implementation of new technologies. Implementations involving student owned notebook computers within academic programs with significant CAD content may receive the greatest benefits, in that this research provides current information defining and describing the critical parameters involved in such implementations. Because these parameters are based on emerging technology, they are not stable and can change significantly over time. The initial information used by leaders within higher education to plan the implementation of new technologies must be based on accurate measures of current conditions and this research provides such information. An example of this is the evaluation of hardware cost and the actual impact of that cost on student educational budgets, both of which can change significantly from year to year.

Equally important to the contemporary measurement of important implementation parameters is an evaluation regarding the volatility of those metrics. Based on the longitudinal nature of the research presented in this study, leaders may be better able to anticipate which policies and procedures based on various measures are required to change, as well as using the research to determine how rapidly these changes will occur. The analysis presented also provides information relating to the interrelationship between the various parameters of implementation and how the linkages between these parameters can be expected to change over time. For example, an evaluation of student hardware cost incurred in obtaining a notebook computer evaluated with respect to reported operational problems can be used to determine if
the expense incurred to obtain greater hardware capability is justified by more
trouble-free performance.

Perhaps the most significant benefit is that this research provides information
to empower leaders to implement new technologies in a timely manner, with less
negative impact to the institution and its stakeholders. Technology has a major impact
on the power relations within an institution and therefore attempts to change
technology can create significant organizational conflict (Morgan, 1997). The use of
pilot programs such as the one described by this research can reduce this conflict by
providing a research based foundation effective in developing organizational
acceptance (Bolman & Deal, 1997). The research may also be of use to higher
educational leaders developing measures of accountability necessary to support
technology driven change from a position of information and expertise.
The most general benefit of the study is it’s ability to provide insight, beyond
implementing student owned, notebook computer based, CAD instruction, to the
implementation of other future technologies. The evolution of the notebook computer
technology described here, initially involving high cost, limited utility and a low level
of acceptance within the subject population, and developing over the time period to
reduced cost, increased utility and wider acceptance, can be expected to be repeated
with other new technologies relevant to higher education. Electronic calculators,
desktop computers and notebook computers reflect a continuing technological
evolution requiring advanced planning and accountability for efficient
implementation. This research provides a documented example applicable to
managing future transitions of this nature.
Definition of Terms

Several terms used in this study are defined as follows:

**CAD**: A mnemonic label for Computer Aided Design in which the graphical representations for products and components are created using a digital computer.

**Course survey**: A survey instrument completed by all students in each class of CAD instruction conducted as part of the pilot program used for this study.

**Desktop computer**: A digital computer operated at a fixed location with a separate display screen (referred to as a monitor) and keyboard.

**Economic Impact**: For purposes of this study, the difference between the prevailing retail cost (PRC) and the amount spent to obtain a notebook computer with requisite capabilities as reported by student participants in the pilot program.

**Notebook computer**: A portable digital computer usually weighing less than 20 pounds having an integrated keyboard and display screen. Alternatively referred to as a laptop computer.

**Personal computer (PC)**: A digital computer originally designed (circa 1982) to have reduced computational capabilities but with a cost suitable for purchase and use by private individuals.

**Pilot program**: For purposes of this study, students during the period of the study receiving CAD instruction using a notebook computer which they were required to provide.

**Prevailing Retail Cost (PRC)**: For purposes of this study, the approximate minimum retail cost of a notebook computer with requisite capabilities prevailing at
the time the student participants in the pilot program were required to obtain this equipment.

*Subject University (SU):* For purposes of this study, the public university sponsoring the pilot program and the classes used as the basis of this research.

*Three dimensional solid modeling software:* CAD software used to develop technical drawings using composite volumes rather than surface representations.

**Limitations and Delimitations**

This research is delimited to evaluating regional notebook computer impact on a solid modeling CAD course within one post-secondary setting. Since the survey database includes all students who took this notebook computer based CAD course since the start of the pilot program at SU, the data does not reflect a random sampling of students involved in such courses on a national level. Therefore the results of the research, while providing an accurate measure of the students participating at SU, cannot be inferred to be generalizable to other student populations completing notebook computer based CAD instruction. It is also significant that, within post-secondary education, the student subjects of this research have completed at least 60 semester credit hours. Significant differences such as the level of student maturity and the level of commitment to their selected academic program are likely to separate the upper level university students used in this study from various notebook computer based programs at the secondary level such as those described by Manchester (2004) and Belanger (2000) and two year institutions such as community colleges.

The relatively small (148 records) size of the survey database used is an acknowledged limitation of the research. Although all students in the subject group
were offered the opportunity to complete the survey as part of a course evaluation, a number of responses were incomplete and/or inconsistent. This means that at least a degree of non-response bias (Light, 1990) may be present. In addition, variation in how students interpreted the questions presented could create a measurement error that could compromise the validity of the results. It should be noted, however, that notebook based CAD instruction is a relatively new phenomenon and that the survey database used here, while small, would be significant relative to the small numbers of students involved in such instruction on a national level.

An important element in the student perceptions central to this research is the amount of experience participating students have had with CAD instruction conducted in conventional desktop computer laboratories prior to experiencing notebook computer based instruction. Because of course pre-requisites, all students surveyed in this research have completed at least one CAD course in a conventional computer laboratory. While no students are known to have had any form of notebook computer based instruction prior to participating in the pilot program, there is wide variation between students in the number of CAD courses completed in a conventional computer laboratory setting. An evaluation of the effects of the amount of prior CAD instruction is not a part of the research. It is also important to note that the research does not include an objective comparative assessment of the actual learning effectiveness of notebook computer based CAD instruction since all students involved used notebook computers and no control group was available for comparison.
The responses of the faculty, obtained by survey after the completion of the eight year period of the study, are a possible source of error in that human memory and perceptions may have been impacted by the passage of time. This inaccuracy in recall data collected after the fact can limit the ability to identify the timing of specific observations and is an acknowledged area of difficulty in the study of the diffusion of innovations (Rogers, 1995). This limitation is of lesser importance in this research however because the primary basis of the study is student, not faculty, survey information and this information was collected in each year of the study.

The use of quantitative based research to investigate the research questions introduces some limitations into its findings. Since the predominant portion of the study is based on numeric responses to the specific questions presented, the depth of response is limited relative to that which would have been available using a qualitative research methodology such as a case study. This research has addressed this limitation by providing each respondent the opportunity to reply to a small number of open-ended questions present in the survey instrument. Responses to these questions are used to detect factors relevant to the study but not evaluated quantitatively.

The eight year duration of the research introduces the possibility of unevaluated confounding variables being developed during the period of the research. The survey instrument supporting this research has remained largely unchanged since its first use in 2001. Since that time, there have been a number of changes in computer hardware capability and software as well as the degree of acceptance of new technology within the student population studied. Although these factors are
known to be potentially causal, it is also possible that other factors not evaluated in
the survey database or considered in this research could impact its results. It is
anticipated that the open ended responses referred to in the prior paragraph can be
used to identify any such factors.

Chapter 1 Summary

The transition of computer based instruction from conventional desktop
computer based laboratories to notebook computers is a relatively recent development
in education. The unique advantages it offers to higher education such as reduced
operating cost, improved classroom flexibility and the opportunity to facilitate a
number of established learning methodologies will continue to make the transition an
area of interest for institutional leaders. Although supported by various educational
pedagogical theories and increasingly more accepted by a student population with
greater access to and experience with a wide variety of computer technology, the
implementation of major changes within an institution can be problematic. The need
to plan the timing, organizational preparation, changes in technical infrastructure and
supporting policies is critical to a successful transition from conventional computer
laboratories to individual notebook computers.

The research presented here provides two significant benefits to leaders of
higher educational institutions. The primary benefit is the presentation of data on a
number of critical parameters collected during an actual implementation of notebook
computers and the use of this data to answer a number of research questions highly
relevant to the development of a successful implementation plan. A secondary benefit
is the insight provided as to using a pilot program and its monitored results as a
means to facilitate the implementation of technological change within a representative higher educational organization. Perhaps the most unique aspect of the research is that it provides a longitudinal, eight year overview of the implementation of new technology from its initial inception to a mature and institutionally accepted state. Although specifically concerned with the transition of computer laboratory based CAD instruction to notebook computer based instruction, the research presented is likely to also be illustrative of a number of past and future implementations of new technology within higher education.
CHAPTER 2
LITERATURE REVIEW

The literature review for this study begins with a brief overview of the development of notebook computer programs in higher education since the earliest recorded implementations in 1995 until present. This element of the literature review establishes the complexity involved in developing these programs and the changes that have occurred in their implementation goals and methodologies. A number of the most significant motivations and justifications identified by institutions and their leaders for initiating notebook computer programs are examined to provide a framework for evaluating the degree of program success. The most significant problems and issues in notebook computer implementations are presented in order to reveal the difficulties experienced by higher educational institutions and their leaders in implementing notebook computer programs. The identification of the program motivations and problem areas are linked to the need for institutional leaders to communicate clear objectives for change, and to ensure that those objectives are attainable based on an assessment of the technical and organizational climate for the implementation. Supporting metrics useful to establishing that the motivations and objectives of an implementation are feasible are suggested. These accountability measures are established as useful in monitoring critical areas for notebook computer programs after the initial implementation.

The theoretical basis of this research is established by a review of existing literature describing the leadership theory applicable to the fundamental challenges in leading technological change such as student notebook computer programs within
higher education. Of specific interest is the literature addressing the definition of feasible goals and the need to communicate those goals to institutional stake-holders. The role of measurements and data in leading technological change are presented with special emphasis placed on research documenting the use of metrics similar to those used in this study. The leadership issues in implementing technological change are explored in greater depth from an organizational or systems theory viewpoint in order to establish how the research in this study provides useful metrics to avoid archetypical systems level failures within higher educational institutions making major technology based changes. Also included in the supporting theoretical basis for this research is a review of the role of educational effectiveness and the relevant principles and practices that have been established as providing an increased degree of learning within higher education. The measurements and data used to evaluate the measurement of learning are presented with special emphasis placed on research documenting the use of metrics similar to those measures used in this study for implementing student notebook computer instruction in CAD.

The final element of this research review is an exploration of prior research addressing the implementation of student notebook computer instruction within higher education. A number of the most prominent research studies are reviewed to identify the relevant characteristics of the research target group, the duration of the study, the type of analysis and metrics used in the study as well as the primary findings of the study. Each study is also examined in terms of its relationship to the research objectives of this study. This establishes that the study presented here is unique in its duration (longitudinal scope), its examination of the interrelationship
between its variables and in its evaluation of the changes exhibited by those interrelationships over time.

**Historical Overview**

The history of mandatory student notebook computer policies within higher education is generally considered to have started at the University of Minnesota at Crookston in 1993. Describing this pioneering initiative, Sergeant and Svec (2003) disclosed that the idea to require all students to purchase a notebook Personal Computer (PC) through the university was developed by university administrators and met with substantial apprehension by the university community. Five years later, a study of a similar program initiated in 1997 found the implementation of notebook computers to be generally more accepted, but substantial questions remained, including concerns over limited classroom implementation and the costs involved (Anderson, 2001). By 1998, the number of mandatory student notebook computer programs had increased and student computer ownership preference had moved to favoring notebook PCs over desktop computers by a 15 to 3 margin (Burg, 1998). Despite the increase in the number of institutions requiring student notebook computer ownership, many schools were reluctant to follow these early implementers in part because of the reduced operational capability and the high costs of contemporary notebook computers. For example, an evaluation of notebook cost-benefit analysis relative to desktop PC configurations by the U.S. Air Force Academy in 1998 indicated that desktop PCs were superior to the costs and capabilities available from notebook computers (Grier, 1998).
The costs of notebook computers have continued to decrease and their capabilities have continued to increase since the mid 1990s. Concurrently, the portability of notebook computers continued to be increasingly attractive to students (Sidener, 2005). As the new millennium dawned, the number of institutions requiring notebook computers continued to grow until by 2001 it was estimated that between two to four percent of higher educational institutions in the United States were requiring their students to provide their own notebook computers (Boettcher, 2001). Although most schools continued to use desktop PC based computer laboratory facilities after 2000, increasing costs led to computing capabilities becoming centralized, leaving departments without outside funding with minimal computing hardware and support (Newby, 2003). In reaction to continuing cost pressures and the appeal of notebook computers to students, some schools such as the University of North Carolina (UNC) at Chapel Hill used the replacement of existing computer laboratories with student owned notebook computers as a way to reduce the impact of state funding reductions (Carnevale, 2003). The number of higher educational institutions requiring their students to use notebook computers for classroom instruction has continued to steadily increase until at least 150 U.S. colleges and universities required students to obtain a notebook computer by 2006 (Carnevale & Young, 2006), and a summary list of such institutions in 2008 numbered approximately 244 worldwide (Brown, 2008).

**Motivations for Notebook Computer Programs**

Since the earliest days of student notebook computer programs, the leaders of many universities have used the implementation of such programs as a means to
improve institutional image. Referring to the UNC notebook initiative, Newby (2003) claimed that “The leading-edge image of the university ... was well served by the laptop requirement” (p. 208). Consistent with this justification, San Jose State University implemented a voluntary student notebook PC pilot program to improve student computer skills and to make the school “...a leader in improving teaching and learning through the utilization of technology” (Brieling, 2004, p. 47). Wake Forest University, a pioneer in requiring student notebook computers, emphasizes the value of the program in making the university a leader in enhancing higher education through technology and the recognition that the program has received (Griffith, Gu, & Brown, 1999). Student perception of value in their education and the resulting positive reflection on institutional image also typically favors student owned notebook PC policies. Consistent with this observation, students evaluated as part of a three year survey (1997, 1998 and 2000) of alumni from Grove City College indicated a positive attitude about their notebook PC experience while at college (Finn & Inman, 2004). A similar evaluation at Vanderbilt University in 2001 found that students prefer personally owned notebook based instruction relative to desktop computer laboratories (Shiavi & Broderson, 2005).

Cost is frequently a motivating element for implementing mandatory notebook computer programs. Measuring the costs and benefits of mandatory student notebook computer policies however has often proved difficult. The cost of the student owned notebook computer program at Valley City State University required student tuition to double by adding a student fee to cover the expense of leasing a computer and institutional infrastructure improvements (Burgert, 2000). The most
obvious apparent benefit of mandatory notebook policies for colleges and universities is a reduction in computer hardware costs for the institution, identified as a primary justification at the University of North Carolina at Charlotte (UNC), by Olsen (2001). The cost savings actually achieved by mandatory student notebook computer ownership, however, were hard to see and never made public (Newby, 2003). In addition, the educational gains from the policy at UNC were described by Olsen (2001) as “evolving and hard to measure” (p. A31). Wake Forest University which implemented a mandatory notebook computer program in 1996, also reported significant student cost based dissatisfaction during the early years of the requirement (Young, 1997) but later research provided support for the requirement by identifying improvement in retention and student achievement (Griffith, 1999).

Student learning is frequently claimed to be enhanced in student notebook based computer programs because students spend more time using their notebook PCs relative to the time they would otherwise spend in computer laboratories. In addition, an educational benefit is derived from students being able to actively construct their learning environment (Thomas, Laxer, Nishida, & Sherlock, 1998). Research by Arend (2004) indicates significant increases in the level of student engagement among students participating in a notebook initiative. A similar student evaluation by Oklahoma’s College of Engineering, conducted three years into a program requiring notebook computers, indicated a slight advantage for notebook computer students in achieving course objectives. These students also reported a more positive learning experience (Kolar, 2002). Winona State was able to demonstrate improved student outcomes as a laptop university through the application of seven
principles of good practice in undergraduate education to their notebook computer initiative (McVay, Snyder, & Graetz, 2005). Engineering students at Vanderbilt University in a personally owned notebook computer pilot program were found to be more comfortable with computer based instruction after one year of experience. The results of this pilot program were, in part, responsible for Vanderbilt's College of Engineering requiring notebook computers for all incoming students beginning in fall 2002 (Shiavi, 2005).

There are number of factors in addition to the image, cost and learning advantages that have been identified as justifications to implement student owned notebook computer programs. These factors are less consistently used as motivations but they have all been identified as important at a number of institutions which have notebook computer programs. Many institutions, including the University of Minnesota Crookston (Sargeant & Svec, 2003), the University of Houston (Grau, 2006) and Valley City State University (Holleque, 2002), have identified the increased development of student computer skills as a program benefit. The desire to provide “anytime, anywhere learning” and allow computer based instruction without restriction due to computer laboratory availability (Brieling, 2004) is another frequently stated objective. A typical viewpoint of institutions that identify increased access to technology as an implementation objective is that when students are personally responsible for their learning, they tend to be less reliant on extrinsic factors for motivation (Lim, 1999). A variation of this goal is Oklahoma Christian University’s “laptop for everyone” policy (Stafford, 2005) that seeks to level the
playing field in the classroom by requiring all students to have the same access to technology, even when additional financial support is required (Jones, 2005).

A number of motivating factors are related to institutional infrastructure concerns. Several institutions have identified the desire for more flexible learning spaces as an objective of notebook computer programs. Within the classroom, notebook computers can offer significant space savings relative to desktop based computer laboratories. At the University of Hawaii, the conversion of a 17 desktop computer laboratory created a 24 notebook PC based seating capacity and also provided superior visibility by eliminating the large fixed monitors present in the typical desktop laboratory (McKimmy, 2005). The need to continuously update computing hardware to keep pace with technology is an expensive problem area for most institutions. Notebook computer programs provide automatic hardware renewal at minimal cost as was noted at Wake Forrest University where student notebook computers are upgraded every two years. The cost of this program, covered by tuition, has been moderate enough so as to not impact student enrollment (Brown, 1998).

Problem Areas for Notebook Computer Programs

There have been a number of negative aspects associated with mandatory notebook computer programs since the creation of such programs in 1995. Many of the problem areas documented can be attributed at least in part to the leadership utilized in implementing this advance in campus technology. In some cases, problems associated with notebook computer implementations were the result of flawed motivations or objectives. Other problem areas reflect motivations that were simply
not feasible because of improper preparation or because the factors required for a successful implementation were not present at a given institution. A number of problem areas reflect an institutional or systems level failure. In such cases the implementation at a specific institution represented an inappropriate escalation of technology or excessively depleted student and institutional financial resources. It is also significant that the number and nature of documented problem areas has changed over time. Problems common among the early implementing institutions were typically different than those experienced as computer technology evolved and information about problem areas became available from the early implementing institutions. To thoroughly assess problem areas in this type of evolving technological environment, a large window of time for evaluation is required.

Faculty resistance to change was identified as a problem at many institutions implementing student notebook computer programs. Brauer (2003) identified, from a review of 15 studies of early notebook PC programs, 14 common problem areas for notebook computer implementations. Although not identified as a direct cause, several of these 14 problems (such as the need to provide adequate infrastructure and to provide faculty incentives) implicated the institutional leadership to faculty relationship (Bauer, 2003). Among the early implementing institutions such as the University of Minnesota at Crookston (UMC), faculty members were ‘quite resistant’ (p. 125) toward using notebook computers in their classrooms and aggressive training and support was required to develop faculty acceptance (Lim, 1999). Faculty resistance at the early implementing university studied by Cooke (1995) was, in part, attributed to a lack of faculty involvement in the decision making process. Many
researchers have reported that a lack of faculty development resources to implement the notebook technology was a problem area for faculty (Cooke, 1995; Corwin, 1998; Heeler, & Van Holzen, 1997; Lord & Bishop, 2001). After initial implementation, new software and hardware upgrades each academic year can also result in faculty “fatigue” when adequate support is not provided to integrate new technology quickly and smoothly into teaching and learning (Lim).

An early and recurrent area of student dissatisfaction with notebook computer implementation is based on a perceived lack of classroom instruction using notebook PCs adequate to justify their large and visible cost (Cooke, 1995). This problem area was identified by Newby (2003) at the University of North Carolina at Chapel Hill. In many cases the lack of classroom implementation was created by a failure to recognize that some classes are not easily adaptable to a computerized format (Bovinet, Newberry, Smith, & Young, 2000). Even in cases where class material was suitable, a lack of faculty training and experience left some courses seeking a role for using classroom computers (Olsen, 2001). Coursework such as CAD, with more demanding graphics and computational requirements, presents additional challenges for notebook computer hardware. A related problem area noted at the University of Vermont identified the difficulty in efficiently taking notes in graphically and mathematically oriented courses with student notebook computers (Frolik, 2005). The negative impact of resulting operational problems can create significant student dissatisfaction (Grau, 2006). Students as well as faculty expressed concern with the distracting effects of off-task notebook computer activities in the classroom in a qualitative study by Anderson (2001) and these computer based distractions in class
games, surfing, instant messaging) have led to unpopular course work only policies and blocked classroom internet access at many schools (Jones, 2005).

Cost is an important area of sensitivity for many students and one that can produce student resistance to mandatory notebook PC programs. Although institutions have used a variety of ways to transfer these additional costs to the students (technology fees, computer leases, additional tuition) significant student negative reaction can result (Cooke, 1995; Grau, 2006). Student dissatisfaction with notebook computer program cost was one motivating factor that forced changes in the notebook implementation at the College of Mt. St. Joseph in Cincinnati, OH where, after the initial three years of institutionally supplied notebook computers for all students, funding shortfalls and student complaints about computing fees forced significant program changes. Program viability in this case was restored by offering students alternative purchase options and reducing an unpopular technology fee (Hunter, Meyer, & Weber, 2006). A final area of cost based problems occurs when inadequate planning for infrastructure support creates unplanned expense for institutions and reduced operation for students. For example, the additional computer virus threats created by student owned notebook computers connected through campus networks have forced universities to deal with additional costs associated with protecting student owned PCs and their campus networks. Although some institutions have successfully transferred these costs to student fees such as was done at the University of North Texas in 2003 (Olsen, 2003), campus computer network security costs have been an area of increasing expense for all universities (Foster, 2004).
Applicable Leadership Theory

Effective leadership is a fundamental element necessary to implement significant change in an organization and student owned notebook computer programs require a variety of organizational changes in the implementing institution and the leadership necessary to facilitate those changes. As described by Peter Lange, Provost of Duke University, in an article announcing that institution’s decision not to implement a student notebook computer program in 2002, “There are lots of very big and foolish things that people can do in technology, so we need really strong leadership to move us forward.” (Olsen, 2002, p. A44). Effective leaders motivate by communicating a shared vision of organization goals (Owens, 2001), emphasizing ultimate objectives and tapping the motivations of the organization to support the targeted change (Burns, 1978). Research has shown that this transformational form of leadership is a common characteristic of the most innovative information technology leaders in higher education (Katz & Salaway, 2004). The need to formulate and communicate the shared vision supporting change is mentioned as one of the five component technologies necessary to innovate learning organizations according to Senge (1990). Leadership theory also suggests that educational organizations are unique in that their objectives are difficult to define and difficult to measure in order to determine if those objectives have been met (Bush, 1995). Technological change such as implementing a student notebook computer program has been shown to require a climate that empowers, provides objective measures of results and focuses on the student (Katz & Salaway, 2004). The presence of these leadership elements are obvious in the notebook computer program motivations previously identified and it is
the ability to define motivating objectives that research has shown to be effective in facilitating the successful implementation of technology initiatives (Green, 1997; Spodark, 2003).

While the need to establish a transformational leadership climate and to provide motivating objectives has been established by leadership theorists and practitioners, there are important characteristics that have been identified as desirable in achieving these objectives. The motivations for implementing change must be meaningful and support the mission of the institution (Rhodes, 2001). Objectives must be also be rational and the more precise and measurable that objectives can be made, the more accurately the results of change can be calculated (Birnbaum, 1999). It is also important that the motivating objectives be feasible and attainable by the implementing institution since setting realistic goals provides a higher likelihood of success (Manz & Sims, 2001). If the motivations established for change try to sustain unrealistic organizational identities there is a danger that important elements of the organization will be destroyed (Morgan, 1997). Unrealistic motivations can also foster negative compensating feedback within the organization that can reduce the chances for successful change (Senge, 1990). Leadership theory also cautions that leaders must carefully evaluate long term impact when planning significant change. Without an extended evaluation of program impact, leaders can create tomorrow's problem from today's solution (Senge). It is the need to provide research describing the long term impact of implementing notebook computer programs that underlies the extended time frame of this study.
The need for metrics to measure progress or success when implementing technological change is emphasized by a number of leadership theorists. The determination of these metrics is clearly a leadership responsibility since leaders making choices about technology without metrics to support their decision making are reducing the process to little more than trial and error (Cohen & March, 2001). Often leaders are required to be proactive in defining such measures because their external constituencies believe that institutional objectives are unitary and can be measured (Hodas, 1993). Leaders who establish meaningful measures to monitor change can define the issues that influence decision making (Morgan, 1997). In addition, the definition of the metrics for change can help a leader reduce organizational uncertainty about the success or failure of the change by defining efficient measures of performance and eliminating the need for an ongoing analysis of less meaningful outcomes (Birnbaum, 1998). A final important element that mandates the use of metrics to evaluate change as a leadership responsibility is the leadership principle that organizations facing changing technologies, such as implementing a notebook computer program, require flexible organizational structures with an emphasis upon expert power (Owens, 2001). One important source of this expert power can be derived from measurement and data (French & Raven, 1968) and according to Morgan the ability to marshal and synthesize facts in an effective manner can increase a leader’s expert power within an organization. The measures developed to evaluate the pilot program described in this study are important because, consistent with the leadership theorists, they provide example measures that have
been shown to effectively monitor the implementation of notebook computers within a CAD environment over an extended period of time.

Applicable Organizational Systems Theory

A review of the documented motivations and problem areas presented for notebook computer program implementations reveals that several problem areas and motivations exhibit linkage to organizational systems theory as well as to leadership theory. Two systems theory archetypes have direct applicability and per Senge (1990), understanding these archetypes is useful in perceiving underlying structures in complex situations such as the implementation of new technologies.

The escalation systems archetype can occur when an organization believes that their welfare is dependent upon gaining a relative advantage over a competing organization. Uncontrolled competition to gain an advantage can escalate to a point destructive to both organizations (Senge, 1990). The applicability of this archetype to notebook computer installations can be seen in the stated motivations of sponsoring institutions to improve their image. The desire to improve institutional image, more frequently found as a motivation among the early implementing organizations, carried an expressed desire to increase enrollment by increasing student appeal as at the Notebook Computer University examined by Anderson (2001) or to enhance image among peer organizations proximal to a transition in university status as at the University of Minnesota at Crookston (Sargeant & Svec, 2003). In some cases the transition was motivated by an established university that viewed the implementation as necessary to maintain its perceived leadership position in higher education as at
Wake Forest University (Griffith, Gu, & Brown, 1999) and Dartmouth College (Brown, 2001).

The escalation archetype applied to the escalation of educational technology to enhance organizational image can become destructive to the point of weakening the competing institutions. In the case of notebook computer implementations, several problem areas can be attributed as symptomatic of a destructive escalation of technology. One negative effect of technology escalation can occur when technology is implemented prematurely or inappropriately. If operational requirements exceed the demands of the notebook computer hardware or its supporting infrastructure, reduced reliability such as was noted by Cooke (1995), Brauer (2003), Demb and Hawkins-Wilding (2004) and Grau (2006) can result. An additional negative effect of technology escalation can occur when an institution implements an institutionally wide notebook computer requirement such as at Wake Forrest University (Griffith, Gu, & Brown, 1999), Winona State (McVay, Snyder, & Graetz, 2005) or the University of Minnesota at Crookston (Lim, 1999) and then attempts to force the use of technology in all classrooms, resulting in faculty resistance to the implementation (Anderson 2001; Cooke; Corwin 1998).

The tragedy of the commons systems archetype can occur when various elements of an organization use a commonly available resource solely on the basis of individual need. Although a short term benefit may be achieved, the long term effects are diminished returns until the common resource is depleted (Senge, 1990). The applicability of this archetype to notebook computer installations can be seen in the problem area of cost as identified previously. Institutions that fail to accurately
evaluate the cost of the transition can experience budget difficulty, such as that noted at Clayton State College (Bryan, 2007) and Mt. St. Joseph College (Hunter, Meyer, & Weber, 2006) where additional costs eventually were passed to the student in various forms. If the costs of implementation at an institution in combination with other costs such as tuition, fees and living expenses compromise the financial limits of the students (the commons), student satisfaction will be reduced and enrollment may be impacted as noted at Floyd College (Lord & Bishop, 2001). Negative student reactions to notebook computer costs have been identified by Grau (2006), Cooke (1995) and Demb and Hawkins-Wilding (2004). The solution to the tragedy of the commons archetype is in the effective management of the commons (Senge). To manage the commons of student financial resources, an accurate means to measure the overall financial impact of a notebook computer implementation is needed.

Educational Theory for Technological Change

A review of the documented motivations and problem areas for notebook computer program implementations reveals that several of the problem areas and motivations exhibit linkage to educational theory as well as to leadership theory. Measures of student satisfaction, student perception of learning and the amount of student hands-on operating time can all be found in existing research addressing student notebook computer initiatives because of their importance as measures of the level of learning. The use of these metrics and the justification for their use in evaluating notebook computer implementations is supported by various elements of educational theory and prior use. A review of the theoretical basis of these measures
and their prior use in the research applicable to this study establishes the rationale for using similar measures in this study.

There is an increasing importance of accountability in education that requires the documentation of learning impact and encourages data driven decision making (Mandinach & Honey, 2008). The need for data and measurement, however, is complicated for notebook computer implementations because the impact of computing on teaching and learning has proved to be difficult to assess objectively (Brown & Pettito, 2003). Wentz (2007) has identified the need to assess learning outcomes in evaluating the success of an implementation. Ni and Branch (2004), researching the impact of a notebook computers in graduate education, concluded that notebook computers offered more efficient learning but provided little supporting evidence. Other studies such as Holleque (2002) used a variety of survey instruments measuring student perceptions to evaluate learning impact. Direct measures of learning impact are difficult to identify in existing research. Research at Wake Forest University concluded that the notebook computer implementation at that institution had a positive learning impact by identifying a small increase in student grade point averages (Griffith, Gu, & Brown, 1999). Research offering direct measures that evaluate differences between students with notebook computers and those without in the same academic setting is very limited. One example of such research, comparing test score performance between notebook and non-notebook psychology students was completed at the U.S. Military Academy (Efaw, Hampton, Martinez, & Smith, 2004). The lack of accountability measures supporting notebook computer implementation can prove to be critical for leadership considering such a change. This was exhibited
in Duke University’s decision to not implement notebook computers because of a lack of documented educational results (Olsen, 2002).

An obvious and important element for leaders considering a notebook computer implementation is the resulting impact on the level of satisfaction that students will have with their educational experience. Measures of student satisfaction, however, have also been established by educational research to be positively correlated with student engagement in their education and such measures have become an accepted way to measure academic quality (Arend, 2004). Significant notebook computer research has included various measures of student satisfaction (Arend; Griffith, Gau, & Brown, 1999; Grau, 2006; Lord & Bishop, 2001; Holleque, 2002) both as a way to assess impact on organizational image as well as to assess impact on student engagement. The degree of access to computer resources (an obvious benefit of notebook computer implementation) has been shown to have a direct relationship to student satisfaction (Noel-Levitz, 2007) and a two year study, including student satisfaction measures, established a linkage between student satisfaction and student self-evaluated computer skill mastery following a notebook computer implementation (Cooke, 1995). Student satisfaction can also be related to problem based learning (Vernon & Blake, 1993) in which relevant problems are used to provide context and motivation for learning (Prince, 2004). The use of notebook computers has been established by research as encouraging the self-directed qualities necessary for this problem based learning (Rockman, 2004).

Educational research has established that active learning can enhance the level of student learning in variety of educational curriculum and active learning has been
established as a major benefit of notebook computer implementation in at least one study (McVay, Snyder, & Graetz, 2005). In a study by Cornell University researchers, a significant relationship was identified between the amount of notebook computer use and academic performance (Grace-Martin & Gay, 2001) and researchers have suggested that the amount and type of notebook computer use by students is a valid indicator of the success or failure of a notebook computer implementation (Grau, 2006). The importance of the amount and type of computer use is reflected by its inclusion in a number of applicable research studies (Grau; Holleque, 2002).

Active learning of computer skills is significantly improved in notebook computer implementations (Kariuki, 2000) and the mastery of computer skills has been established as important in developing self-confidence with a positive impact on educational achievement in a study by Hutchinson, Follman, Sumpter and Bodner (2006). The active or hands-on learning opportunities provided by notebook computers are well suited to the preferred learning styles of the engineering and engineering technology students typically involved in CAD instruction (Broberg, Lin, Griggs, & Steffen, 2008). Research has also established that hands on problem solving assists in the development of the student spacial abilities important in CAD instruction (Leopold, Gorska, & Sorby, 2001). The value of measuring the amount and nature of notebook computer use as an indirect measure of active learning, with a direct impact upon the effectiveness of CAD instruction, supports its inclusion as one of the measures evaluated in this study.
While direct measures of student learning are difficult to establish in evaluating the impact of technological change such as a notebook computer implementation, one method that is frequently used in educational research is the self-assessment of learning by students. In a review of 15 contemporary research studies Bauer (2003) determined the amount and quantity of learning to be the fourth most commonly used student feedback measure in evaluating notebook computer implementations. A 2003 study of notebook computer students at Ohio Dominican University included a student determined perception of academic success (Demb, Erickson, & Hawkins-Wilding, 2004). Notebook computer students at the University of Houston were asked to evaluate the impact the notebook computer program had on their perceived quality of learning (Grau, 2006). Research by Holleque (2002) on the impact of the notebook computer implementation at Valley City State University included several student evaluated learning measures such as the program’s benefits in meeting learning goals and how much the program enhanced the learning experience. In some cases, prior studies of notebook computer implementations found that student perceived enhancement in learning had occurred but the instrument used in making this determination was not provided (Lord & Bishop, 2001).

Assessment of Prior Notebook Computer Implementation Research

A number of research studies specifically addressing notebook computer implementations were reviewed as part of this study. The review included studies targeting implementations in higher education since that of the initial implementation in 1995. Although it is highly probable that other, unpublicized, internal research studies exist, a total of 23 studies applicable to this work were identified. The prior
research studies reviewed as aligned to the timeframe presented in this study is presented in Table 3.

Table 3

_Prior Research Studies by Year Group_

<table>
<thead>
<tr>
<th>Timeframe</th>
<th>Studies</th>
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<tr>
<td>Prior to 2001</td>
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<tr>
<td>2001 – 2003</td>
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<td>Early</td>
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<tr>
<td>2004 – 2005</td>
<td>5</td>
<td>Intermediate</td>
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<tr>
<td>2006 - 2008</td>
<td>2</td>
<td>Recent</td>
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It is notable that in 2001, the initial year of the initiative evaluated in this study, the greatest number (8) of prior research studies existed. Two studies (Corwin, 1998; Wentz, 2007) included in Table 3 did not involve student responses and were therefore not generally applicable to this study. The remaining 21 studies involving student based research regarding the implementation of notebook computers in higher education presented a wide variety of information. Nine studies used a qualitative methodology, nine studies used a quantitative methodology and three studies used mixed methods. The number of participants in the studies reviewed ranged from three students to institution wide evaluations exceeding several thousand students. The characteristics of the students evaluated in the prior research also exhibited a wide variety. Studies were directed to all students at an institution, all students of a specific class year as well as research limited to students of a specific course or program. Of the prior research reviewed, however, only two studies (Efaw, Hampton, Martinez, &
Smith, 2004; Lowry, 2001) were limited to students in mathematics and science based curriculums. No existing research was directed at students, programs or courses in CAD classes. The duration of prior research also presented wide variation. The majority of prior research studies reviewed (18 studies) were of single semester or academic year in scope. Of the remaining research studies two (Griffith, Gu, & Brown, 1999; Heeler & Van Holzen, 1997) were of a two year duration and studies by Collins, Easterling, Fountain and Stewart (2001) and Lim (2001) were of three and four year duration respectively. The study providing information on the most extensive timeframe was a quantitative presentation of student survey data collected from notebook computer students at Valley City State University during six consecutive academic years (96-97 through 01-02) (Holleque, 2002). Only four studies with comparative evaluations as an objective (Efaw, 2004; Grace-Martin & Gay, 2001; Grau, 2006; Lowry, 2001) included meaningful analysis between selected measures used in this study.

The review of prior research evaluating notebook computer implementations in higher education disclosed no prior research similar in duration to the longitudinal scope of this research or prior research involving notebook computer based CAD instruction. In addition only a small number of prior studies included an evaluation of the interrelationship between the study variables used as provided in this research. A number of prior research studies did however include measures similar to those evaluated in this research. The review of the use of these metrics, similar to the five research variables used in this study, is presented in the following sections.
Student Learning Measures

The improvement of student learning has been a recurrent motivation used by educational leaders in higher education to promote and justify notebook computer implementations. This has in turn made student learning an important metric in studies evaluating such implementations. In a small number of studies an attempt was made to objectively and comparatively evaluate the learning impact of the notebook computer initiative. At a private university, Griffith, Gu and Brown (1999) found a slight increase in student grade point averages after notebook computers were introduced. A comparison of notebook psychology students at the US Military Academy found a significant increase in classroom performance relative to non-notebook students (Efaw, Hampton, Martinez, & Smith, 2004), however a study involving calculus students at Lawrence Technological University found no significant relationship between course performance and the amount of notebook computer use (Lowry, 2001). These differences would tend to support the position of McVay, Snyder and Graetz (2005), developed during studies of the implementation at Winona State University, that the impact of a technological change can be different for different disciplines.

There are a number of studies that have used student self-assessment as a means to determine learning impact of notebook computers in the classroom. In some cases the evaluation was made by interview, focus group discussion or some other qualitative instrument. This qualitative evaluation method of student self-assessed learning impact was used by Anderson (2001), Grau (2006), Lord and Bishop (2001), Ni and Branch (2004) and Cooke (1995). A study at Northwest Missouri State
University measuring student perceptions of a notebook pilot program used a student survey to find students in the program believed notebook computers improved their ability to think and reason (Heeler & Van Holzen, 1997), and students at the all notebook computer based Waldorf College indicated their computers were important for learning (Hanson, 1998). Other studies using a student survey instrument with Likert scale based measurement such as that used in this study to evaluate student self-evaluated learning were completed by Bauer (2003), Collins, Easterling, Fountain, and Stewart (2001), Demb, Erickson and Hawkins-Wilding, (2004) and Holleque (2002). In all cases evaluated, student self-assessed perception of learning measures indicated students believed notebook computers had improved the amount and quality of learning.

*Student Satisfaction Measures*

Student satisfaction is a valuable indicator for higher educational leaders evaluating the impact of a notebook computer implementation and it has been included in a number of studies. Increased student engagement has been used to indirectly evaluate student satisfaction as well as the learning impact of a notebook computer implementation (Arend, 2004). Other research by Lord and Bishop (2001) and Bauer (2003) has identified student preference for notebook based instruction as a measure of student satisfaction. A positive attitude about computers and greater confidence regarding the use of computers has been used as a student satisfaction indicator in at least two research studies (Bauer, 2003; Lord & Bishop, 2001). The relevance of satisfaction in the form of positive attitude was identified by Griffith et al. (1999) in a study of a private university that also identified an improvement in first
year student retention. A similar university study found more positive attitudes and computer confidence in a study completed by Janz (2001) which compared these measures at a notebook university to those of a traditional university.

There are a number of studies that have evaluated the impact of student notebook computer implementation with a quantitative methodology using a Likert based survey of student satisfaction measure similar to that used in this research. Using such a survey instrument at Ohio Dominican University, Demb et al. (2004) identified a 54% student preference for notebook computer instruction. Students were determined to be satisfied with the cost-benefit of a notebook computer initiative at Winona State University (McVay, Snyder, & Graetz, 2005) and a study by Heeler and Van Holzen (1997) at Northwest Missouri State University reported a similar positive effect in student satisfaction. Although most research including student satisfaction as a metric indicated that notebook computer implementation increased student satisfaction, no difference in student satisfaction was found in a study comparing mobile (with notebook PC) with non-mobile (without notebook PC) students at Seton Hall University (Collins, Easterling, Fountain, & Stewart, 2001).

It is important to note that existing research indicates a major common element in producing a positive impact on student satisfaction when implementing a notebook computer initiative is the level of utilization in coursework. Research by Anderson (2001), Grau (2006), Demb et al. (2004), McVay et al. (2005), Cooke (1995) and Bauer (2003) all indicated that a high level of incorporation of the notebook computer produces a higher level of student satisfaction with the requirement to have the notebook computer.
Active Learning Measures

The measurement of the type and frequency of notebook computer use has been a common recurring metric in many research studies since the earliest implementations of notebook computer programs. In part this measure was used because of a commonly accepted belief that student use of the computers equated to the success of a notebook initiative. The research reviewed here can be separated into those studies that provided general information regarding the nature and amount of notebook computer use by students and those studies that presented some type of quantified data on these factors.

Of the research providing more general information, research at Waldorf College explored student computer usage but, after determining the most common use category to be word processing, provided no quantified results (Hanson, 1998). Griffith et al. (1999) claimed the amount of student computer use increased with notebook computers but provided no supporting data. The students at the notebook university evaluated by Janz (2001) were described as being more confident in various areas of computer use than their counterparts at a non-notebook university but additional supporting information was not provided. Relatively superficial descriptions of student computer use after notebook computer implementations were provided in several studies (Demb, Erickson, & Hawkins-Wilding, 2004; Kariuki, 2000; Ni & Branch, 2004). A study at Floyd College described students as spending more time doing coursework activities after notebook computer implementation (Lord & Bishop, 2001) and similar increase in academic use of notebook computers was identified as related to increased student engagement in a study by Arend (2004).
In all cases, the research presenting general information regarding student computer use, did not present adequate information to allow further evaluation and comparison to the research of this study.

There were a number of research studies evaluated that provided limited quantified information regarding the type and amount of student notebook computer use. Bauer (2003), in a study of a notebook initiative, found 61% of responding students claimed students spent 3 to 6 hours per day using their computer. A study at the University of Houston included measures for the number of hours per day that students used their notebook computers at home (1 to 5 hours per day) and the portion of that use related to coursework (66%) (Grau, 2006). Research at Valley City State University measured a significant increase in the number of students reporting specific frequencies of daily computer use (Holleque, 2002). Research by McVay et al. (2005) at Winona state identified that students used their notebook computers for an estimated five hours per day, the same use reported in a study at Northwest Missouri State University (Heeler & Van Holzen, 1997), while more detailed information from a study at Seton Hall University found that 75% of students used their notebook computer for more than 10 hours per day (Collins, Easterling, Fountain, & Stewart, 2001). Li and Newby (2002), in research completed with University of North Carolina at Chapel Hill notebook students, measured the percentage of out of class use and found out of class use to be approximately twice that of in class use. Two studies providing quantified notebook student use metrics presented unique aspects. A study of Lawrence Technological University students by Lowry (2001) actually reported very low outside of class use by notebook calculus
students and a study by Grace-Martin and Gay (2001), based on the amount of
notebook student web access, was unique in presenting the amount of student
computer use as a continuous variable.

Operational Problem Measures

The successful implementation of notebook computers in higher education, as
with any new technology, is very dependent upon the proper operation of the
hardware and software when used for its intended applications. The operational
performance of the notebook computer equipment (in most cases selected or specified
by the institution) was, however, seldom included as a research measure in the studies
reviewed. Even without directed inquiry, student concern with reliable operation was
noted in a number of studies in response to open ended questions asking about
problem areas or concerns. In studies completed at institutions that implemented
notebook computers relatively early, such as the University of Minnesota at
Crookston (Lim, 1999) and the Case Study University evaluated by Cooke (1995), a
number of problems with the operation of the notebook computers and/or their
compatibility with required software were noted. In an evaluation of the notebook
computer initiative for a teacher preparation program at Ohio University, problems
were identified with both hardware, interaction with software and compatibility with
peripheral equipment. This study also identified the importance of readily available
technical support as a factor capable of mitigating the impact of operational problems
(Kariuki, 2000). An additional related finding from an early implementation was
made by Lim (1999), who identified that the continuing need to monitor and pre-
check hardware and software operation was an overlooked additional workload for faculty.

It may be logically expected that operational problems related to the implementation of new technologies such as notebook computers would improve over time as standardization and reliability mature. This aspect underscores the need for leaders in higher education to accurately assess what is currently available with respect to what is needed when timing a notebook initiative. A measure of operating reliability was included in a study at the University of Houston, where a metric allowing students to evaluate satisfaction with notebook computer hardware was used. Unfortunately, no results for this metric were presented in the study results (Grau, 2006). In some cases the impact of operational problems can be reduced by other related factors. At Ohio Dominican University, students overwhelmingly preferred notebook computers for their portability even though 69% of those reporting identified notebook computer reliability as a problem (Demb et al., 2004). Bauer (2003) similarly concludes that reliable hardware is important to the success of a notebook program based on the large number of hardware problems identified by the students in a study of undergraduate notebook students. Even though the incidence of student reported operational problems seems to have decreased since the initial implementations of notebook computers, reliable operation under battery power has remained a concern at some institutions (Ni & Branch, 2004; Efaw, Hampton, Martinez, & Smith, 2004).
Cost Measures

An important consideration in implementing a notebook computer initiative is the cost impact to the institution and its students. Cost reduction, however, is seldom identified formally as a justification for an implementation and it is obvious that increasing student computer access to a one to one relationship requires additional expense. Anderson (2001), in an early qualitative study at a four year public Notebook Computer University, effectively summarized the concern about the expenditure of large implementation costs without research establishing significant educational benefit. In rare cases this expense is covered by external funding but most institutions pass the additional expense for notebook computer implementation on to the students in a variety of ways. Although in most cases the additional costs transferred to the student for a given implementation would be available, none of the research reviewed here evaluated cost in a quantitative manner and cost appeared within a study only when it was identified as problematic or an area of concern for students. As a pioneer in campus wide notebook computing, the institution referred to as Case Study University initiated their program in 1993 when notebook computer hardware was most limited and costs were highest. In a qualitative case study Cooke (1995) indentified that during interviews, students indicated that they believed the costs of the initiative were a hardship.

Graduate students at the University of North Carolina at Chapel Hill also indicated cost as their most important area of concern in their responses to an opened ended question as part of an on-line student survey that did not include a direct cost inquiry (Li & Newby, 2002). In a similar manner, in response to an opened ended
survey question, students in a qualitative case study at a four year, private, liberal arts college identified concerns with the costs of its notebook computer initiative (Bauer, 2003). The only research study reviewed that included direct questions regarding cost was conducted at Winona State University. In this study students were presented with a number of questions relating to their satisfaction with the cost vs. benefits of the program. The results of this survey indicated that students (leasing their notebook computers) considered cost to be very important and the response to a question asking if the cost of participating in the initiative was “reasonable” (p. 520) produced an average value of 2.45 on a 5.0 Likert scale (with 5.0 indicating completely reasonable) (McVay et al., 2005). Research at Ohio Dominican University disclosed that most students thought cost of the notebook initiative at that institution was important (Demb et al., 2004). The lack of cost evaluation in prior research and its frequent presence as an area of concern for students indicates that a meaningful evaluation of the cost impact on students should be an important component for educational leaders considering implementing a notebook computer initiative. In addition, with large changes in costs and capabilities typical of the incorporation of new technology, leaders would benefit greatly from information that could describe how the cost impact to students is evolving. This time based evaluation of cost impact is not provided by any known study or research.

Summary of Literature Review

Notebook computer programs have been implemented in higher education for a variety of motivations and have experienced a number of problems. This literature review has shown that leadership theory establishes the need for leaders to clearly
communicate motivating objectives that are attainable by an organization implementing a notebook computer program. In addition, leadership theory mandates that these objectives should be linked to various metrics for monitoring purposes. If selected carefully, the measures used to evaluate a notebook computer implementation can assist higher education leadership in avoiding common problem areas identified by existing research on prior notebook implementations. The measurement of computer operational problems and student satisfaction can be useful in avoiding the negative escalation archetype as described by organizational systems theory. Cost impact and student satisfaction measures can be useful in avoiding a failure of the initiative due to the tragedy of the commons systems theory archetype.

The literature reviewed indicates that the need to evaluate learning impact is very important to leaders as evidenced by its frequent identification as a motivation for implementing notebook computers. Student evaluations of perceived learning impact have been used for this purpose in educational research and a number of prior research studies regarding notebook computer implementations have included this type of metric as a means to measure learning impact. Student satisfaction has been shown as a useful means to assess learning as supported by educational research involving student engagement. This literature review has established that student satisfaction measures have been frequently used in evaluating notebook computer implementations. The value of active-learning in providing a positive impact on learning has been well documented in educational research and theory. Of direct importance to the CAD classes evaluated by this study, prior research supports the inclusion of the out of class use measure included in this study.
The final element of this literature review summarizes prior research addressing notebook computer implementations in higher education. The inadequacy of prior research in evaluating student cost impact and as well as a lack of prior research evaluating the inter-relationship between measured factors supports the unique contribution of this research to the existing body of knowledge. The literature review has also determined that degree of longitudinal measure provided by this study is much more extensive than any prior research. Finally a review of the prior use of each measure utilized in this study provides additional rationale and precedent for the inclusion of such measures in this research.
CHAPTER 3
METHODOLOGY

This non-experimental, longitudinal quantitative study examines the implementation of student owned notebook computers within a CAD-based university curriculum. It examines data collected during the first 8 years of the implementation investigating the characteristics of, and the relationship between, several variables obtained from a survey instrument used as part of a pilot implementation. The use of a survey instrument as part of a quantitative study can be used to measure both data and participant perceptions (Neuman, 2000). Since this research tests the relationship between several numerically represented variables using primarily closed end questions, the quantitative approach used is appropriate (Creswell, 2003). Using a statistical analysis of the survey data, meaningful quantitative descriptions and conclusions are developed about student owned notebook computer programs (Locke, Spirduso, & Silverman, 2000). The inclusion of a small faculty survey involving faculty with direct classroom knowledge of the pilot implementation provides an enhanced understanding of the student survey results from an alternate perspective and allows meaningful information regarding institutional motivation for the implementation to be included in the research. This chapter (a) describes the institutional setting of the research, (b) presents the motivations responsible for implementing the pilot program, (c) explains the instrumentation and data collection methodologies used, (d) describes the study variables, (e) details the specific method analysis used for each research question and (f) details the role of the researcher as a participant in the pilot program.
The analysis involved in this research has the objective of providing higher educational leaders with valuable information necessary to help implement successful student owned notebook computer programs or other types of technological change. In addition the research provides leaders with strategic information of value in developing policies necessary to ensure the success and meaningful evaluation of such programs. The methodology employed analyzes the characteristics and trends in selected implementation metrics as well as the interrelationship between those metrics over an extended period of time. The results of this research can be used by leaders to plan timing and to reduce organizational resistance to implementing notebook computers as well as providing a means to evaluate whether an implementation improves the educational experience at a college or university.

Institutional Setting

The institutional setting for the study is a four year public university of approximately 12,500 students located in the northern midwest region of the United States. The institution sponsoring the notebook computer program evaluated, referred to as the Subject University (SU), has sustained a regionally recognized position in applied technical education since 1884. The specific academic degree program requiring the class evaluated by this research has been located within the College of Technology at SU since the program’s inception in 1988. This college, one of several at SU, is led by a Dean that reports to the Vice President of Academic Affairs who in turn reports directly to the SU President. Within the College of Technology, the course evaluated and its academic program are located within the Mechanical Design Department, the operation of which is coordinated by a faculty chairperson.
The academic degree program including the course evaluated by this research was developed for students who have completed a minimum of two years of post secondary education either at SU or at a different college or university. Students involved in this research are enrolled at SU for the final two years in a four semester sequence of highly integrated coursework in applied mechanical engineering and CAD-based design. Students within the SU College of Technology are typically career motivated and have a preference for classes that provide skills that enhance their employment opportunities. The course evaluated by this research is an example of this emphasis since the content of the course and the solid modeling CAD software utilized were developed in response to needs expressed by industry through the program’s advisory board. The academic degree program involved in this research was the first degree program at SU to require its students to provide a notebook computer as part of an exploratory pilot implementation approved by the SU administration beginning in the 2000 – 2001 academic year. The 2001 class providing the initial data set for this research was the first notebook computer based class conducted at SU.

Pilot Program Motivations

The need for leaders to establish and communicate the objectives of any initiative that significantly impacts the past practices and structure of a higher educational institution has been established by the literature reviewed in Chapter 2. Since the motivations of organizational leaders in promoting a technological initiative can be useful in understanding the basis of many specific aspects of the methodology
used in its implementation, the decision making process at SU leading to the notebook computer implementation described in this research merits review.

The notebook computer initiative at SU was initiated by the program faculty. The primary motivation for the faculty (including the researcher) in proposing this change was to facilitate student access to industry standard solid modeling software. An additional important motivation was to provide expanded access to CAD software outside of class and thereby improve student learning by increasing the opportunity for hands-on learning. There were several important considerations however that were carefully evaluated by the faculty before making this recommendation. One critical element was to secure a practical licensing agreement with a solid modeling software manufacturer. Several years were necessary to develop an agreement that would allow students to use the selected software on a personally owned notebook computers while maintaining adequate provisions to protect the software from illegal use and copying. A second element was the need to have notebook computers with the operating capability necessary to use the graphics intensive CAD software available at a retail cost acceptable to student budgets. As early as 1995, the program faculty periodically investigated the capability and cost of current notebook hardware. The information developed was then reviewed with the current students in the program. Only when both hardware cost and capability were thought to be adequate, was a recommendation to implement a student owned notebook requirement submitted. To minimize impact to student finances, the SU financial aid office was contacted to increase the degree cost for students participating in the initiative, thereby providing the opportunity for additional financial aid for some students.
The recommendation to require students to provide their own notebook computers was initially made by the program faculty to the acting Dean of the SU College of Technology. The acting Dean was influenced to support the proposal by the Assistant Dean of the College of Technology as a low risk opportunity to enhance the image of the college within the campus community (K. K., personal communication, August 8, 2008). The recommendation was then submitted to the SU Vice President of Academic Affairs for review. The pivotal meeting in which the decision was made to allow the implementation to proceed occurred in the fall of 2000. At this meeting the proposal was supported by the SU President, SU Vice President of Academic Affairs and SU Dean of the College of Technology. Other SU academic and administrative leaders present at this meeting generally supported or did not actively oppose the recommendation. The reasons voiced as supporting the initiative at the meeting as described by an Assistant Vice President of Academic Affairs in attendance (T.O., personal communication, August 15, 2008) were as follows:

1. The notebook computer initiative supported the technologically and educationally innovative image of the SU President.

2. Because the pilot program was limited to one relatively small academic program, the impact of an unsuccessful initiative would be minimal.

3. With many indications in various educational publications that notebook computer use in higher education was central to future campus information technology planning, the pilot program would provide the opportunity to
develop parameters for any later decision to implement a similar requirement campus wide.

4. The recommendation required no financial investment by SU.

5. The program faculty was clearly behind the recommendation and willing to accept full responsibility for the success of the initiative.

The only opposition to the initiative voiced at the decision making meeting was that of the SU Information Technology staff. This organization was opposed to the initiative (T.O., personal communication, August 15, 2008) for the following reasons;

1. The initiative allowed students to obtain a notebook computer of their choosing. The lack of hardware standardization would make technical support difficult.

2. No additional technical support staff was included in the recommendation.

3. The software licensing agreement, allowing software licensed to the university to be used on student owned computer hardware, was unique and without precedent at SU.

4. The operational requirements of the solid modeling software to be used were thought to exceed the capabilities of commercially available notebook computers of the time.

Each of these objections was neutralized by the SU President by removing all responsibility for supporting the notebook computer initiative from the IT staff and the transference of responsibility for all aspects of the implementation to the program
faculty. With this understanding in place, the recommendation to proceed with a pilot program requiring student owned notebook computers was approved.

Pilot Program Participants

The students participating in the notebook computer pilot program at SU were third year students enrolled in a unique Bachelor of Science program based on applied mechanical engineering with a CAD emphasis. The participating students are overwhelmingly male and many have substantial work experience. The course providing the survey information used in this study is a core course in the pilot program curriculum and is taken by all students in the program. Because enrollment in the class providing the survey data was limited to students enrolled in the notebook computer pilot program, all students surveyed had the same academic field of study and similar backgrounds. No students are known to have taken the class used in the research more than once. The course evaluated by the survey information has been offered each winter semester at SU with the same content since 2001. The course has been taught by the same instructor since 2003.

All students taking the class providing the survey data were required to have successfully completed at least one prior, post secondary CAD course as a prerequisite. Most participating students in the surveyed class, however, had completed several CAD classes prior to entering the pilot program and were very familiar with operating personal computers. It is likely that some students had been previously exposed to operating some type of CAD software on a personally owned notebook computer, but no students are known to have had prior post secondary classroom instruction using notebook computers.
All students can be assumed to have had at least one CAD class in a conventional desktop computer based laboratory prior to joining the pilot program. Because a large number of student participants in the pilot program had transferred to SU from another college or university, a variety of academic backgrounds and levels of experience were involved in this research. The solid modeling software used in the pilot program is widely used in industry and other higher educational institutions, however, no prior experience operating the software can be assumed for the participating students.

The faculty members participating in the faculty survey element of this research were responsible for teaching classes in the notebook computer pilot program. Two faculty members are included in this study and both are tenured faculty members at SU. One faculty member has two years of experience teaching the subject course immediately following the implementation of the pilot program and had the opportunity to observe the organizational decision making involved in its initial approval. The other faculty member has had six years experience in teaching the subject course during the most recent six year period, but was not a SU faculty member during the pilot program’s initial implementation.

Instrumentation and Data Collection

This research evaluates eight years of existing class survey data taken from a short self-administered exit survey completed by students completing a CAD class utilizing solid modeling software as part of the notebook computer pilot program at SU. An example of a typical survey is presented in Appendix A. The survey instrument was developed by the researcher in 2001 for purposes of program
implementation and evaluation and includes both closed ended and open ended
responses. Seven questions from the survey instrument were used as the data source
for this research. Three questions utilized a 5 point Likert scale with the general
format of 1 indicating a positive response to a selected element of notebook computer
use within the course or academic program and 5 indicating a negative response. Two
questions requested the entry of a numeric response in a space provided. Two
questions were open ended and allowed students to evaluate their experience beyond
the more specific questions of the survey instrument. No prior or alternative use of
the survey instrument was used to establish its validity and reliability (Rudestam &
Newton, 2001).

The questions contained in the survey that were used as the basis of this
research were identical throughout all eight academic years surveyed with the
exception of Survey Question 9 which was not included in the initial survey
conducted in Winter semester 2001. The survey instrument was issued to students in a
single double sided format and completed during a regularly scheduled class period
within the last three weeks of the fifteen week academic semester. No specific
instructions or additional information was provided to the participating students by
the class instructor issuing the survey other than a general statement that the survey
was being used to evaluate and develop the course and the role of notebook
computers within the academic program comprising the pilot program. The
instructions presented to the participating students at the time of survey
administration were never formalized or recorded. All surveys, other than the survey
conducted in Winter semester 2001, were conducted by the same classroom
instructor. The researcher did not administer and was not present during the completion of any surveys included as part of this research. All surveys were completed anonymously, without collaboration, and no student names or identification were included in the survey data. All students were issued a survey form to be completed during the class period, but no review of the submitted forms was conducted as they were submitted. Because of this there was no mechanism to avoid the submission of incomplete or erroneously completed surveys.

In addition to the data provided by the survey instrument, this research required a representative estimated prevailing retail cost for each of the eight years comprising the study. This information is used to estimate the economic impact experienced by students and which was calculated using the response obtained from a survey question and then comparing that response to the prevailing retail cost established for the year of the survey data containing the response. Since other survey information (see question 7, Appendix A) indicated that most students in the pilot program purchased new computer hardware for the class, one can assume that student survey responses generally represented the retail purchased price for a new notebook computer paid by the student. The determination of the prevailing retail cost is a critical element in the determination of economic impact. Economic impact is defined for the purpose of this study as the difference between the amount that students paid for their notebook computer (the response to a survey question) and the amount that they could have paid for a notebook computer adequate to operate the required software (the Prevailing Retail Cost). If students paid more than necessary, it can be logically inferred that they had more financial resources than required to participate in
the pilot program evaluated. To be a valid methodology, however, it was necessary that the prevailing retail cost be a purchasing opportunity known and available to all students involved in the study at the time they obtained their notebook equipment. The source for Prevailing Retail Cost used for this study is that of a suitable DELL Inc. notebook computer as advertised to the public in a large regional newspaper during the late Fall immediately preceding the January in which the equipment was required for use in class. DELL Inc. was selected as the reference manufacturer because of the broad availability of DELL equipment. In support of this choice, it can be noted that, based on responses to a survey question not evaluated in this study but included in Appendix F, a majority of students have elected to purchase a DELL Inc. notebook computer in each year of the study.

The decision to use an advertised retail price from a large regional newspaper is based on a number of factors. This paper is widely available at the Subject University. In addition all students in the pilot program were required to take an introductory seminar about the program in the Fall semester immediately before they were required to have their computer. In this seminar, advertised notebook computers were a recurring topic and all students were exposed to suitable DELL Inc. notebook computers (as well as other manufacturers) as advertised in the large regional newspaper. The timing of the selected price is based on the fact that the students were advised to avoid purchasing their required computer until as near as possible to the time that it was needed in order to take advantage of the latest operational features and the lowest expense. In many cases, especially in the early years of the pilot program, many students received their notebook computers as Christmas gifts with a
purchase date typically in the November or December timeframe. Collectively, the
use of a price obtained from a large regional newspaper for a DELL Inc. notebook
computer advertised at the end of the Fall semester, represents the best available
measure of the Prevailing Retail Cost for a given survey year.

As described in the overview of the pilot program, the development and
implementation was faculty driven. In order to evaluate the motivations and
perceptions of the faculty with first hand knowledge of the pilot program, a separate
survey instrument was developed and completed by two faculty members. This
instrument is included as Appendix B and was submitted to the faculty members
involved electronically. The identification of the two participating faculty members is
known only to the researcher and their completed written responses do not identify
the respondents by name. Information from this instrument is included as part of this
research to document the motivations involved in the pilot program from a faculty
perspective and for comparison with the student information developed using the
instrument included as Appendix A.

Description of Variables

The research evaluates the characteristics and inter-relationships between five
quantitative variables developed from the student survey responses to specific survey
questions obtained over the eight years of the study. In addition, student written
responses developed from two open ended survey questions are evaluated as
qualitative variables. The variable to survey question assignment is shown in Table 4.
Table 4

Variable Labels and Source Questions

<table>
<thead>
<tr>
<th>Variable Label</th>
<th>Variable Description</th>
<th>Applicable Survey Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNCI</td>
<td>Preference for notebook computer based</td>
<td>Question 1</td>
</tr>
<tr>
<td></td>
<td>instruction</td>
<td></td>
</tr>
<tr>
<td>POL</td>
<td>Student perception of learning</td>
<td>Question 3</td>
</tr>
<tr>
<td>OCOT</td>
<td>Out of class operating time</td>
<td>Question 2</td>
</tr>
<tr>
<td>EI</td>
<td>Economic Impact</td>
<td>Derived from Question 9</td>
</tr>
<tr>
<td>OP</td>
<td>Operational problems</td>
<td>Question 12</td>
</tr>
<tr>
<td>SCOM</td>
<td>Student Perceptions</td>
<td>Questions 15 and 16</td>
</tr>
</tbody>
</table>

A more detailed description of each variable used in the study is provided in the following sections.

Preference for Notebook Computer Instruction (PNCI)

The Preference for Notebook Computer Instruction (PNCI) variable is based on student responses to the survey question shown in figure 2.

![Survey question 1](image)

1. Overall, how do you feel about conducting this course using laptops, compared to computer lab based class.

   1. rather use the laptop  
   2  3  4  5. rather use the computer lab

Figure 2. Survey question 1.

This variable reflects the expressed student preference for classes using notebook computers relative to conventional computer laboratory classes using desktop computers. The PCNI variable ranges from 1 to 5 with 1 indicating that students
prefer notebook computer classes and 5 indicating that students prefer instruction in conventional computer laboratories. It is an assumption of this study that students interpreted the interval between the ordinal values as equally spaced, allowing the PCNI variable to be used as an interval variable (Frankfort-Nachmias & Leon-Guerrero, 2002). Responses of students electing to mark a preference between the ordinal values presented, were entered as the ordinal value closest to the position of the mark.

*Student Perception of Learning (POL)*

The Student Perception of Learning (POL) variable is based on student responses to the survey question shown in figure 3.

| 3. How much did you learn using laptops compared to a normal CAD course taught in a computer lab? |
| 1 learned more with laptops | 2 | 3 | 4 | 5 would have learned more in a lab |

*Figure 3.* Survey question 3.

This variable reflects the expressed student self-evaluated perception of learning. The POL variable ranges from 1 to 5 with 1 indicating that students perceived that they learned more using notebook computers and 5 indicating that students perceived that they would have learned more in a conventional computer laboratory. It is an assumption of this study that students interpreted the interval between the ordinal values as equally spaced, allowing the POL variable to be used as an interval variable. Responses of students electing to mark a preference between the ordinal values presented, were entered as the ordinal value closest to the position of the mark.
Out of Class Operating Time (OCOT)

The Out of Class Operating Time (OCOT) variable is based on student responses to the survey question shown in figure 4.

2. For each hour of class, about how much out of class time did you spend using PRO-E? _____ hours

Figure 4. Survey question 2.

This variable reflects the expressed student self-evaluated estimate of the out of class time that they spent in hours, for each hour of class time, operating the solid modeling CAD software utilized in the class evaluated. Since this software was not known to be available from other sources during the time of the study, it can be inferred that this measure of operating time equates to operating the software on their notebook computer outside of class. The OCOT variable is an interval variable with a positive value extending from and including zero hours (indicating that students spent no time operating the solid modeling CAD software outside of class). It is expressed in the survey data as a whole number indicating the number of hours of out of class spent using the software. Since this variable had no upper limit, special consideration to eliminate outlier responses was necessary.

Economic Impact (EI)

The Economic Impact (EI) variable is based on student responses to the survey question shown in figure 5.

9. About how much did you spend to get your laptop?

Figure 5. Survey question 9.
The response to question 9 reflects the expressed student estimate of the amount that they spent in purchasing the requisite notebook computer for the course evaluated. It is a value expressed as a whole number in U.S. dollars. Since other survey information indicated that most students in the pilot program purchased new computer hardware for the class, this variable generally represents the retail purchased price paid by the student. To calculate the estimated economic impact experienced by the student, the EI variable is calculated using the response obtained from Question 9 and the Prevailing Retail Cost established for the year of the survey data containing the response. The EI variable is an interval random variable expressed as the whole number difference (positive or negative) in U.S. dollars between the student response to question 9 and the Prevailing Retail Cost. Non-responses and zero indicated values were not included in the evaluation. There was no survey inquiry as to the amount that students paid in the initial year (2001) of the pilot program and therefore the initial year of the study is not included in the Early implementers group (2001, 2002 & 2003) for analysis involving the EI variable.

Operational Problems (OP)

The Operational Problems (OP) variable is based on student responses to the survey question shown in figure 6.

<table>
<thead>
<tr>
<th>12. Describe your laptop PC's operation running PRO-E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worked well</td>
</tr>
<tr>
<td>No Problems</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*Figure 6. Survey question 12.*
This variable reflects the expressed student self-evaluated perception of the number and nature of problems encountered while operating the required CAD solid modeling software (PRO-E). The OP variable ranges from 1 to 5 with 1 indicating that students perceived that they had experienced no problems and 5 indicating that students perceived that they experienced operational problems to an unacceptable level. It is an assumption of this study that students interpreted the interval between the ordinal values as equally spaced, allowing the OP variable to be used as an interval variable. Responses of students electing to mark a preference between the ordinal values presented, were entered as the ordinal value closest to the position of the mark.

**Student Perceptions**

The Student Perceptions variable is based on student responses to the survey questions shown in figure 7.

| 15. Overall do you think that PDET classes using student owned laptop PCs are: |
|----------------|----------------|----------------|----------------|----------------|
|                  | 1 | 2 | 3 | 4 | 5 |
| A good idea      |   |   |   |   | A bad idea |

Please explain your answer.

| 16. Are there any changes you would recommend regarding laptops for future classes? |

*Figure 7. Survey questions 15 and 16.*

The written student responses to survey questions 15 and 16 were used as qualitative and categorical quantitative variables for the purposes of this study. The questions provided the opportunity for students to identify concerns with the pilot program and
the continued use of notebook computers for program classes. Responses ranged from no response to multiple responses for each question. The common focus of these two questions allows the responses to be collectively evaluated and for any redundancy between the questions to be eliminated. For example, in some cases the student identified a specific problem in Question 15 and then simply recommended fixing the problem as a response to Question 16. In effect these are redundant responses identifying a single problem. Student perception responses allow the qualitative identification of the most common positive and negative student perceptions of pilot program participation by year group (Early, Intermediate and Recent) and allow the quantitative comparison of these groups longitudinally to identify changes over time.

Data Analysis

The survey data includes a total of 148 survey instruments submitted by pilot program students. For the purpose of analysis, the available student data is placed into three groups: Early implementers (from the first three years of the pilot program), Intermediate implementers (from the middle two years) and Recent implementers (from the most recent three years of the program). The analysis of the data used for this non-experimental study was divided into two segments. Parametric analysis is used for the five quantitative variables. Non-parametric analysis is used for the relationship between categorical variables and the qualitative open-ended student responses. The results obtained by surveying two faculty members with teaching experience in the subject course is used in the qualitative interpretation and validation of student survey data as well as to provide useful insight from a faculty perspective as to the organizational motivations behind the pilot program.
Parametric Analysis

The five quantitative variables used in this study exhibit a reasonably balanced survey design. As reflected in Table 5, the survey data as used for parametric analysis provide aggregate totals ranging from 33 to 75 responses per year group. It should be noted that survey data from the Early Year Group only provides 41 responses for parametric analysis involving Economic Impact because the 2001 survey instrument did not include the student notebook computer cost question.

Table 5

Survey Responses Used for Parametric Analysis by Year Group

<table>
<thead>
<tr>
<th>Timeframe</th>
<th>Survey Responses</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001 – 2003</td>
<td>75 / 41a</td>
<td>Early</td>
</tr>
<tr>
<td>2004 – 2005</td>
<td>33</td>
<td>Intermediate</td>
</tr>
<tr>
<td>2006 – 2008</td>
<td>40</td>
<td>Recent</td>
</tr>
</tbody>
</table>

*Note. The class survey for the 2001 year did not include a question asking students how much they spent on their computer. Therefore analysis regarding the Economic Impact variable is limited to 41 survey responses from the Early group. All other analysis uses 75 survey responses available for the Early group.

Two of the quantitative random variables used in this study, the student expressed Preference for Notebook Computer Instruction (PNCI) and the student self-evaluated Perception of Learning (POL) are considered to be dependent for purposes of analysis upon the three independent variables. The three independent variables included in the study are the student estimated Out of Class Operating Time (OCOT),
the Economic Impact (EI) and the Operational Problems (OP) experienced by the student.

Two of the quantitative independent variables provided unbounded responses. The EI variable allowed values from $0 to an unlimited upper dollar value and the OCOT variable allowed values from 0 hours to an unlimited number of hours. These variables are initially analyzed in order to eliminate outlying values using stem and box plots. After outlying responses were eliminated, all five quantitative variables (PNCI, POL, OCOT, EI, OP) are described statistically in terms of their characteristics for the composite eight years of the study and by year group (Early, Intermediate, Recent). Descriptive statistics for each of the resulting twenty sets of statistics are developed including the number of valid responses, minimum value, maximum value, mean value, standard deviation, skew and kurtosis. The descriptive results are then analyzed for observable trends.

Research Question 1 states, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in: (a) expressed student preference for CAD classes conducted using notebook computers; (b) student’s self-evaluated perception of learning in notebook computer CAD instruction; (c) active learning as indicated by out of class operating time; (d) economic impact in obtaining the required notebook computer hardware; and (e) operational problems in operating CAD software on notebook computers.” To answer this question each of the five quantitative survey variables are evaluated for statistically significant changes between year groups. This was done using a one-way
ANOVA General Linear Model analysis with each quantitative variable used as a dependent variable with the three year groups used as a categorical independent variable. Each of the five tests completed for this analysis and shown in Table 6 uses a criteria of statistical significance ($\alpha$) of .05, representing an appropriate level of improbability minimizing the likelihood of both type I and type II errors (Lockhart, 1998). The null hypothesis for all tests predicts there to be no significant changes in a given survey variable during the overall period of evaluation for any of the three year groups evaluated.

Table 6

*Analysis Methodology for Research Question 1*

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Method</th>
<th>Dependent Variable</th>
<th>Independent Variable</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ANOVA</td>
<td>PNCI</td>
<td>Year Group</td>
<td>75 / 33 / 40</td>
</tr>
<tr>
<td>2</td>
<td>ANOVA</td>
<td>POL</td>
<td>Year Group</td>
<td>75 / 33 / 40</td>
</tr>
<tr>
<td>3</td>
<td>ANOVA</td>
<td>OCOT</td>
<td>Year Group</td>
<td>75 / 33 / 40</td>
</tr>
<tr>
<td>4</td>
<td>ANOVA</td>
<td>EI</td>
<td>Year Group</td>
<td>41 / 33 / 40</td>
</tr>
<tr>
<td>5</td>
<td>ANOVA</td>
<td>OP</td>
<td>Year Group</td>
<td>75 / 33 / 40</td>
</tr>
</tbody>
</table>

Faculty survey information is used to provide enhanced qualitative understanding of the student survey information from a faculty perspective. Predictions of student responses as well as observable trends are noted and compared with the parametric data analysis obtained from the student surveys.

Research Question 2 states, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer
based CAD instruction, to what extent, if any, were there any statistically significant changes in the relationship between the following: *expressed student preference for CAD classes conducted using notebook computers* and the *student's self-evaluated perception of learning* in notebook computer CAD instruction.” The analysis for this question is conducted using a paired samples student’s t-test for each year group and the entire eight year duration of the study as shown in Table 7.

Table 7

<table>
<thead>
<tr>
<th>Analysis Methodology for Research Question 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Number</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

Each of the four tests completed for this analysis and shown in Table 6 uses a criteria of statistical significance ($\alpha$) of .05. The null hypothesis for all tests predicts there to be no significant difference in the average mean differences for these two dependent variables for the timeframe evaluated.

Research Question 3 states, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationships between the *expressed student preference for CAD classes conducted using notebook computers* and each of the following measures: (a)
active learning as indicated by *out of class operating time*; (b) *operational problems* in operating CAD software on notebook computer; and (c) *economic impact* in obtaining the required notebook computer hardware." The analysis for this question is conducted using an Analysis of Covariance (ANCOVA) as shown in Table 8.

Table 8

*Analysis Methodology for Research Question 3*

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Method</th>
<th>Dependent Variable</th>
<th>Categorical Independent Variable</th>
<th>Covariates</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ANCOVA</td>
<td>PNCI</td>
<td>Year Group</td>
<td>OCOT, OP, EI</td>
<td>114</td>
</tr>
</tbody>
</table>

The ANCOVA test completed for this analysis and shown in Table 7 uses a criteria of statistical significance (α) of .05. The null hypothesis for this test predicts there to be no significant difference in Student Preference for Notebook Computer Instruction between the three year groups of the study, controlling for the effects of Out of Class Operating Time, Operational Problems and Economic Impact.

Research Question 4 states, "During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationships between the student's self-evaluated perception of *learning* in notebook computer CAD instruction and each of the following: (a) active learning as indicated by *out of class operating time*; (b) *operational problems* in operating CAD software on notebook computers; and (c) *economic impact* in
obtaining the required notebook computer hardware.” The analysis for this question is conducted using an Analysis of Covariance (ANCOVA) as shown in Table 9.

Table 9

*Analysis Methodology for Research Question 4*

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Method</th>
<th>Dependent Variable</th>
<th>Categorical Independent Variable</th>
<th>Covariates</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ANCOVA</td>
<td>POL</td>
<td>Year Group</td>
<td>OCOT, OP, EI</td>
<td>114</td>
</tr>
</tbody>
</table>

The ANCOVA test employed for this analysis and shown in Table 8 uses a criteria of statistical significance (α) of .05. The null hypothesis for this test predicts there to be no significant difference in student Perception of Learning between the three year groups of the study, controlling for the effects of Out of Class Operating Time, Operational Problems and Economic Impact.

Research Question 5 states, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationship between the following; (a) active learning as indicated by *out of class operating time* and *operational problems* in operating CAD software on notebook computers; (b) *operational problems* in operating CAD software on notebook computers and the *economic impact* in obtaining the required notebook computer hardware; and (c) active learning as indicated by *out of class operating time* and the *economic impact* in obtaining the required notebook computer hardware.” To answer this question, each of the three pairings of survey independent variables is
evaluated for statistically significant changes between year groups. This is done using a two-way Analysis of Variance (ANOVA) with a continuous dependent variable and two categorical independent variables. A Chi Squared test of significance is used for the testing involving only categorical variables. For purposes of this analysis, the Economic Impact and Operational Problems are used as categorical variables. The Year Group provides the second categorical variable in all tests. Each of the three tests completed for this analysis and shown in Table 10 use a criteria of statistical significance ($\alpha$) of .05. The null hypothesis for all tests predicts there to be no significant differences in a given survey variable due to the categorical variables for the three year groups evaluated.

Table 10

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Method</th>
<th>Dependent Variable</th>
<th>Independent Variables</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ANOVA</td>
<td>OCOT</td>
<td>Year Group, OP</td>
<td>148</td>
</tr>
<tr>
<td>2</td>
<td>ANOVA</td>
<td>OCOT</td>
<td>Year Group, EI</td>
<td>114</td>
</tr>
<tr>
<td>3</td>
<td>CHI SQUARE</td>
<td>OP</td>
<td>Year Group, EI</td>
<td>114</td>
</tr>
</tbody>
</table>

Non-Parametric Analysis

Research Question 6 states, "To what extent, if any, have the perceptions of students taking CAD classes utilizing notebook computer based instruction changed during the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction as indicated by (a) their most commonly expressed advantages and (b) their most commonly
expressed disadvantages of such instruction.” To answer this question, student responses from the eight years of survey data are reviewed to identify general themes and to assign qualitative survey responses to the categories identified. The frequencies of occurrence for each response category (positive & negative) are developed for all year groups. These frequencies are used to determine the most commonly expressed positive and negative perceptions and to determine if the frequency of occurrence of those perceptions changed during the three year groups of the study. The null hypothesis for this question predicts there to be no significant differences in the number and essential content of the student responses for the three year groups evaluated.

Role of the Researcher

At the time of this study, the researcher has been a tenured faculty member at SU for fifteen years and is the senior faculty member of the academic program evaluated by the research. The researcher was responsible for initiating the notebook computer pilot program and assumed primary responsibility for its operation since its inception in 2001 through the time period of this study. In developing the pilot program the researcher was responsible for specifying student notebook computer hardware and negotiating the license agreement for the solid modeling CAD software used. In addition, nearly all students in the pilot program completing the survey used for this research were the academic advisees of the researcher. The survey instrument used in the research and developed by the researcher was intended to provide a measure of objective student perceptions about the pilot program and to provide information for use in modifying the program. It is important to note, however, that
the researcher did not teach any of the classes surveyed as part of this study and the researcher was not present at the time any survey was administered.

Summary of Methodology

The methodology of this research provides statistically supportable, quantitative results necessary to answer the six research questions presented in Chapter 1. The use of eight years of survey information, collected as part of ongoing course evaluation, provides the research with a longitudinal aspect that is unique relative to existing research involving student owned notebook computer programs. The analysis provided by this methodology includes statistically based information regarding the changes over time in five quantitative variables with relevance to CAD-based instruction using student owned notebook computers. In addition, the research investigates important relationships between those variables over time. In order to provide additional information to assist in interpreting the results developed, the methodology of this research also identifies the most important positive and negative factors perceived by students studying CAD regarding a student owned notebook computer requirement. Student perceptions are evaluated over time to allow the identification of any significant changes during the duration of the study. Enhanced understanding of student perceptions and changes in those perceptions are provided by the inclusion of survey information obtained from faculty with direct experience teaching the course providing the student survey information. Collectively the methodology of the study provides meaningful and unique results contributing to the body of knowledge involving CAD instruction using student owned notebook computers.
CHAPTER 4

RESULTS

This study examines the pilot implementation of student owned notebook computers within a CAD-based curriculum at one 4 year institution in the Midwest, and is based primarily on information collected from class survey data collected during the first 8 years after implementation. The data was taken from a short self-administered exit survey taken by students completing a CAD class which utilized solid modeling software. An example of a typical survey is presented in Appendix A. The survey content provided the ability to track a number of variables over time and to use this information to explore the characteristics and inter-relationships between five quantitative variables developed from the student survey responses. In addition, student written responses developed from two open ended survey questions are evaluated as qualitative variables. This chapter presents the analysis relevant to answering the research questions as set forth in Chapter 3. The chapter begins with a detailed description of each variable used in the study and then presents the analysis addressing each research question.

In addition to the student survey based analysis, secondary information collected from the faculty survey instrument is compared with the results of the student information where appropriate. This information is used only to enhance understanding of the research question analysis.

Analysis of Variables

There were 148 student surveys completed over the eight year time period covered by this study. From the survey information, seven questions were used as the
data source for this research and provided six variables. Three survey questions utilized a 5 point Likert scale (Preference for Notebook Computer Instruction - PNCI, Perception of Learning - POL, Operational problems - OP), two survey questions requested the entry of a numeric response in a space provided (Out of Class Operating Time - OCOT, Economic Impact - EI) and two survey questions were open ended allowing written responses. The responses for these two open ended questions were used as indicators of Student Perceptions and described by a categorical variable (Student Comment - SCOM).

Preference for Notebook Computer Instruction (PNCI)

This variable reflects the expressed student preference for classes using notebook computers relative to conventional computer laboratory classes using desktop computers. The PNCI variable ranges from 1 to 5, with 1 indicating that students prefer notebook computer classes and 5 indicating that students prefer instruction in conventional computer laboratories. PNCI was evaluated as an interval variable and combined into three year groups (Early, Intermediate and Late) for purposes of analysis.

The presentation of question 1 in the survey instrument for the early class years was discovered to be confusing to students. The surveys during this time period were constructed so that scales presented for PNCI were inconsistent with the other scaled survey variables. In the 2001, 2002 and 2003 surveys, Question 1, as shown in Figure 8, placed a response supportive of notebook computer classes at the right hand end of the scale while all other survey responses placed the response supportive of notebook computer learning on the left hand end of the scale. To correct this
inconsistency, question 1 was revised to the form shown in Figure 9 beginning with the 2004 survey.

| 1. Overall, how do you feel about conducting this course using laptops, compared to computer lab based class. |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| rather use | the computer lab | | | rather use the laptop |

*Figure 8. Survey question 1 (2001, 2002, 2003).*

Because of the change in the format of question 1 on the 2001, 2002 and 2003 survey instruments, it was necessary to transpose the responses of question 1 from those years to establish consistency with the data collected from surveys from 2004 and subsequent years. To do this, student responses to question 1 on the early surveys were transposed by changing a response of 1 to 5, a response of 2 to 4, a response of 4 to 2 and a response of 5 to 1. A response of 3 did not require change. The transposition of question 1 survey data was made and verified before the statistical analysis of the PNCI variable, derived from this question, was used in this research.

The summary PNCI data for the three class years (2001, 2002, 2003) combined into the Early year group is shown in Table 11.
Table 11

Preference for Notebook Computer Instruction (PNCI) – Early Group

<table>
<thead>
<tr>
<th>Year</th>
<th>1 rather use the laptop</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 rather use the computer lab</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>N</td>
<td>M</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>13 (38.2)</td>
<td>13 (38.2)</td>
<td>6 (17.6)</td>
<td>1 (2.9)</td>
<td>34</td>
<td>1.94</td>
<td>.17</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>9 (81.8)</td>
<td>2 (18.2)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>11</td>
<td>1.18</td>
<td>.12</td>
</tr>
<tr>
<td>2003</td>
<td>20 (66.7)</td>
<td>9 (30.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>1 (3.3)</td>
<td>30</td>
<td>1.43</td>
<td>.15</td>
</tr>
<tr>
<td>Overall</td>
<td>42 (56.0)</td>
<td>24 (32.0)</td>
<td>6 (8.0)</td>
<td>1 (1.3)</td>
<td>2 (2.7)</td>
<td>75</td>
<td>1.63</td>
<td>.90</td>
</tr>
</tbody>
</table>

The summary PNCI data for the two class years (2004, 2005) combined into the Intermediate year group is shown in Table 12.

Table 12

Preference for Notebook Computer Instruction (PNCI) – Intermediate Group

<table>
<thead>
<tr>
<th>Year</th>
<th>1 rather use the laptop</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 rather use the computer lab</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>N</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>2004</td>
<td>4 (28.6)</td>
<td>4 (28.6)</td>
<td>3 (21.4)</td>
<td>3 (21.4)</td>
<td>0 (0.0)</td>
<td>14</td>
<td>2.36</td>
<td>.31</td>
</tr>
<tr>
<td>2005</td>
<td>12 (63.2)</td>
<td>3 (15.8)</td>
<td>2 (10.5)</td>
<td>1 (5.3)</td>
<td>1 (5.3)</td>
<td>19</td>
<td>1.74</td>
<td>.27</td>
</tr>
<tr>
<td>Overall</td>
<td>16 (48.4)</td>
<td>7 (21.2)</td>
<td>5 (15.2)</td>
<td>4 (12.1)</td>
<td>1 (3.0)</td>
<td>33</td>
<td>2.00</td>
<td>1.20</td>
</tr>
</tbody>
</table>
The summary PNCI data for the three class years (2006, 2007, 2008) combined into the Recent year group is shown in Table 13.

Table 13

*Preference for Notebook Computer Instruction (PNCI) – Recent Group*

<table>
<thead>
<tr>
<th>Year</th>
<th>1 (rather use the laptop)</th>
<th>2 (%)</th>
<th>3 (%)</th>
<th>4 (%)</th>
<th>5 (rather use the computer lab)</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>10 (66.7)</td>
<td>0 (0.0)</td>
<td>3 (20.0)</td>
<td>1 (6.7)</td>
<td>1 (6.7)</td>
<td>15</td>
<td>1.87</td>
<td>.35</td>
</tr>
<tr>
<td>2007</td>
<td>9 (90.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>1 (10.0)</td>
<td>0 (0.0)</td>
<td>10</td>
<td>1.30</td>
<td>.30</td>
</tr>
<tr>
<td>2008</td>
<td>9 (60.0)</td>
<td>6 (40.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>15</td>
<td>1.40</td>
<td>.13</td>
</tr>
<tr>
<td>Overall</td>
<td>28 (70.0)</td>
<td>6 (15.0)</td>
<td>3 (7.5)</td>
<td>2 (5.0)</td>
<td>1 (2.5)</td>
<td>40</td>
<td>1.55</td>
<td>1.01</td>
</tr>
</tbody>
</table>

The summary PNCI data for the three year groups used in this research (Early, Intermediate, and Recent) is shown with the summary description for all eight years of the data in Table 14. The characteristics of the PNCI variable exhibited a significant positive skewness for all three year groups and the overall data. This implies that more students preferred notebook computer instruction to that of conventional computer laboratories. In addition the PCNI data exhibited significant leptokurtic characteristics (peaked) in all groups except the Intermediate year group which was significantly mesokurtic (normal). This descriptive information is shown in Table 15.
Table 14

Preference for Notebook Computer Instruction (PNCI) - Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>1 rather use the laptop</th>
<th>2</th>
<th>3</th>
<th>4 rather use the computer lab</th>
<th>5</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>42 (56.0)</td>
<td>24 (32.0)</td>
<td>6 (8.0)</td>
<td>1 (1.3)</td>
<td>2 (2.7)</td>
<td>75</td>
<td>1.63</td>
<td>.90</td>
</tr>
<tr>
<td>Interm.</td>
<td>16 (48.4)</td>
<td>7 (21.2)</td>
<td>5 (15.2)</td>
<td>4 (12.1)</td>
<td>1 (3.0)</td>
<td>33</td>
<td>2.00</td>
<td>1.20</td>
</tr>
<tr>
<td>Recent</td>
<td>28 (70.0)</td>
<td>6 (15.0)</td>
<td>3 (7.5)</td>
<td>2 (5.0)</td>
<td>1 (2.5)</td>
<td>40</td>
<td>1.55</td>
<td>1.01</td>
</tr>
<tr>
<td>Overall</td>
<td>86 (58.1)</td>
<td>37 (25.0)</td>
<td>14 (9.5)</td>
<td>7 (4.7)</td>
<td>4 (2.7)</td>
<td>148</td>
<td>1.69</td>
<td>1.01</td>
</tr>
</tbody>
</table>

Table 15

Characteristics of the Preference for Notebook Computer Instruction (PNCI) Variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>skewness</th>
<th>kurtosis</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>1.86*</td>
<td>+4.09*</td>
<td>1.00</td>
</tr>
<tr>
<td>Interm.</td>
<td>.93*</td>
<td>-.275*</td>
<td>2.00</td>
</tr>
<tr>
<td>Recent</td>
<td>1.97*</td>
<td>+3.32*</td>
<td>1.00</td>
</tr>
<tr>
<td>Overall</td>
<td>1.58*</td>
<td>+2.00*</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Note. * Indicates value exceeds 2 standard errors.

The descriptive analysis of the PNCI variable indicates that students in all class years, in all year groups and as a group, indicated a preference for notebook computer instruction over instruction conducted in a conventional computer laboratory. The
descriptive analysis also indicates that the lack of normality of the PNCI variable may be significant for parametric analysis.

The faculty perceptions expressed in a separate survey supported this description of the PNCI variable. Both of the two faculty members participating indicated that they believed, from their experience in teaching the class evaluated, that students would indicate a strong preference for notebook computer classes.

Student Perception of Learning (POL)

The Student Perception of Learning (POL) variable is based on student responses to the survey question shown in figure 10.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>learned more with laptops</td>
<td></td>
<td></td>
<td></td>
<td>would have learned more in a lab</td>
</tr>
</tbody>
</table>

*Figure 10. Survey question 3.*

This variable reflects the expressed student self-evaluated perception of learning. The POL variable ranges from 1 to 5 with 1 indicating that students perceived that they learned more using notebook computers and 5 indicating that students perceived that they would have learned more in a conventional computer laboratory. POL was evaluated as an interval variable and combined into three year groups (Early, Intermediate and Late) for purposes of analysis. It should be noted that the POL data contained two survey responses (both from 2004) indicating a response placed approximately at the midpoint between 2 and 3. Based on the responses to survey
question 1, it was noted that one student/survey clearly preferred notebook computer instruction whereas the other student/survey indicated that they preferred instruction in conventional computer laboratories. Based on this observation one mid point response was recorded as 2 and the other response was recorded as 3.

The summary POL data for the three class years (2001, 2002, 2003) combined into the Early year group is shown in Table 16.

Table 16

Perception of Learning (POL) – Early Group

<table>
<thead>
<tr>
<th>Year</th>
<th>1 learned more with laptops</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 would have learned more in a lab</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>4 (12.1)</td>
<td>17 (51.5)</td>
<td>11 (33.3)</td>
<td>1 (3.0)</td>
<td>0 (0.0)</td>
<td>33</td>
<td>2.27</td>
<td>.72</td>
</tr>
<tr>
<td>2002</td>
<td>4 (57.1)</td>
<td>2 (28.6)</td>
<td>0 (0.0)</td>
<td>1 (14.3)</td>
<td>0 (0.0)</td>
<td>7</td>
<td>1.71</td>
<td>1.11</td>
</tr>
<tr>
<td>2003</td>
<td>15 (53.6)</td>
<td>8 (28.6)</td>
<td>5 (17.9)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>28</td>
<td>1.64</td>
<td>.78</td>
</tr>
<tr>
<td>Overall</td>
<td>23 (33.8)</td>
<td>27 (39.7)</td>
<td>16 (23.5)</td>
<td>2 (2.9)</td>
<td>0 (0.0)</td>
<td>68</td>
<td>1.96</td>
<td>.84</td>
</tr>
</tbody>
</table>

The summary POL data for the two class years (2004, 2005) combined into the Intermediate year group is shown in Table 17.
Table 17

*Perception of Learning (POL) – Intermediate Group*

<table>
<thead>
<tr>
<th>Year</th>
<th>1 learned more with laptops</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 would have learned more in a lab</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>3 (21.4)</td>
<td>5 (42.1)</td>
<td>5 (35.7)</td>
<td>1 (7.1)</td>
<td>0 (0.0)</td>
<td>14</td>
<td>2.29</td>
<td>.91</td>
</tr>
<tr>
<td>2005</td>
<td>8 (42.1)</td>
<td>3 (15.8)</td>
<td>5 (26.3)</td>
<td>3 (15.8)</td>
<td>0 (0.0)</td>
<td>19</td>
<td>2.16</td>
<td>1.17</td>
</tr>
<tr>
<td>Overall</td>
<td>11 (33.3)</td>
<td>8 (24.2)</td>
<td>10 (30.3)</td>
<td>4 (12.1)</td>
<td>0 (0.0)</td>
<td>33</td>
<td>2.21</td>
<td>1.05</td>
</tr>
</tbody>
</table>

The summary POL data for the three class years (2006, 2007, 2008) combined into the Recent year group is shown in Table 18.

Table 18

*Perception of Learning (POL) – Recent Group*

<table>
<thead>
<tr>
<th>Year</th>
<th>1 learned more with laptops</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 would have learned more in a lab</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>5 (33.3)</td>
<td>6 (40.0)</td>
<td>4 (26.7)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>15</td>
<td>1.93</td>
<td>.80</td>
</tr>
<tr>
<td>2007</td>
<td>4 (40.0)</td>
<td>3 (30.0)</td>
<td>3 (30.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>10</td>
<td>1.90</td>
<td>.88</td>
</tr>
<tr>
<td>2008</td>
<td>5 (33.3)</td>
<td>5 (33.3)</td>
<td>5 (33.3)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>15</td>
<td>2.00</td>
<td>.85</td>
</tr>
</tbody>
</table>
The summary POL data for the three year groups used in this research (Early, Intermediate, Recent) is shown with the summary description for all eight years of the data in Table 19.

Table 19

Perception of Learning (POL) - Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>1 learned more with laptops</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 would have learned more in a lab</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>N</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Early</td>
<td>23 (33.8)</td>
<td>27 (39.7)</td>
<td>16 (23.5)</td>
<td>2 (2.9)</td>
<td>0 (0.0)</td>
<td>68</td>
<td>1.96</td>
<td>.84</td>
</tr>
<tr>
<td>Interm.</td>
<td>11 (33.3)</td>
<td>8 (24.2)</td>
<td>10 (30.3)</td>
<td>4 (12.1)</td>
<td>0 (0.0)</td>
<td>33</td>
<td>2.21</td>
<td>1.05</td>
</tr>
<tr>
<td>Recent</td>
<td>14 (35.0)</td>
<td>14 (35.0)</td>
<td>12 (30.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>40</td>
<td>1.95</td>
<td>.81</td>
</tr>
<tr>
<td>Overall</td>
<td>48 (34.0)</td>
<td>49 (34.8)</td>
<td>38 (27.0)</td>
<td>6 (4.3)</td>
<td>0 (0.0)</td>
<td>141</td>
<td>2.01</td>
<td>.88</td>
</tr>
</tbody>
</table>

The characteristics of the POL variable exhibited a slight positive skewness for all three year groups and overall. This implies that slightly more students thought that they learned more with the notebook computer than they would have in a conventional computer laboratory. In addition the POL data exhibited significant platykurtic characteristics (flat) for the Recent group and overall. The Early and Intermediate year groups were relatively mesokurtic (normal). This descriptive information is shown in Table 20.
Table 20

*Characteristics of the Perception of Learning (POL) Variable*

<table>
<thead>
<tr>
<th></th>
<th>skewness</th>
<th>kurtosis</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>.40</td>
<td>-.70</td>
<td>2.00</td>
</tr>
<tr>
<td>Interm.</td>
<td>.23</td>
<td>-1.21</td>
<td>2.00</td>
</tr>
<tr>
<td>Recent</td>
<td>.09</td>
<td>-1.48*</td>
<td>2.00</td>
</tr>
<tr>
<td>Overall</td>
<td>.37</td>
<td>-.85*</td>
<td>2.00</td>
</tr>
</tbody>
</table>

*Note.* * Indicates value exceeds 2 standard errors.

The descriptive analysis of the POL variable indicates that students in all class years, in all year groups and overall, perceived learning more with notebook computer instruction relative to classes conducted in a conventional computer laboratory. The descriptive analysis also indicates that the lack of normality of the POL variable may be significant for parametric analysis.

The faculty perceptions expressed in a separate survey supported this description of the POL variable. Both of the two faculty members participating indicated that they believed, from their experience in teaching the class evaluated, that students would indicate that they perceived learning more in notebook computer classes than those CAD classes taught in a conventional computer laboratory.

*Out of Class Operating Time (OCOT)*

This variable reflects the expressed student self-evaluated estimate of the out of class time that they spent in hours operating the solid modeling CAD software utilized in the class evaluated. Since this software was not known to be available from
other sources during the time of the study, it can be inferred that this measure of operating time equates to operating the software on their notebook computer outside of class. The OCOT variable is an interval variable with a positive value extending from and including zero hours (indicating that students spent no time operating the solid modeling CAD software outside of class). It is expressed in the survey data as a whole number indicating the number of hours of out of class spent using the software. Since this variable had no upper limit, the data was evaluated to eliminate outlier responses. Three survey responses of 100, 55, 25 and 20 hours were identified as having values significantly higher than other student responses. Since it is unlikely that a student would spend 20 - 100 hours outside of class operating the CAD software for each hour of class time, these values were eliminated from the OCOT data.

OCOT responses, with the four outlying values excluded, provided a data set of 142 ranging from a low of .20 hours to a maximum of 8 hours. Descriptive summaries of the OCOT variable for each year group are shown in tables 21, 22 and 23. Summary descriptions for each year group and the overall eight years are provided in table 24.
Table 21

*Out of Class Operating Time (OCOT) – Early Group*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Max</th>
<th>Min</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>32</td>
<td>7.0</td>
<td>.25</td>
<td>2.68</td>
<td>1.70</td>
</tr>
<tr>
<td>2002</td>
<td>8</td>
<td>6.0</td>
<td>1.5</td>
<td>3.31</td>
<td>1.36</td>
</tr>
<tr>
<td>2003</td>
<td>30</td>
<td>4.0</td>
<td>.5</td>
<td>1.88</td>
<td>.93</td>
</tr>
<tr>
<td>Overall</td>
<td>70</td>
<td>7.0</td>
<td>.25</td>
<td>2.41</td>
<td>1.45</td>
</tr>
</tbody>
</table>

Table 22

*Out of Class Operating Time (OCOT) – Intermediate Group*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Max</th>
<th>Min</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>14</td>
<td>3.0</td>
<td>.75</td>
<td>1.95</td>
<td>.93</td>
</tr>
<tr>
<td>2005</td>
<td>18</td>
<td>5.0</td>
<td>.75</td>
<td>2.35</td>
<td>1.13</td>
</tr>
<tr>
<td>Overall</td>
<td>32</td>
<td>5.0</td>
<td>.75</td>
<td>2.17</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Table 23

*Out of Class Operating Time (OCOT) – Recent Group*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Max</th>
<th>Min</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>.15</td>
<td>3.5</td>
<td>.2</td>
<td>1.66</td>
<td>1.01</td>
</tr>
<tr>
<td>2007</td>
<td>10</td>
<td>3.5</td>
<td>.5</td>
<td>1.40</td>
<td>.88</td>
</tr>
<tr>
<td>2008</td>
<td>15</td>
<td>8.0</td>
<td>.5</td>
<td>2.22</td>
<td>1.83</td>
</tr>
<tr>
<td>Overall</td>
<td>40</td>
<td>8.0</td>
<td>.20</td>
<td>1.81</td>
<td>1.36</td>
</tr>
</tbody>
</table>
Table 24

*Out of Class Operating Time (OCOT) – Summary*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Max.</th>
<th>Min.</th>
<th>M</th>
<th>SD</th>
<th>skewness</th>
<th>kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>70</td>
<td>7.0</td>
<td>.25</td>
<td>2.41</td>
<td>1.45</td>
<td>1.18*</td>
<td>1.23*</td>
</tr>
<tr>
<td>Interm.</td>
<td>32</td>
<td>5.0</td>
<td>.75</td>
<td>2.17</td>
<td>1.05</td>
<td>.69</td>
<td>.24</td>
</tr>
<tr>
<td>Recent</td>
<td>40</td>
<td>8.0</td>
<td>.20</td>
<td>1.81</td>
<td>1.36</td>
<td>2.56*</td>
<td>10.09*</td>
</tr>
<tr>
<td>Overall</td>
<td>142</td>
<td>8.0</td>
<td>.20</td>
<td>2.19</td>
<td>1.36</td>
<td>1.44*</td>
<td>3.06*</td>
</tr>
</tbody>
</table>

*Note.* * Indicates value exceeds 2 standard errors.

The characteristics of the OCOT variable exhibited a positive skew for all groups and overall. This indicates that the mean time students reported operating the CAD software outside of class was shifted to the left of the median reported value.

Significant positive skewness was present for two year groups (Early, Recent) and overall. In addition the OCOT data exhibited significant leptokurtic characteristics (peaked) in two groups and overall.

Analysis of the OCOT variable indicates that students reported spending an average of 2.19 hours operating the CAD software outside of class over the eight years of the study. Both of the two faculty members participating indicated that they believed, from their experience in teaching the class evaluated, that students would indicate that they spent 2 to 3 hours outside of class operating the software. The descriptive analysis also indicates that the lack of normality of the OCOT variable may be significant for parametric analysis.
Economic Impact (EI)

The Economic Impact variable reflects the difference between the self-reported amount that students paid for their notebook computer (the response to survey question 9) and the amount that they could have paid for a notebook computer adequate to operate the required software (the Prevailing Retail Cost). The amount that students reported that they paid for the requisite notebook computer was expressed as a whole number in U.S. dollars. Only values from students purchasing a new computer to take the course were used. Non-responses and zero indicated values were excluded. The survey instrument used in the initial year (2001) of the pilot program did not include self-reported cost and therefore the Early implementers group included data for only 2002 and 2003 students.

Student cost. The survey self reported cost was recorded as an interval variable with a positive value extending from and including zero dollars (indicating that students had received their notebook computer as a gift). It was expressed as a whole number indicating the U.S. Dollars that the student spent. Since this variable had no upper limit and receiving a gift computer at no cost would invalidate the purpose of the measure, the data was evaluated to eliminate outlier responses. One potential outlying value was noted as an abnormally high reported cost. This student reported paying $2800 for a new notebook computer in 2004, a year with a Prevailing Retail Cost of $799. Upon review of this survey response however, it was determined that it would not be unreasonable that a student could have spent $2800 for a new (and very well appointed) notebook computer in the fall of 2003. For this reason, the $2800 value was retained and used. One reported cost showed no cost for a new
notebook PC because, according to a comment made in the margin, the student's parents bought the computer and it did not cost the student anything. The cost for this record was eliminated from the data. Five other records without cost data but indicating new computer had been purchased were also excluded.

*Prevailing retail cost.* The source for Prevailing Retail Cost used for this study is that of a suitable DELL Inc. notebook computer as advertised to the public in a large regional newspaper during the late Fall immediately preceding the January in which the equipment was required for use in class. The reference time of purchase and associated survey class year are shown as Purchase Year and Survey Year in the Prevailing Retail Cost summary provided in table 25.

Table 25

*Prevailing Retail Cost*

<table>
<thead>
<tr>
<th>Purchase Year</th>
<th>Survey Year</th>
<th>Operating System</th>
<th>Processor</th>
<th>Display</th>
<th>Memory</th>
<th>Retail Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2002</td>
<td>Windows XP</td>
<td>Pentium III 900 MHz</td>
<td>14 inch</td>
<td>128 MB</td>
<td>$1,149b</td>
</tr>
<tr>
<td>2002</td>
<td>2003</td>
<td>Windows XP</td>
<td>Pentium 4 M 1.7GHz</td>
<td>15 inch</td>
<td>512 MB</td>
<td>$1,199c</td>
</tr>
<tr>
<td>2003</td>
<td>2004</td>
<td>Windows XP</td>
<td>Pentium 4 M 2.2GHz</td>
<td>14 inch</td>
<td>256 MB</td>
<td>$799d</td>
</tr>
<tr>
<td>2004</td>
<td>2005</td>
<td>Windows XP</td>
<td>Pentium 4 M 1.4GHz</td>
<td>14 inch</td>
<td>512 MB</td>
<td>$1,199e</td>
</tr>
<tr>
<td>2005</td>
<td>2006</td>
<td>Windows XP</td>
<td>Pentium 4 M 1.7GHz</td>
<td>15 inch</td>
<td>512 MB</td>
<td>$699f</td>
</tr>
</tbody>
</table>
Table 25 Continued

<table>
<thead>
<tr>
<th>Purchase Year</th>
<th>Survey Year</th>
<th>Operating System</th>
<th>Processor</th>
<th>Display</th>
<th>Memory</th>
<th>Retail Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>2007</td>
<td>Windows XP</td>
<td>INTEL Core-Duo</td>
<td>14 inch</td>
<td>1 GB</td>
<td>$799\textsuperscript{e}</td>
</tr>
<tr>
<td>2007</td>
<td>2008</td>
<td>Windows VISTA</td>
<td>INTEL Dual-Core</td>
<td>14 inch</td>
<td>1 GB</td>
<td>$699\textsuperscript{h}</td>
</tr>
</tbody>
</table>

\textit{Note.} All prices are in US Dollars and do not include taxes.

\textit{Economic impact determination.} The Economic Impact variable was calculated as the difference between the self-reported student cost and the Prevailing Retail Cost at the time of purchase. To allow economic impact to be evaluated on an equal basis across the eight years of the study, the difference was adjusted for the effects of inflation. Table 26 shows the inflation factors based on the Consumer Price Index (CPI) established by the U.S. Department of Labor (2009) which were used to adjust the difference between self-reported student costs and retail cost for each year of the study.
Table 26

*CPI Inflation Adjustment for the EI Variable*

<table>
<thead>
<tr>
<th>Survey Date</th>
<th>CPI Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>1.20</td>
</tr>
<tr>
<td>2003</td>
<td>1.17</td>
</tr>
<tr>
<td>2004</td>
<td>1.14</td>
</tr>
<tr>
<td>2005</td>
<td>1.10</td>
</tr>
<tr>
<td>2006</td>
<td>1.07</td>
</tr>
<tr>
<td>2007</td>
<td>1.04</td>
</tr>
<tr>
<td>2008</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Economic impact variable (EI) description.* The EI variable, with outlying values excluded and adjusted for inflation to a 2008 cost basis, provided a data set of 73 records ranging from a low of -$539 to a maximum of $2281. Negative cost values reflect survey data with student self reported costs below the Prevailing Retail Cost for the survey year. Descriptive summaries of the EI variable for each year group are shown in tables 27, 28 and 29. Summary descriptions for each year group and the overall eight years are provided in table 30. The EI variable exhibited a positive skew for all groups and overall. This indicates that the Economic Impact experienced by students was shifted to the right of the median reported value. Skewness was not significant for any year group or overall. In addition the EI data exhibited mesokurtic characteristics in all groups and overall.
Table 27

*Economic Impact (EI) - Early*

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Max. ($)</th>
<th>Min. ($)</th>
<th>M ($)</th>
<th>SD ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>8</td>
<td>1621</td>
<td>-539</td>
<td>573</td>
<td>660</td>
</tr>
<tr>
<td>2003</td>
<td>21</td>
<td>1522</td>
<td>-466</td>
<td>578</td>
<td>575</td>
</tr>
<tr>
<td>Overall</td>
<td>29</td>
<td>-1621</td>
<td>-539</td>
<td>561</td>
<td>592</td>
</tr>
</tbody>
</table>

Table 28

*Economic Impact (EI) - Intermediate*

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Max. ($)</th>
<th>Min. ($)</th>
<th>M ($)</th>
<th>SD ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>11</td>
<td>2281</td>
<td>343</td>
<td>607</td>
<td>611</td>
</tr>
<tr>
<td>2005</td>
<td>10</td>
<td>991</td>
<td>-274</td>
<td>452</td>
<td>404</td>
</tr>
<tr>
<td>Overall</td>
<td>21</td>
<td>2281</td>
<td>-274</td>
<td>748</td>
<td>586</td>
</tr>
</tbody>
</table>

Table 29

*Economic Impact (EI) - Recent*

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Max. ($)</th>
<th>Min. ($)</th>
<th>M ($)</th>
<th>SD ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>10</td>
<td>1392</td>
<td>-277</td>
<td>778</td>
<td>489</td>
</tr>
<tr>
<td>2007</td>
<td>6</td>
<td>729</td>
<td>209</td>
<td>408</td>
<td>224</td>
</tr>
<tr>
<td>2008</td>
<td>7</td>
<td>1101</td>
<td>101</td>
<td>486</td>
<td>421</td>
</tr>
<tr>
<td>Overall</td>
<td>23</td>
<td>1392</td>
<td>-277</td>
<td>593</td>
<td>431</td>
</tr>
</tbody>
</table>
Table 30

**Economic Impact (EI) - Summary**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Max. ($)</th>
<th>Min. ($)</th>
<th>M  ($)</th>
<th>SD  ($)</th>
<th>skewness</th>
<th>kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>29</td>
<td>+1621</td>
<td>-539</td>
<td>561</td>
<td>592</td>
<td>.08</td>
<td>-.53</td>
</tr>
<tr>
<td>Interm.</td>
<td>21</td>
<td>2281</td>
<td>-274</td>
<td>748</td>
<td>586</td>
<td>.82</td>
<td>1.03</td>
</tr>
<tr>
<td>Recent</td>
<td>23</td>
<td>1392</td>
<td>-277</td>
<td>593</td>
<td>431</td>
<td>.12</td>
<td>-.48</td>
</tr>
<tr>
<td>Overall</td>
<td>73</td>
<td>2281</td>
<td>-539</td>
<td>631</td>
<td>540</td>
<td>.33</td>
<td>.29</td>
</tr>
</tbody>
</table>

*Note.* * Indicates value exceeds 2 standard errors.

Analysis of the EI variable indicates that students reported spending an average of $631 (adjusted to 2008) more than the Prevailing Retail Cost to obtain the notebook computer used in the class. In other words, this finding indicates that students spent more than necessary for the required computer. The descriptive analysis also indicates that the EI variable is adequately normal for parametric analysis.

**Operational Problems (OP)**

This variable reflects the level of operational problems with the notebook computer hardware and software as evaluated by students. The OP variable ranges from 1 to 5 with 1 indicating that students perceived that they thought their notebook computer worked well with no operational problems and 5 indicating that students thought that the operation of their notebook computer was unacceptable. OP was evaluated as an interval variable and combined into three year groups (Early,
Intermediate and Late) for purposes of analysis. The Operational problems (OP) variable is based on student responses to the survey question shown in figure 11.

<table>
<thead>
<tr>
<th></th>
<th>Worked well</th>
<th>Some Problems</th>
<th>never worked/ Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Problems</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>But adequate</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 11. Survey question 12.*

It should be noted that the OP data contained two survey responses (one from 2002 and one from 2006) with a response placed approximately at the mid point between 1 and 2. To convert these responses to appropriate whole number values, the student responses to survey question 1 were used. In the responses to question 1, it was noted that one student/survey clearly preferred notebook computer instruction whereas the other student/survey indicated that they preferred instruction in conventional computer laboratories. Based on this observation, one mid point response was recorded as 1 and the other response was recorded as 2.

The summary OP data for the three class years (2001, 2002, 2003) combined into the Early year group is shown in Table 31.
<table>
<thead>
<tr>
<th>Year</th>
<th>1 worked well No Problems</th>
<th>2</th>
<th>3 Some Problems But adequate</th>
<th>4</th>
<th>5 never worked/Unacceptable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>7 (20.6)</td>
<td>14 (41.2)</td>
<td>10 (29.4)</td>
<td>1 (2.9)</td>
<td>2 (5.9)</td>
<td>34</td>
<td>2.32</td>
<td>1.04</td>
</tr>
<tr>
<td>2002</td>
<td>4 (36.4)</td>
<td>3 (27.3)</td>
<td>4 (36.4)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>11</td>
<td>2.00</td>
<td>.89</td>
</tr>
<tr>
<td>2003</td>
<td>19 (63.3)</td>
<td>6 (20.0)</td>
<td>3 (10.0)</td>
<td>2 (6.7)</td>
<td>0 (0.0)</td>
<td>30</td>
<td>1.60</td>
<td>.93</td>
</tr>
<tr>
<td>Overall</td>
<td>30 (40.0)</td>
<td>23 (30.7)</td>
<td>17 (22.7)</td>
<td>3 (4.0)</td>
<td>2 (2.7)</td>
<td>75</td>
<td>1.99</td>
<td>1.02</td>
</tr>
</tbody>
</table>

The summary OP data for the two class years (2004, 2005) combined into the Intermediate year group is shown in Table 32.

Table 32

**Operational Problems (OP) – Intermediate Group**

<table>
<thead>
<tr>
<th>Year</th>
<th>1 worked well No Problems</th>
<th>2</th>
<th>3 Some Problems But adequate</th>
<th>4</th>
<th>5 never worked/Unacceptable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>6 (42.9)</td>
<td>4 (28.6)</td>
<td>3 (21.4)</td>
<td>1 (7.1)</td>
<td>0 (0.0)</td>
<td>14</td>
<td>1.93</td>
<td>1.00</td>
</tr>
<tr>
<td>2005</td>
<td>11 (57.9)</td>
<td>5 (26.3)</td>
<td>1 (5.3)</td>
<td>2 (10.5)</td>
<td>0 (0.0)</td>
<td>19</td>
<td>1.68</td>
<td>1.00</td>
</tr>
<tr>
<td>Overall</td>
<td>17 (51.5)</td>
<td>9 (27.3)</td>
<td>4 (12.1)</td>
<td>3 (9.1)</td>
<td>0 (0.0)</td>
<td>33</td>
<td>1.79</td>
<td>.99</td>
</tr>
</tbody>
</table>
The summary OP data for the three class years (2006, 2007, 2008) combined into the Recent year group is shown in Table 33.

Table 33

**Operational Problems (OP) — Recent Group**

<table>
<thead>
<tr>
<th>Year</th>
<th>1 Worked well No Problems</th>
<th>2</th>
<th>3 Some Problems But adequate</th>
<th>4</th>
<th>5 never worked/Un acceptable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (% )</td>
<td>n (% )</td>
<td>n (% )</td>
<td>n (% )</td>
<td>n (% )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>4 (30.8)</td>
<td>7 (53.8)</td>
<td>2 (15.4)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>13</td>
<td>1.85</td>
<td>.69</td>
</tr>
<tr>
<td>2007</td>
<td>2 (22.2)</td>
<td>5 (55.6)</td>
<td>1 (11.1)</td>
<td>1 (11.1)</td>
<td>0 (0.0)</td>
<td>9</td>
<td>2.11</td>
<td>.93</td>
</tr>
<tr>
<td>2008</td>
<td>9 (60.0)</td>
<td>6 (40.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>15</td>
<td>1.40</td>
<td>.51</td>
</tr>
<tr>
<td>Overall</td>
<td>15 (40.5)</td>
<td>18 (48.6)</td>
<td>3 (8.1)</td>
<td>0 (2.7)</td>
<td>0 (0.0)</td>
<td>37</td>
<td>1.73</td>
<td>.73</td>
</tr>
</tbody>
</table>

The summary OP data for the three year groups used in this research (Early, Intermediate, Recent) is shown with the summary description for all eight years of the data in Table 34.
Table 34

*Operational Problems (OP) - Summary*

<table>
<thead>
<tr>
<th>Year</th>
<th>1 Worked well No Problems</th>
<th>2 Some Problems But adequate</th>
<th>3</th>
<th>4</th>
<th>5 never worked/Un acceptable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>30 (40.0)</td>
<td>23 (30.7)</td>
<td>17 (22.7)</td>
<td>3 (4.0)</td>
<td>2 (2.7)</td>
<td>75</td>
<td>1.99</td>
<td>1.02</td>
</tr>
<tr>
<td>Interm.</td>
<td>17 (51.5)</td>
<td>9 (27.3)</td>
<td>4 (12.1)</td>
<td>3 (9.1)</td>
<td>0 (0.0)</td>
<td>33</td>
<td>1.79</td>
<td>0.99</td>
</tr>
<tr>
<td>Recent</td>
<td>15 (40.5)</td>
<td>18 (48.6)</td>
<td>3 (8.1)</td>
<td>1 (2.7)</td>
<td>0 (0.0)</td>
<td>37</td>
<td>1.73</td>
<td>0.73</td>
</tr>
<tr>
<td>Overall</td>
<td>62 (42.8)</td>
<td>50 (34.5)</td>
<td>24 (16.6)</td>
<td>7 (4.8)</td>
<td>2 (1.4)</td>
<td>145</td>
<td>1.88</td>
<td>0.95</td>
</tr>
</tbody>
</table>

The characteristics of the OP variable exhibited a significant positive skewness for all three year groups and overall. This implies that most students thought that their notebook computer operated acceptably. In addition the OP data exhibited slight leptokurtic characteristics (peaked) for all groups and overall. This descriptive information is shown in Table 35.

Table 35

*Characteristics of the Operational Problems (OP) Variable*

<table>
<thead>
<tr>
<th></th>
<th>skewness</th>
<th>kurtosis</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>.89*</td>
<td>.40</td>
<td>2.00</td>
</tr>
<tr>
<td>Interm.</td>
<td>1.07*</td>
<td>.08</td>
<td>1.00</td>
</tr>
<tr>
<td>Recent</td>
<td>.93*</td>
<td>1.16</td>
<td>2.00</td>
</tr>
<tr>
<td>Overall</td>
<td>.99*</td>
<td>.57</td>
<td>2.00</td>
</tr>
</tbody>
</table>

*Note.* * Indicates value exceeds 2 standard errors.
The descriptive analysis of the OP variable indicates that students in all class years, in all year groups and as a group, experienced few operational problems and believed that their notebook computer operated acceptably. The descriptive analysis also indicates that the lack of normality of the OP variable may be significant for parametric analysis.

*Student Perceptions*

The Student Comments (SCOM) variable is based on the written student responses to survey questions 15 and 16. The student responses, which identified concerns with the pilot program and the continued use of notebook computers for program classes, are used both quantitatively and qualitatively in this study. Student responses are primarily used to expand the understanding of the results of the quantitative evaluations included in the study. To evaluate the statistical significance of any trends present in the student responses over the eight years of the study however, a categorical variable (SCOM) was used to summarize the general tone of the student responses.

The Student Comments (SCOM) variable was developed by classifying student responses into four categories. These categories were *Positive*, *Negative*, *Neutral* and *Both*. The *Positive* category included all student responses that expressed a supportive or positive opinion of the notebook computer requirement for CAD instruction and the *Negative* response category included all student responses that expressed a non-supportive or negative opinion. The *Neutral* category included all responses that could not be described as positive or negative as well as all non-responses. The *Both* category included those responses that expressed positive as well
as negative opinions. For classification purposes, the student responses to questions 15 and 16 were collectively evaluated to eliminate redundancy.

The summary of student perceptions for the three class years (2001, 2002, 2003) combined into the Early year group as described by the SCOM variable is shown in Table 36.

Table 36

*Student Comments (SCOM) – Early Group*

<table>
<thead>
<tr>
<th>Year</th>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
<th>Both</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>16 (47.1)</td>
<td>6 (17.6)</td>
<td>6 (17.6)</td>
<td>6 (17.6)</td>
<td>34</td>
</tr>
<tr>
<td>2002</td>
<td>8 (72.7)</td>
<td>1 (9.1)</td>
<td>1 (9.1)</td>
<td>1 (9.1)</td>
<td>11</td>
</tr>
<tr>
<td>2003</td>
<td>24 (80.0)</td>
<td>3 (10.0)</td>
<td>2 (6.7)</td>
<td>1 (3.3)</td>
<td>30</td>
</tr>
<tr>
<td>Overall</td>
<td>48 (64.0)</td>
<td>10 (13.3)</td>
<td>9 (12.0)</td>
<td>8 (10.7)</td>
<td>75</td>
</tr>
</tbody>
</table>

The positive student responses in the early group identified flexibility (the ability to operate CAD when and where desired) and the general educational benefit of being able to use the notebook computer for other classes as the primary basis for their response. All ten negative student responses in the Early Group identified cost as a problem. This response is supported by the faculty teaching the course during this early period in that the faculty also reported that cost was a frequently expressed student complaint in the classroom during that period of time. The student responses
that contained both positive and negative comments typically identified cost as a negative factor and flexibility as a positive factor.

The summary of student perceptions for the two class years (2004, 2005) combined into the Intermediate year group as described by the SCOM variable is shown in Table 37.

Table 37

*Student Comments (SCOM) – Intermediate Group*

<table>
<thead>
<tr>
<th>Year</th>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
<th>Both</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>63.4</td>
<td>28.6</td>
<td>7.1</td>
<td>0.0</td>
<td>14</td>
</tr>
<tr>
<td>2005</td>
<td>42.1</td>
<td>15.8</td>
<td>36.8</td>
<td>5.3</td>
<td>19</td>
</tr>
<tr>
<td>Overall</td>
<td>51.5</td>
<td>21.2</td>
<td>24.2</td>
<td>0.0</td>
<td>33</td>
</tr>
</tbody>
</table>

All 17 positive student responses in the intermediate group identified flexibility and convenience as the primary basis for this response. Five student responses in the Intermediate Group identifying cost as a problem were the largest source of negative response. The other negative responses in the intermediate group were a concern for the lack of utilization of the computers in other classes and operational problems. The single student response that contained both positive and negative comments identified cost as a negative factor but stated that the notebook computer was “...good to have.”
The summary of student perceptions for the three class years (2006, 2007, 2008) combined into the Recent year group as described by the SCOM variable is shown in Table 38.

Table 38

*Student Comments (SCOM) – Recent Group*

<table>
<thead>
<tr>
<th>Year</th>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
<th>Both</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>7 (46.7)</td>
<td>2 (13.3)</td>
<td>3 (20.0)</td>
<td>3 (20.0)</td>
<td>15</td>
</tr>
<tr>
<td>2007</td>
<td>7 (70.0)</td>
<td>1 (10.0)</td>
<td>2 (20.0)</td>
<td>0 (0.0)</td>
<td>10</td>
</tr>
<tr>
<td>2008</td>
<td>12 (80.0)</td>
<td>1 (6.7)</td>
<td>0 (0.0)</td>
<td>2 (13.2)</td>
<td>15</td>
</tr>
<tr>
<td>Overall</td>
<td>26 (65.0)</td>
<td>4 (10.0)</td>
<td>5 (12.5)</td>
<td>5 (12.5)</td>
<td>40</td>
</tr>
</tbody>
</table>

All but two positive student responses in the Recent group identified flexibility (the ability to operate CAD when and where desired) as the primary basis for their response. The two remaining responses identified improved operation and reliability relative to typical computer laboratory equipment as the basis of their evaluation. The student responses that contained both positive and negative comments all identified cost as a negative factor but identified a variety of positive factors with a vague reference to the notebook requirement as being a ‘good idea’ as the most common positive response. The faculty members with experience teaching this class also both identified the flexibility to work outside of class as the reason students preferred
notebook computer classes. Two negative student responses in the Recent Group identified cost as a problem. Other negative responses were that the notebook hardware was unnecessary and that adequate advance notice of the requirement was not provided.

The summary SCOM data for the three year groups used in this research (Early, Intermediate, Recent) is shown with the summary description for all eight years of the data in Table 39.

Table 39

*Student Comments (SCOM) – Summary*

<table>
<thead>
<tr>
<th>Year</th>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
<th>Both</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>48 (46.7)</td>
<td>10 (13.3)</td>
<td>9 (20.0)</td>
<td>8 (20.0)</td>
<td>75</td>
</tr>
<tr>
<td>Interm.</td>
<td>17 (70.0)</td>
<td>7 (10.0)</td>
<td>8 (20.0)</td>
<td>1 (0.0)</td>
<td>33</td>
</tr>
<tr>
<td>Recent</td>
<td>26 (80.0)</td>
<td>4 (6.7)</td>
<td>5 (0.0)</td>
<td>5 (13.2)</td>
<td>40</td>
</tr>
<tr>
<td>Overall</td>
<td>91 (65.0)</td>
<td>21 (10.0)</td>
<td>22 (12.5)</td>
<td>14 (12.5)</td>
<td>148</td>
</tr>
</tbody>
</table>

The summary data shows that during all year groups as well as the eight year period of the study, positive student responses greatly outnumbered negative comments. Overall, the major source of positive responses was the added flexibility provided by being able to operate the CAD software at any time or place. The overwhelming basis of negative responses was the added cost to obtain the notebook computer. While cost
was identified as a negative factor for students by one of the two faculty members with experience teaching the course, that faculty member limited the observation to the Early year group period.

*General Relationship between Parametric Variables*

Because of the limited normal characteristics of the survey data, a Spearman’s rho bivariate correlation was used to explore the general relationship between the parametric variables obtained from the survey data. This was done using the data from all year groups. This analysis indicated a highly significant correlation between student preference for notebook computer instruction (PNCI) and the student’s perception of learning (POL). This correlation, $r_s(141) = .535$, $p = .000$, was moderate in effect and positive. In addition a significant but weaker correlation was found between Operational Problems (OP) and Perception of Learning (POL). This correlation, $r_s(138) = .182$, $p = .033$, was small in effect and positive. Table 40 displays the Spearman’s rho correlations for the parametric variables from the survey data.

Table 40  
*Correlation Table for Variables*

<table>
<thead>
<tr>
<th></th>
<th>PNCI</th>
<th>POL</th>
<th>OCOT</th>
<th>EI</th>
<th>OP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNCI</td>
<td>1.00</td>
<td>.540*</td>
<td>.077</td>
<td>-.030</td>
<td>.128</td>
</tr>
<tr>
<td>POL</td>
<td></td>
<td>.000</td>
<td>.361</td>
<td>.802</td>
<td>.125</td>
</tr>
<tr>
<td>OCOT</td>
<td></td>
<td>.065</td>
<td>.449</td>
<td>-.210</td>
<td>.182*</td>
</tr>
<tr>
<td>EI</td>
<td></td>
<td></td>
<td>-.159</td>
<td>.079</td>
<td>.033</td>
</tr>
<tr>
<td>OP</td>
<td></td>
<td></td>
<td>.184</td>
<td>.041</td>
<td>.628</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level (2-tailed)*
Research Question Analysis

Research Question 1

Research Question 1 asked, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in: (a) expressed student preference for CAD classes conducted using notebook computers; (b) student's self-evaluated perception of learning in notebook computer CAD instruction; (c) active learning as indicated by out of class operating time; (d) economic impact in obtaining the required notebook computer hardware; and (e) operational problems in operating CAD software on notebook computers.” To answer this question each of the five quantitative survey variables were evaluated for statistically significant changes between year groups. The null hypothesis for all tests predicted there to be no significant changes in a given survey variable during the overall period of evaluation for any of the three year groups evaluated.

Changes in PNCI. The expressed student preference for CAD classes conducted using notebook computers was measured using the PNCI variable with responses based on a 5 point Likert scale. The student responses consisted of 1 (rather use the laptop), 2, 3, 4, and 5 (rather use the computer lab). The student survey responses for the PNCI variable were separated into the three year groups used in this study as described previously in Table 14. A one-way, fixed effects ANOVA was used to determine if there were significant differences among the PNCI variable between different year groups (early, intermediate and recent). An evaluation of the
homogeneity of variance was conducted and verified using Levine's Test
\((F_{2,145}=2.577, p=.079)\). The results of the ANOVA test for the PNCI variable by year
group are shown in Table 41 and indicated no significant changes in the PNCI
variable mean value during the period of evaluation at a .05 level of significance.

Table 41

| Analysis of Variance for Preference for Notebook Computer Instruction (PNCI) |
|---|---|---|---|
| PNCI | df | Mean Square | \(F\) | Sig. |
| **Between Groups** | | | | |
| Year Group | 2 | 2.194 | 2.245 | .110 |
| **Within Groups** | | | | |
| Error | 145 | .977 | | |

Further analysis motivated by the large kurtosis and skewness values present
in the PNCI variable (see Table 15) was conducted to evaluate the normality of the
PNCI variable. Both the Kolmogorov-Smirnov and Shapiro-Wilk tests of normality
indicated a significant (\(p < .001\)) lack of normality in this variable. Although the
analysis of variance is robust for departures from normality, the potential errors
resulting from parametric analysis due to a lack of normality required further
evaluation. Alternative verification of the analysis of variance results for the PCNI
variable was conducted using the Kruskal-Wallis non-parametric rank based tests for
three independent samples (year groups). The results of this testing \((X^2_{2,148} = 4.09, p\)
\(= .130)\) indicated no significant difference in the PNCI variable for the three year
groups. Based on this analysis, the null hypothesis as presented in research question 1
cannot be rejected for the PNCI variable. There were no significant changes in the
PNCl variable during the overall period of evaluation due to the three year groups evaluated.

*Changes in POL.* The expressed student self-evaluated perception of learning using notebook computers was measured using the POL variable with such responses based on a 5 point Likert scale. The POL variable ranged from 1 to 5 with 1 indicating that students perceived that they learned more using notebook computers and 5 indicating that students perceived that they would have learned more in a conventional computer laboratory. The student survey responses for the POL variable were separated into the three year groups used in this study and a one-way, fixed effects ANOVA was used to determine if there were significant differences among the POL variable between different year groups (early, intermediate and recent). An evaluation of the homogeneity of variance was conducted and the assumption of equal variances rejected using Levene’s Test ($F_{2,138} = 3.342, p = .038$). Due to the unequal variances results for the POL variable, a Kruskal-Wallis non-parametric rank based test for three independent samples (year groups) was conducted instead of the planned ANOVA evaluation. The results of this testing ($X_{2,141}^2 = 1.391, p = .499$) indicated no significant difference in the POL variable between the three year groups. Based on this analysis, the null hypothesis as presented in research question 1 cannot be rejected for the POL variable. There were no significant changes in the POL variable mean value during the period of evaluation.

*Changes in OCOT.* The expressed student self-evaluated estimate of the out of class time that they spent in hours operating the solid modeling CAD software utilized in the class evaluated was measured by using the OCOT variable. The OCOT
variable is an interval variable with a positive value extending from and including zero hours (indicating that students spent no time operating the solid modeling CAD software outside of class). The student survey responses for the OCOT variable were separated into the three year groups used in this study as shown previously in Table 24.

A one-way, fixed effects ANOVA was used to determine if there were significant differences among the OCOT variable between different year groups (early, intermediate and recent). An evaluation of the homogeneity of variance was conducted and verified using Levene's Test ($F_{2,139}=1.311$, $p=.273$). The results of the ANOVA test for the OCOT variable by year group are shown in Table 42 and indicated no statistically significant differences existed between the OCOT variable mean values during the period of evaluation at a .05 level of significance and an observed power of .500.

Table 42

*Analysis of Variance for Out of Class Operating Time (OCOT)*

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year Group</td>
<td>2</td>
<td>4.588</td>
<td>2.530</td>
<td>.083</td>
</tr>
<tr>
<td>Within Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>139</td>
<td>1.813</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Further analysis, motivated by the large skew and kurtosis noted for all but one groups for the OCOT variable (see Table 21) was conducted to evaluate the normality of the OCOT variable. Both the Kolmogorov-Smirnov and Shapiro-Wilk
tests of normality indicated a significant ($p < .001$) lack of normality in this variable. Although the analysis of variance is robust for departures from normality, the potential errors resulting from parametric analysis due to a lack of normality required further evaluation. Alternative verification of the analysis of variance results for the OCOT variable was conducted using the Kruskal-Wallis non-parametric rank based tests for three independent samples (year groups). The results of this testing ($X^2_{2,142} = 6.73, p = .035$) indicated a significant difference in the OCOT variable for the three year groups at a statistical significance ($\alpha$) of .05. Based on this analysis, the null hypothesis as presented in research question 1 can be rejected for the OCOT variable. There were significant changes in the OCOT variable mean values during the period of evaluation.

*Changes in EI.* The EI variable is the whole number difference (positive or negative) in U.S. dollars used to measure the economic impact (or hardship) that students experienced in obtaining the notebook computer required for class. A positive value indicates the student paid more than necessary to obtain their computer. A negative value indicates that the student paid less than the prevailing retail price when they purchased their computer. Only data measuring new computer purchases were used and all values were adjusted for inflation to a 2008 basis. The student survey responses for the EI variable were separated into the three year groups used in this study as shown previously in Table 24. Note that there was no survey inquiry as to the amount that students paid in the initial year (2001) of the pilot program and therefore the initial year of the study is not included in the Early implementers group (2001, 2002 & 2003).
A one-way, fixed effects ANOVA was used to determine if there were significant differences among the EI variable mean values between different year groups (early, intermediate and recent). An evaluation of the homogeneity of variance was conducted and verified using Levine’s Test ($F_{2,71} = .675, p = .512$). The results of the ANOVA test for the EI variable by year group are shown in Table 43 and indicated no statistically significant differences existed between the EI variable mean value and the year groups at a .05 level of significance with a very low observed power of .179.

Table 43

*Analysis of Variance for Economic Impact (EI)*

<table>
<thead>
<tr>
<th>EI</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Between Groups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year Group</td>
<td>2</td>
<td>$2.31 \times 10^5$</td>
<td>.784</td>
<td>.461</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Within Groups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>71</td>
<td>$2.96 \times 10^5$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on this analysis, the null hypothesis as presented in research question 1 cannot be rejected for the EI variable. There were no significant changes in the EI variable mean value during the overall period of evaluation between the three year groups evaluated.

The faculty perceptions expressed in a separate survey did not support the conclusion that there has been no change in economic impact during the eight years of the study. Both of the two faculty members participating indicated that they believed, from their experience in teaching the class evaluated, that the economic
impact in obtaining an appropriate notebook computer had significantly decreased. This belief however was based on the reduction of notebook computer retail cost over the eight years and an increase in the general expectation among students that a notebook computer is a necessary purchase for a college or university student. The faculty responses did not, therefore, directly address the economic impact experienced.

Changes in OP. The expressed student self-evaluated perception of the number and severity of problems encountered while operating the required CAD solid modeling software on their notebook computers was indicated by the OP variable. The OP variable ranged from 1 to 5 with 1 indicating that students perceived that they had experienced no problems and 5 indicating that students perceived that they experienced operational problems to an unacceptable level. The student survey responses for the OP variable were separated into the three year groups used in this study as shown previously in Table 34. A one-way, fixed effects ANOVA was used to determine if there were significant differences among the OP variable mean value between different year groups (early, intermediate and recent). An evaluation of the homogeneity of variance was conducted and verified using Levine’s Test ($F_{2,142}=1.782$, $p=.172$). The results of the ANOVA test for the OP variable by year group as shown in Table 44 indicated no statistically significant differences existed between the OP variable and year group at a .05 level of significance with an observed power of .239.
Further analysis, motivated by the large skew noted for all groups and overall for the OP variable (see Table 29) was conducted to evaluate the normality of the OP variable. Both the Kolmogorov-Smirnov and Shapiro-Wilk tests of normality indicated a significant (p<.001) lack of normality in this variable. Although the analysis of variance is robust for departures from normality, the potential errors resulting from parametric analysis due to a lack of normality required further evaluation. Alternative verification of the analysis of variance results for the OP variable was conducted using the Kruskal-Wallis non-parametric rank based tests for three independent samples (year groups). The results of this testing ($X^2_{2,145} = 1.714$, p = .424) indicated no significant difference in the OP variable for the three year groups at the statistical significance ($\alpha$) of .05. Based on this analysis, the null hypothesis as presented in research question 1 cannot be rejected for the OP variable. There were no significant changes in the OP variable during the overall period of evaluation between the three year groups evaluated.
The faculty perceptions expressed in a separate survey did not support the conclusion that there had been no change in operational problems during the eight years of the study. Both of the two faculty members participating indicated that they believed, from their experience in teaching the class evaluated, that the number and severity of operational problems significantly decreased in the eight years of this research.

Research Question 2

Research question 2 asked, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there any statistically significant changes in the relationship between the following; expressed student preference for CAD classes conducted using notebook computers and the student’s self-evaluated perception of learning in notebook computer CAD instruction.” To answer this question, the difference between the PNCI and POL variables was evaluated using a paired samples student’s t-test conducted for each year group and the entire eight year duration of the study. The results of these tests, shown in Table 45, indicated a statistically significant correlation between PNCI and POL in all year groups and a statistically significant difference in these variables for the Early and Recent year groups. In addition, a statistically significant correlation and a statistically significant difference between the variables were found for the entire eight year period.
Table 45

Paired Samples t-test (Preference for Notebook Computer Instruction - Perception of Learning) Results

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>r</th>
<th>Sig</th>
<th>M</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>68</td>
<td>.467</td>
<td>.000*</td>
<td>-.353</td>
<td>.842</td>
<td>-3.456</td>
<td>67</td>
<td>.001*</td>
</tr>
<tr>
<td>Interm.</td>
<td>33</td>
<td>.668</td>
<td>.000*</td>
<td>-.212</td>
<td>.927</td>
<td>-1.314</td>
<td>32</td>
<td>.198</td>
</tr>
<tr>
<td>Recent</td>
<td>40</td>
<td>.439</td>
<td>.005*</td>
<td>-.400</td>
<td>.982</td>
<td>-2.576</td>
<td>39</td>
<td>.014*</td>
</tr>
<tr>
<td>Overall</td>
<td>141</td>
<td>.535</td>
<td>.000*</td>
<td>-.333</td>
<td>.900</td>
<td>-4.399</td>
<td>140</td>
<td>.000*</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level (2-tailed)

The testing therefore indicated a significant difference between the PNCI and the POL variables for all year groups except for Intermediate at a statistical significance ($\alpha$) of .05. The power observed power for this testing was .862 for the early year group, .230 for the intermediate year group, .682 for the recent year group, and .980 for the overall eight year period. Based on this analysis, the null hypothesis as presented in research question 2 can be rejected. The survey data indicates a significant difference existed in the mean difference for these two variables over the timeframe evaluated. Based on this analysis, there is a significant difference between student preference for notebook computer classes and their perception of learning improvement in those classes for the entire eight years and for all year groups except
the Intermediate Year Group. In addition, student preference for notebook computer classes is significantly greater than their perception of learning in those classes.

The faculty perceptions expressed in a separate survey supported the rejection of the null hypothesis for this question. Both of the two faculty members participating indicated that they believed, from their experience in teaching the class evaluated, that students would indicate a stronger preference for notebook computer classes than they would associate with the amount of learning that they achieved.

Research Question 3

Research Question 3 asked, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationships between the expressed student preference for CAD classes conducted using notebook computers and each of the following measures: (a) active learning as indicated by out of class operating time; (b) operational problems in operating CAD software on notebook computer; and (c) economic impact in obtaining the required notebook computer hardware.” To answer this question an Analysis of Covariance (ANCOVA) was performed with PNCI as the dependent variable, Year Group as an independent categorical variable and OCOT, EI and OP as independent covariates. As a parametric means test, this statistical test was chosen to maximize statistical power while evaluating the combined and individual effects of the three independent interval variables on the PNCI variable with respect to the three year groups. The null hypothesis for this question predicts there to be no statistically significant relationship between the expressed student preference for CAD classes
using notebook computers and out of class operating time, operational problems and economic impact during the overall period of evaluation for any of the three year groups.

Analysis indicated an acceptable homogeneity of variance using Levene's Test ($F_{2,66}=1.237, p=.166$). The results of the ANCOVA test for the PNCI variable with respect to the Year Group and the three covariate variables are shown in Table 46 and indicated no statistically significant differences existed between the PNCI variable, the Year Group or any of the three covariates at a .05 level of significance and an observed power of .616.

Table 46

*Analysis of Covariance for Preference for Notebook Computer Instruction (PNCI)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between Subjects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PNCI</td>
<td>5</td>
<td>2.348</td>
<td>1.932</td>
<td>.101</td>
</tr>
<tr>
<td>Year Group</td>
<td>2</td>
<td>2.451</td>
<td>2.017</td>
<td>.142</td>
</tr>
<tr>
<td>EI</td>
<td>1</td>
<td>.048</td>
<td>.039</td>
<td>.843</td>
</tr>
<tr>
<td>OP</td>
<td>1</td>
<td>4.628</td>
<td>3.809</td>
<td>.055</td>
</tr>
<tr>
<td>OCOT</td>
<td>1</td>
<td>1.524</td>
<td>1.254</td>
<td>.267</td>
</tr>
<tr>
<td><strong>Error</strong></td>
<td>63</td>
<td>1.215</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on this analysis, the null hypothesis as presented in research question 3 cannot be rejected. There was no statistically significant variation in the expressed student
preference for notebook computer CAD classes due to year group, economic impact, operational problems, or out of class operating time during the eight year period of evaluation.

Research Question 4

Research Question 4 asked, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationships between the student's self-evaluated perception of learning and each of the following measures: (a) active learning as indicated by out of class operating time; (b) operational problems in operating CAD software on notebook computer; and (c) economic impact in obtaining the required notebook computer hardware.” To answer this question an Analysis of Covariance (ANCOVA) was performed with POL as the dependent variable, Year Group as an independent categorical variable and OCOT, EI and OP as independent covariates. As a parametric means test, this statistical test was chosen to maximize statistical power while evaluating the combined and individual effects of the three independent interval variables on the POL variable with respect to the three year groups. The null hypothesis for this question predicts there to be no statistically significant relationship between the expressed student preference for CAD classes using notebook computers and out of class operating time, operational problems and economic impact during the overall period of evaluation for any of the three year groups.

Analysis using Levene’s Test indicated an acceptable homogeneity of variance (F_{2,64}=3.061, p=.054). The results of the ANCOVA test for the POL variable
with respect to Year Group and the three covariate variables, shown in Table 47, indicated no statistically significant differences existed between in the POL variable mean value, the Year Group or any of the three covariates at a .05 level of significance and an observed power of .585.

Table 47

*Analysis of Covariance for Perception of Learning (POL)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POL</td>
<td>5</td>
<td>1.456</td>
<td>1.825</td>
<td>.121</td>
</tr>
<tr>
<td>Year Group</td>
<td>2</td>
<td>1.097</td>
<td>1.375</td>
<td>.261</td>
</tr>
<tr>
<td>EI</td>
<td>1</td>
<td>2.466</td>
<td>3.091</td>
<td>.084</td>
</tr>
<tr>
<td>OP</td>
<td>1</td>
<td>.024</td>
<td>.031</td>
<td>.862</td>
</tr>
<tr>
<td>OCOT</td>
<td>1</td>
<td>1.947</td>
<td>2.441</td>
<td>.123</td>
</tr>
<tr>
<td>Error</td>
<td>61</td>
<td>.798</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on this analysis, the null hypothesis as presented in research question 4 cannot be rejected. There was no statistically significant variation in the expressed student preference for notebook computer CAD classes due to year group, economic impact, operational problems, or out of class operating time during the eight year period of evaluation.
Research Question 5

Research Question 5 asked, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationship between the following; (a) active learning as indicated by out of class operating time and operational problems in operating CAD software on notebook computers; (b) operational problems in operating CAD software on notebook computers and the economic impact in obtaining the required notebook computer hardware; and (c) active learning as indicated by out of class operating time and the economic impact in obtaining the required notebook computer hardware.” To answer this question, each of the three pairings of independent variables were evaluated for statistically significant changes between year groups. The null hypothesis for all tests predicted there to be no significant changes in a given variable pair during the overall period of evaluation for any of the three year groups evaluated.

Changes in OCOT - OP. The relationship between the out of class operating time was evaluated using a two-way Analysis of Variance (ANOVA) test with Out of Class Operating Time (OCOT) used as a continuous dependent variable. Year Group and Operational problems (OP) were used as categorical variables. This test required the Operating Problem (OP) variable to be converted from the five value survey response used as an interval variable to a three level categorical variable (cOP). The grouping of the new variable was based on the highly skewed nature of the Operating Problem variable and combined the three low frequency responses into a single
categorical response. Table 48 describes the frequency distribution of the categorical operating problem variable and its relationship to the five level OP variable.

Table 48

*Categorical Operational Problems (COP) - Frequency Distribution*

<table>
<thead>
<tr>
<th>OP</th>
<th>1 Worked well</th>
<th>2 No Problems</th>
<th>3 Some Problems But adequate</th>
<th>4 Never worked/Unacceptable</th>
<th>5 / 4 / 5 Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>30 (40.0)</td>
<td>23 (30.7)</td>
<td>22 (29.3)</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Intern.</td>
<td>17 (51.5)</td>
<td>9 (27.3)</td>
<td>7 (21.2)</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Recent</td>
<td>15 (40.5)</td>
<td>18 (48.6)</td>
<td>4 (10.8)</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>62 (42.8)</td>
<td>50 (34.5)</td>
<td>33 (22.8)</td>
<td>145</td>
<td></td>
</tr>
</tbody>
</table>

A two-way, fixed effects ANOVA was used to determine if there were significant differences in OCOT variable due to categorical operational problems (cOP) and Year Group. This statistical test was chosen to maximize statistical power by using a parametric means test suitable for one dependent interval variable and two categorical variables. An evaluation of the homogeneity of variance was conducted and verified using Levene's Test ($F_{8,130}= .571$, $p=.800$). The results of the ANOVA test for the OCOT variable, the categorical operating problem variable and year group are shown in Table 49. This testing indicated no statistically significant relationship between mean out of class operating time and the operational problems experienced
over the three year groups when evaluated at a .05 level of significance with an observed power of .423.

Table 49

*Analysis of Variance for Out of Class Operating Time (OCOT), Categorical Operational Problems (COP) and Year Group*

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCOT</td>
<td>8</td>
<td>1.784</td>
<td>.941</td>
<td>.485</td>
</tr>
<tr>
<td>Year Group</td>
<td>2</td>
<td>2.484</td>
<td>1.310</td>
<td>.273</td>
</tr>
<tr>
<td>cOP</td>
<td>2</td>
<td>1.281</td>
<td>.676</td>
<td>.511</td>
</tr>
<tr>
<td>Year Group X cOP</td>
<td>4</td>
<td>.534</td>
<td>.282</td>
<td>.889</td>
</tr>
<tr>
<td>Error</td>
<td>130</td>
<td>1.896</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Changes in OCOT - EI.* The relationship between the out of class operating time and economic impact was evaluated using a two-way Analysis of Variance (ANOVA) test with Out of Class Operating Time used as a continuous dependent variable. Year Group and Economic Impact were used as categorical variables. This test required the Economic Impact (EI) variable to be converted from an interval variable with a range of -$539 to +$2,281 to a categorical variable (cEI). Based on the approximate mean and standard deviation for the EI variable, a center point and an interval size of $500 was used to create a three level categorical variable. Table 50 describes the frequency distribution of the categorical Economic Impact variable and
its relationship to the interval based Economic Impact variable obtained from the survey data.

Table 50

*Categorical Economic Impact (CEI)*

<table>
<thead>
<tr>
<th></th>
<th>EI less than $250</th>
<th>more than $250 to $750</th>
<th>more than $750</th>
</tr>
</thead>
<tbody>
<tr>
<td>cEI</td>
<td>n</td>
<td>(%)</td>
<td>n</td>
</tr>
<tr>
<td>Early</td>
<td>9  (32.1)</td>
<td>10 (35.7)</td>
<td>9  (32.1)</td>
</tr>
<tr>
<td>Interm.</td>
<td>3 (14.3)</td>
<td>8 (38.1)</td>
<td>10 (47.6)</td>
</tr>
<tr>
<td>Recent</td>
<td>6 (26.1)</td>
<td>8 (34.8)</td>
<td>9 (39.1)</td>
</tr>
<tr>
<td>Overall</td>
<td>18 (25.0)</td>
<td>26 (36.1)</td>
<td>28 (38.9)</td>
</tr>
</tbody>
</table>

A two-way, fixed effects ANOVA was used to determine if there were significant differences in OCOT variable due to categorical Economic Impact (cEI) and Year Group. This statistical test was chosen to maximize statistical power by using a parametric means test suitable for one dependent interval variable and two categorical variables. An evaluation of the homogeneity of variance was conducted and verified using Levene's Test ($F_{8,61} = 1.772, p = .100$). The results of the ANOVA test for the OCOT variable, the categorical economic impact variable and year group are shown in Table 51. This testing indicated no statistically significant relationship between mean out of class operating time and the economic impact.
experienced by students over the three year groups when evaluated at a .05 level of significance and an observed power of .408.

Table 51

*Analysis of Variance for Out of Class Operating Time (OCOT), Categorical Economic Impact (CEI) and Year Group*

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Between Groups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCOT</td>
<td>8</td>
<td>1.119</td>
<td>.637</td>
<td>.743</td>
</tr>
<tr>
<td>Year Group</td>
<td>2</td>
<td>.768</td>
<td>.437</td>
<td>.648</td>
</tr>
<tr>
<td>cEI</td>
<td>2</td>
<td>2.224</td>
<td>1.266</td>
<td>.289</td>
</tr>
<tr>
<td>Year Group X cEI</td>
<td>4</td>
<td>.682</td>
<td>.388</td>
<td>.816</td>
</tr>
<tr>
<td>Error</td>
<td>61</td>
<td>1.756</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Changes in OP - EI.* The relationship between the operational problems experienced by students and the economic impact that they experienced in obtaining their notebook computer was evaluated using a Pearson's Chi-Squared test with Operational problems (cOP) and Economic Impact (cEI) used as categorical variables. This test was selected because it is a nonparametric test suitable for the evaluation of the relationship between two categorical variables. These variables were developed as described previously in the analysis description for research question 5. The results of the Chi-Squared test for the cOP and cEI categorical variables, shown
in Table 52, indicated no significant differences in the distribution of these variables during any Year Group or for the overall eight year period.

Table 52

*Chi-Squared for Categorical Operational Problems (COP) and Categorical Economic Impact (CEI)*

<table>
<thead>
<tr>
<th>Year Group</th>
<th>N</th>
<th>df</th>
<th>$X^2$</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>28</td>
<td>4</td>
<td>1.798</td>
<td>.773</td>
</tr>
<tr>
<td>Interim.</td>
<td>21</td>
<td>4</td>
<td>3.465</td>
<td>.483</td>
</tr>
<tr>
<td>Recent</td>
<td>21</td>
<td>4</td>
<td>3.281</td>
<td>.512</td>
</tr>
<tr>
<td>Overall</td>
<td>70</td>
<td>4</td>
<td>.356</td>
<td>.986</td>
</tr>
</tbody>
</table>

*Research Question 6*

Research Question 6 asked, “To what extent, if any, have the *perceptions of students* taking CAD classes utilizing notebook computer based instruction changed during the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction as indicated by (a) their most *commonly expressed advantages* and (b) their most *commonly expressed disadvantages* of such instruction.” To answer this question, student responses from the three Year Groups from the eight years of survey data were reviewed to identify general themes and to assign written survey responses to one of four categories. These categories, based on the student responses to survey questions 15 and 16, were *Positive, Negative, Neutral* and *Both.* The resulting frequency
distributions for this classification were presented previously in this chapter as Tables 30, 31, 32 and 33.

The distribution of classified comments was evaluated using a Pearson’s Chi-Squared test with Year Group and the comment classification used as categorical variables. This test was selected because it is a nonparametric test suitable for the evaluation of the relationship between two categorical variables. The results of the Chi-Squared test ($\chi^2_{6,148} = 6.837, p = .336$), indicated no significant difference in the distribution of student comments by Year Group during the overall eight year period. Based on this analysis, the null hypothesis as presented in research question 6 cannot be rejected. There was no statistically significant variation in the number and essential content of the student responses for the three year groups evaluated during the eight year period of evaluation.

The information obtained from the survey of faculty experienced in teaching the class evaluated did not directly identify any change in student perceptions during the three year groups or over the eight year period. The faculty did indicate that they perceived that student objections to the cost of the notebook computer and the number of complaints due to operational problems were notable during the initial years of the implementation. The faculty also indicated that these complaints were very infrequent during the most recent years of the study. This decrease in classroom expressed negative perceptions, which matches a similar decrease in the negative comment percentage shown in Table 33, was however not statistically significant in the quantitative analysis.
Summary of Results

The survey data examined in this chapter was primarily quantitative in nature and based on the eight years of class survey data reflecting student perceptions and observations. The quantitative analysis of this data began with a detailed description of each variable. This analysis showed that the expressed student preference for notebook computer classes consistently indicated notebook computer based CAD classes were preferred by students to similar classes in conventional computer laboratories at SU in all year groups and during the overall eight year time period. A similar conclusion that students thought that they learned more in notebook computer based CAD classes was also established in all year groups and during the overall eight year time period although to a lesser degree than the measure of student preference for those classes. The quantitative analysis also established that students reported using the required CAD software on their computers for slightly more than 2 hours for each class hour of instruction. The quantitative evaluation of the economic impact that students experienced in obtaining their notebook computer for the class determined that students spent approximately $600 more than required when adjusted for inflation over the eight years of the study. The quantitative descriptive analysis also indicated that students reported that their notebook computers operated acceptably when used for CAD during all year groups and overall.

After describing the quantitative variables, the analysis presented in this chapter answered six research questions related to the data. The analysis of the first research question indicated that all quantitative variables did not vary in a statistically significant manner during the eight year period of evaluation except for Out of Class
Operating Time (OCOT) which exhibited a significant decrease. The analysis of the second research question determined that the expressed student preference for CAD classes using notebook computers exceeded the student perception of improved learning in those classes. This difference was established as significant for all year groups as well as for the overall eight year period of evaluation. The analysis related to research question three determined that there was no statistically significant relationship between either student preference for notebook classes and three independent variables (out of class operating time, the severity of operational problems experienced and the economic impact experienced by students) during the three year groups used in the study. The results related to research question four provided similar non-significant results for the student perception of learning. The three independent variables were subjected to a pair-wise analysis to answer research question five and this analysis indicated that there was no statistically significant relationship between either out of class operating time and operational problems, out of class operational problems and economic impact, or operational problems and economic impact.

In addition to the quantitative analysis of student survey data, this research also included qualitative data obtained from written student responses and information obtained from a survey administered to faculty with direct experience in teaching the notebook computer class which provided the student survey information. In research question six, student comments were found to be much more positive than negative during all year groups. This positive tone was found to exist as well in the eight years of the study overall. The student comment responses were also found to
be consistent with the results obtained from the quantitative evaluation of expressed student preference for notebook computer classes and the student evaluated perception of learning in that the number of comments of a positive nature significantly exceeded the number of negative comments. Student comments and quantitative evaluation both indicated that most students thought that CAD classes using notebook computers were a good idea and provided an educational benefit. Also consistent with the quantitative survey results indicating that students preferred notebook computer CAD classes but did not strongly base this preference on improved learning, is the observation that the preponderance of positive student comments identified flexibility, not learning improvement, as the basis of their positive response. The flexibility identified as the primary positive factor did, in a small number of survey responses refer to the ability to explore the required software more than necessary for class, but there were no comments that directly indicated that students were spending more time operating the required software outside of class than they would have for a CAD class taught in a conventional computer laboratory.

Student comments identified the cost that they incurred to obtain their notebook computer as the primary negative factor in notebook computer based CAD classes at SU. Cost as a negative factor however was notably inconsistent with the quantitative result that students in all year groups and the entire eight year period were shown to have spent more than necessary in purchasing their notebook computers. The lack of negative student comments identifying operational problems with their notebook computers did support the quantitative measure in that most
students did not report significant problems in operating the required CAD software on their notebook computers.

Faculty perceptions as expressed by two faculty members with experience teaching the notebook computer class at SU were obtained in a separate survey. The observations by these faculty members were in general agreement with most areas of the analysis presented in this chapter. The experienced faculty perceived that students have consistently preferred notebook computer based classes and perceived that students would acknowledge learning more in those classes. The faculty responses also indicated that student preference would be greater than the level of perceived increase in learning. Both faculty members indicated however that they believed that student learning had increased during the time period evaluated. Faculty members also correctly identified the cost of the notebook computer as the most significant negative factor but, contrary to the results indicated in the analysis, expressed the opinion that the economic impact of the purchase had significantly decreased over time. The experienced faculty members also indicated, contrary to the analysis results, that they perceived the number and severity of operational problems to have significantly decreased during the eight year period. Faculty members also accurately identified the amount of time that students would report operating the software outside of class but, unlike the student perception results presented, both faculty thought that the level of out of class operation had actually increased during the survey period.
CHAPTER 5
DISCUSSION

This research focuses on providing information for higher education leaders that have or are considering implementing student notebook computer based curriculum. Specifically concerned with CAD instruction using student owned notebook computers, this study presents and analyzes various metrics obtained from classroom survey data collected over eight years following the implementation of a pilot notebook computer requirement for engineering technology students at a four year public university. The research objectives of this study are designed to provide higher educational leaders with the information necessary to implement notebook computer programs as well as other types of future technological changes within higher education.

The conceptual foundation of the research is based on relevant elements of leadership, organizational systems and learning theory. It has been established by leadership theory that the successful implementation of change requires leaders to motivate their organizations and to define objectives of change that are attainable by the organization (Birnbaum, 1999; Burns, 1978; Owens, 2001, Senge, 1990). Leadership theory also emphasizes the value of defining objectives which allow progress toward their achievement to be measured. The review of prior research on the implementation of notebook computer programs in higher education presented in this study established that leaders implementing such programs have frequently identified an improvement in organizational image (Griffith, Gu, & Brown, 1999), an improvement in student learning (McVay, Snyder, & Graetz, 2005) and / or cost
reduction as justification (Newby, 2003; Olsen, 2001). The review of prior research has also shown, however, that notebook computer implementations in higher education have often lacked substantive measures to establish if those objectives were achieved (Brown & Pettito, 2003; Newby; Olsen). This study addresses both of these leadership elements by presenting metrics used to identify the image, learning and cost impact for the notebook computer initiative at the Subject University. The need established by leadership theory for defining goals that are realistic and attainable (Birnbaum; Green, 1997; Spodark, 2003) are similarly addressed in this research by providing the metrics used at SU to ensure that the timing of its notebook computer initiative was such that the notebook computer hardware necessary for acceptable CAD operation was readily available at a cost within student financial limits.

The review of prior notebook computer implementations within higher education as provided by this study indicates that higher educational organizations have experienced a variety of problems which can be explained using organizational systems theory (Brauer, 2003; Cooke, 1995; Demd & Hawkins-Wilding, 2004; Grau, 2006). Colleges and universities which have implemented notebook computer programs in an attempt to improve organizational image have, in several cases, experienced problems because their implementation occurred before notebook computer hardware was adequately affordable or before the selected required equipment was capable of reliable operation. As with any technological advance, the cost of notebook computer hardware has decreased and performance capability has increased over time. This effect, when evaluated relative to prior notebook computer implementations within higher education, is predictive in explaining the number and
severity of the problems experienced by the first schools implementing such programs. Systems theory describing the escalation archetype and the tragedy of the commons archetype (Senge, 1990) as described in this research is consistent with the problems experienced in a number of prior notebook computer implementations.

The pilot program at SU described in this research occurred at a time when notebook computer cost and capabilities were significantly improved from the earliest notebook computer programs. The CAD class used for the SU pilot program, however, placed significantly higher operational (and cost) requirements on the notebook computers used because of the graphics processing requirements of the target software than those present in earlier implementations at other institutions. This study provides the metrics used at SU to evaluate the financial impact experienced by students and the level of operational problems experienced during the eight years of the study. Since there is an obvious tradeoff in hardware capability and cost, the study also evaluates the relationship between these performance and cost metrics.

The improvement of student learning has been frequently identified by leaders in higher education as a justification for implementing notebook computer programs (Brieling, 2004; Holleque, 2002; Lim 1999; Sargeant & Svec, 2003). The review of prior research for this study has established that existing research is notably lacking in providing quantitative and objective comparison measures of learning effectiveness between classes conducted in conventional computer laboratories using desktop computers and those conducted using student notebook computers. Although the limitation of only one class per academic year in the pilot program at SU prevented such a comparative evaluation, this research describes alternative measures used at
SU which have been established by learning theory and prior research as predictive of student learning. Student engagement, indicative of a positive learning environment, can be evaluated by student self-evaluation of learning and by measures of student satisfaction (Anderson, 2001; Brauer, 2003; Cooke, 1995; Lord & Bishop, 2001; Ni & Branch, 2004). In addition it has been established that empowering students to structure their own hands-on, self-directed learning environments increases the amount and quality of student learning (Thomas, Laxer, Nishida, & Sherlock, 1998).

This research describes and analyzes two measures used at SU for the pilot implementation that measure the student self-perception of learning and the amount of hands-on operation of the applicable CAD software on the notebook computers outside of class. These measures are used to provide an evaluation of the impact of the notebook computer initiative on student learning. In addition the research evaluates the relationship between these measures of student learning and other factors that can be directly related such as the number and severity of operational problems experienced by students.

Research Question Summary

The fundamental objectives of this research are summarized in the analysis and resolution of six research questions using the eight years of survey data collected at SU during the pilot implementation. These research questions were designed to describe the collected data in a manner that would be understandable and useful to higher educational leaders and to explore trends and interrelationships between the various survey variables over the period of the study.
Research question 1 states, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in: (a) expressed student preference for CAD classes conducted using notebook computers; (b) student’s self-evaluated perception of learning in notebook computer CAD instruction; (c) active learning as indicated by out of class operating time; (d) economic impact in obtaining the required notebook computer hardware; and (e) operational problems in operating CAD software on notebook computers.” For this question the null hypothesis is accepted for expressed student preference for CAD classes conducted using notebook computers, student’s self-evaluated perception of learning, economic impact and operational problems. No statistically significant changes are noted in these four quantitative variables. A significant decrease in out of class operating time was determined and the null hypothesis is rejected for this variable.

Research Question 2 states, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there any statistically significant changes in the relationship between the following: expressed student preference for CAD classes conducted using notebook computers and the student’s self-evaluated perception of learning in notebook computer CAD instruction.” For this question the null hypothesis is rejected, there is a very significant difference in these variables during two of the three year groups as well as for the overall eight year period of the study.
Research Question 3 states, "During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationships between the expressed student preference for CAD classes conducted using notebook computers and each of the following measures: (a) active learning as indicated by *out of class operating time*; (b) operational problems in operating CAD software on notebook computer; and (c) economic impact in obtaining the required notebook computer hardware." For this question the null hypothesis is accepted. No statistically significant changes are noted in the relationship between the student preference for notebook computer classes and the three independent variables identified.

Research Question 4 states, "During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationships between the student's self-evaluated perception of learning in notebook computer CAD instruction and each of the following: (a) active learning as indicated by *out of class operating time*; (b) operational problems in operating CAD software on notebook computers; and (c) economic impact in obtaining the required notebook computer hardware." For this question the null hypothesis is accepted. No statistically significant changes are noted in the relationship between the student perception of learning and the three independent variables identified.
Research Question 5 states, “During the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction, to what extent, if any, were there statistically significant changes in the relationship between the following; (a) active learning as indicated by out of class operating time and operational problems in operating CAD software on notebook computers; (b) operational problems in operating CAD software on notebook computers and the economic impact in obtaining the required notebook computer hardware; and (c) active learning as indicated by out of class operating time and the economic impact in obtaining the required notebook computer hardware.” For this question the null hypothesis is accepted. No statistically significant changes are noted in the relationship between out of class operating time, operational problems and economic impact during the three year groups of the study.

Research Question 6 states, “To what extent, if any, have the perceptions of students taking CAD classes utilizing notebook computer based instruction changed during the three phases (early, intermediate and recent) of the initial eight years following the incorporation of notebook computer based CAD instruction as indicated by (a) their most commonly expressed advantages and (b) their most commonly expressed disadvantages of such instruction.” For this question the null hypothesis is accepted. No statistically significant changes are noted in the number and nature of student perceptions as expressed in the written survey comments. The most commonly expressed positive comment expressed by students reflecting the advantages of notebook computer instruction was that notebook computer based instruction provided more flexibility to work on class material at a time and place of
their choosing. The most commonly expressed negative comment expressed by students reflecting the disadvantages of notebook computer instruction was that the cost incurred to acquire the required notebook computer was excessive.

Relationship to Prior Research

The research of this study is based on CAD instruction using student owned notebook computers. A review of prior research as provided in Chapter 2 found 23 prior studies applicable to this research. Of these 21 were studies that included or were based on student responses as is the case for this research. This research is unique relative to prior studies in that no prior research involving CAD instruction using notebook computers was noted. The longitudinal scope of this research also significantly exceeds that of prior research in that 18 of the prior research studies were limited to one semester or academic year in scope. Previously only a quantitative presentation of student survey data collected from notebook computer students at Valley City State University during six consecutive academic years (96-97 through 01-02) (Holleque, 2002) approximates the eight year duration of this research.

The examination of student learning impact included in this research extends the use of student self-assessment of learning as included in a number of studies that have used student self-assessment as a means to determine the learning impact of notebook computers in the classroom. This method of evaluating student self-assessed learning impact was used by Anderson (2001), Grau (2006), Lord and Bishop (2001), Ni and Branch (2004), Cooke (1995), Heeler and Van Holzen (1997), and Hanson (1998). Other studies using a student survey instrument with Likert scale
based student self-assessment measurement such as that used in this study were
completed by Bauer (2003), Collins, Easterling, Fountain, and Stewart (2001), Demb,
Erickson and Hawkins-Wilding, (2004) and Holleque (2002). In all cases evaluated,
the student self-assessed perception of learning measures indicated, as in this
research, that students believed that notebook computers had improved the amount
and quality of learning. This study expands on this result by establishing that students
are able to differentiate between perceived learning impact and their preference for
notebook computer based classes.

A number of prior research studies evaluated included limited information
regarding the type and amount of student notebook computer use. Studies by Bauer
(2003), Grau (2006), Holleque (2002), McVay et al. (2005), Heeler and Van Holzen
Lowry (2001) and Grace-Martin and Gay (2001) all evaluated the amount of
notebook computer use by students outside of class as is included in this study. The
out of class operating time measure used in this research, however, is the only
quantitative evaluation of CAD software operation outside of class in comparison to
the amount of in class usage. In addition this study evaluates the relationship of out
of class operation to other relevant measures such as operational reliability.

A conclusion made in prior research by Anderson (2001), Grau (2006), Demb
et al. (2004), McVay et al. (2005), Cooke (1995) and Bauer (2003) was that a high
level of incorporation of notebook computers in a curriculum produces a higher level
of student satisfaction. This study supports this result but extends the finding in its
identification of flexibility as the primary reason responsible for a high level of student satisfaction.

This study is unique in its evaluation of the impact that obtaining the notebook computer had on students participating in the pilot implementation. An important consideration in implementing a notebook computer initiative is the cost impact to the institution and its students. Cost reduction, however, is seldom identified formally as a justification for an implementation and it is obvious that increasing student computer access to a one to one relationship requires additional expense. Prior studies which evaluated cost such as Anderson (2001), Cooke (1995), Li and Newby (2002), Bauer (2003), McVay et al. (2005), and Demb et al. (2004) determined cost to be an area of concern for students. The analysis of student comments in this research supports this finding but adds significance by including a quantitative cost measure intended to evaluate the actual economic impact of the added costs to students. This measure discovered that students in all eight years of the SU study voluntarily paid more than necessary to obtain their computer. This research also evaluates the relationship of cost to other relevant factors such as student satisfaction.

The reliable operation of notebook computer hardware has seldom been included as a direct measure in prior research. Prior studies by Lim (1999), Cooke (1995), Kariuki (2000), Demb et al. (2004), and Bauer (2003) have all provided evidence of operational reliability as a problem area for notebook computer implementations the study results. Only one prior study provided a direct measure of operating reliability (Grau, 2006) but no results were provided for evaluation. This operational reliability of this research is therefore unique in providing a measure of
operational reliability and evaluating its characteristics over the eight years of the pilot implementation.

Analysis of Research Results

The analysis of each of the five quantitative study variables provides a comprehensive and logical means to document and interpret the notebook computer pilot implementation at SU. By using study variables as a focal point, greater depth of discussion and analysis can be provided than that offered by the acceptance or rejection of the research hypothesis. In addition to the results obtained from the six research questions, student survey written comments and information from a survey of involved faculty is used to analyze each variable as to its meaning both in interpreting the experiences of the SU notebook computer pilot program as well its potential for use as a metric in implementing similar programs at other institutions. The discussion begins with the two dependent variables that are the focus of the conceptual basis of this research and then extends its analysis to the impact and interrelationship of the supporting independent variables over time.

Analysis of Student Preference for Notebook Computer Instruction

The two primary dependent variables used in this study are the student Preference for Notebook Computer Instruction (PNCI) and the self-evaluation of the Student Perception of Learning (POL). The PNCI variable, reflecting student preference for CAD classes using notebook computers relative to similar classes conducted in conventional computer laboratories using desktop computers, is useful as a measure of student satisfaction and attitude regarding the notebook computer requirement. This variable is a valuable indicator of appropriate timing in initiating a
notebook computer initiative from a student viewpoint. A low PNCI measure indicates a low level of student support for such an initiative and would be indicative of a premature implementation likely to encounter problems such as those identified in prior research. A high PNCI measure indicates appropriate timing for an implementation and that the implementation timing supports a positive learning environment with a higher level of student engagement.

The research presented in this study indicates that there was a decided preference for notebook computer instruction at SU for the eight years between 2001 and 2008. The research also indicates that there was no statistically significant difference in the student preference between any of the three year groups used in the study. The student comments were predominantly positive and consistent with the PNCI quantitative results throughout the period evaluated. The faculty survey information also accurately predicted this high level of student support for notebook computer instruction. The reasons responsible for the student support of notebook computer instruction as indicated by the PNCI variable were determined by this research through an analysis of the student and faculty written comments. Both the students and the instructional faculty participating in this research indicated that flexibility was the predominant reason that students strongly preferred classes using notebook computers. Students indicated that they placed a high value on being able to complete class assignments at a time and place of their choice as opposed to being limited to the class time available and the restrictive times offered by open computer laboratories. Based on these results, this research indicates the notebook computer implementation at SU was not premature. In addition this research indicates that, as
early as 2001, student owned notebook computer instruction in higher education, including the more demanding requirements of CAD operation, was possible and that there was no significant reduction in the level of student support during the following eight years.

*Analysis of Student Evaluated Perception of Learning*

The POL variable, reflecting the student's self-evaluated perception of learning in the CAD classes evaluated, is useful as an indirect measure of student learning. Although not as definitive as an objective comparative measure of actual learning, the POL variable is consistent with similar measures used in the prior research presented in this study and is indicative of a positive learning environment. Similar in context to the PNCI variable, the POL variable was designed to separate the preference for notebook computer classes from the amount of learning that was perceived as being achieved in those classes. A strong positive correlation between these variables was detected, indicating that students who expressed a strong preference for notebook computer classes also thought that they learned more in those classes. This research, however, by detecting that a significant difference existed between the mean values of the PNCI and POL variables, established that they were differentiated measures. The POL variable is a valuable indicator of the improved learning frequently used as a justification for notebook computer implementation. A high POL value would be consistent with a perceived improvement in student learning and would justify a notebook computer implementation. A low POL value indicates a perceived reduction in learning and would indicate that an implementation was inappropriate.
The research presented in this study indicates that students perceived that the notebook computer initiative at SU for the eight years between 2001 and 2008 provided greater learning than that offered in a conventional computer laboratory using desktop computers. It is notable that none of the 141 student responses to survey question 3 (see Figure 3) strongly indicated that they would have learned more in a conventional computer laboratory. The research also indicates that there was no statistically significant difference in the perception of learning between any of the three year groups used in the study. The student comments were similarly positive and consistent with the POL quantitative analysis throughout the period evaluated. The faculty survey information accurately predicted the student perception of greater learning. The reasons responsible for the perception of improved learning in notebook computer instruction as indicated by the POL variable were determined by evaluating student and faculty written comments. Although the comments by the students addressing their level of learning were few in number, they indicated that the ability to spend additional, self-paced, time outside of class provided both improved mastery of the CAD software as well as improved computer skills. No student comments indicated that any student perceived a reduction of learning due to notebook computer use. The faculty comments were similar in identifying that notebook computer classes offered students the ability to resolve problems on their own timetable outside of class and that notebook computer based CAD classes were able to cover more material in the same amount of class time than classes taught in conventional computer laboratories. Based on these results, this research supports the notebook computer implementation at SU in that notebook computer classes were perceived as
improving student learning by both the faculty and the students involved during the eight years of the study.

The relationship between the two primary dependent variables used by the study (PNCI and POL) is the focus of research question 2. The purpose of this question is to determine if these dependent variables were differentiated measures in that they produced different responses by students. The analysis for this question determined there to be a statistically significant difference between these variables in two of the three year groups evaluated. In addition a highly significant difference between these variables was established for the overall eight year period with a high level of observed power. This research therefore strongly establishes (refer to Table 45) that the measures of student preference for notebook computer classes and that of perception of learning, as used in this study, were different measures and provided different student responses. In this case, the student preference for notebook computer classes was shown to be significantly greater than the perception that students learned more in those classes. This result is also supported by the faculty survey information in which both faculty members predicted this difference in student responses. This result can be interpreted as meaning that the strong student preference for notebook computer instruction was not based on a perceived improvement in learning.

Analysis of Out of Class Operating Time

The measure of the time, in hours, spent outside of class operating the CAD software for each class hour is included in the study as the Out of Class Operating Time (OCOT) variable. This variable reflects the student perception of this amount of time and is not an actual objective measure. The amount of time spent operating the
CAD software outside of class is useful as an indicator of the amount of hands-on learning critical to the mastery of the class software. In addition the use of the CAD software outside of class offers students the opportunity to self-direct their learning and allows students to apply the software beyond class assignments thereby allowing them to experience a variety of uses for the software and their notebook computer. A large value of the OCOT variable represents a large amount of time outside of class spent operating the software and a high level of student engagement.

The research presented in this study indicates that students reported spending an average of 2.19 hours outside of class operating the CAD software for each hour of class time over the eight years of the study. Since the class evaluated consisted of one lecture hour and three hours of laboratory for a total of 4 class hours per week, this measure indicates that students are using their computers an average of 8.76 hours each week. The OCOT measure exhibited a statistically significant decrease between the three year groups of the study (p = .035) and a downward trend from 2.41 hours (2001 through 2003), to 2.17 hours (2004 through 2005) and to a low of 1.81 hours (2006 through 2008) was measured. Out of class operating time was mentioned in a number of student comments as well as the faculty surveys as a desirable benefit of the notebook computer requirement. The OCOT measure did not exhibit a statistically significant relationship to either the student preference for notebook computer classes or the student perception of learning. This conclusion is supported by the observation that the progressive decrease in the OCOT measure did not match the relatively constant values for the PNCI and POL variables during the eight years of the study. The research also shows that the amount out of class operating time is unrelated to
both the amount of operational problems experienced and the economic impact
experienced by the student in obtaining the required notebook computer although the
lack of observed power of these evaluations (.423 and .408) is notable.

There are a number of possible reasons behind the progressive decrease in the
amount of out of class operation noted in this study. One possible factor is that the
decrease in this measure is the result of a continuing improvement in the user
interface for the solid modeling software used in the course. During the eight years of
the study common CAD operations performed by the software have become more
intuitive and the steps required to execute modeling operations have required
progressively less operator actions, leading to a decrease in the amount of time
required to do the same work. A second possible reason for the reduction in out of
class operation is that students are entering the class with greater prior exposure to
CAD solid modeling. This prior experience factor would allow students already
somewhat familiar with the operation of similar solid modeling software to complete
their assignments in less time.

This research indicates the notebook computer implementation at SU
produced significant out of class operation of the CAD software by students in the
pilot program. While this measure cannot be directly compared to the amount of time
that students would have spent operating the software in an open computer laboratory
for a non-notebook computer class, the student comments indicate that they valued
the ability to easily work outside of class and the faculty survey responses include an
observation that more class material can be covered because of enhanced out of class
operating time. For this reason it is likely, though not demonstrable with the data
available for this research, that the SU implementation actually increased the amount of operating time relative to that of a class conducted in a conventional computer laboratory. This research is therefore generally supportive of the claim that a notebook computer requirement facilitates the out of class operation of required software and that an educational benefit can be achieved by that operation.

*Analysis of Economic Impact*

Cost as a factor in deciding to implement a notebook computer requirement is of obvious importance to the educational leaders responsible for making that decision. The impact of cost on student finances as a critical resource has been established by prior research as important to avoiding a systems level organizational failure as well as a commonly reported source of student dissatisfaction. The fact that the costs associated with emerging technologies is likely to change rapidly also underscores the importance of cost as a critical element in determining the timing of a notebook computer implementation. The survey data collected at SU included the self-reported student cost in obtaining their notebook computer in seven of the eight years evaluated by this research. This raw data was limited to new computer purchases for purposes of analysis and then compared to a known retail cost appropriate for each survey year. In order to evaluate the difference between the amount spent and the prevailing retail cost on an equal basis, the difference was adjusted for inflation to 2008 dollars. The resulting variable (EI), reflecting the economic impact experienced by students, if positive and large would indicate that students paid much more than required to obtain their computer and therefore the expense did not place excessive demands on their financial resources.
The economic impact experienced by students at SU as measured by this study averaged $631 for the eight years of the study and indicates that students spent significantly more than necessary when they purchased their computer. This indication of additional and voluntary over-expenditure did not change significantly between the three year groups. A very low level of observed power (.179) should be noted for this result however. The EI measure also did not exhibit a statistically significant relationship to either the student preference for notebook computer classes or the student perception of learning. The research shows the economic impact to be unrelated to both the amount of out of class operating time and the amount of operational problems experienced. This later result is notable because it indicates that paying more than necessary for the notebook computer did not provide the student with more reliable operation.

Cost was the predominant basis of the negative comments expressed by students in the written comments collected in the survey data. The percentage of negative comments and therefore the percentage of negative comments involving economic hardship in obtaining the notebook computer decreased to a low of 6.7% in the most recent year group of the study, indicating that the perceived degree of hardship decreased while the actual level of hardship was relatively constant. The faculty survey responses indicated that more students taking the class already had a notebook computer prior to taking the class and this may provide a possible reason for the reduction in economic based negative comments since these students would be unlikely to hold the notebook computer requirement responsible for any economic hardship.
This research establishes that economic impact experienced by students at SU did not change significantly during the eight years of the study and that most students paid more than necessary to obtain the required notebook computer. This is somewhat surprising because the cost of notebook computers has significantly decreased during the same period. It is also evident from this research that cost was the most significant factor in negative student reactions at the same time that many students were spending extra money to add features not required for the class. The implication is that a negative cost reaction by students can be expected when implementing a notebook computer requirement even if that reaction is not based on any actual student financial hardship. The findings indicate that educational leaders should evaluate the actual financial impact carefully, but to expect a negative student reaction and base their decision to implement and the timing of that decision on more than student reactions.

Analysis of Operational Problems

Reliable operation is an important factor in the decision and timing of a notebook computer requirement. For educational programs involving CAD, with its significantly higher demands upon graphical and computational capabilities, this factor is exceptionally important. In this research the OP variable, reflecting the student perception of the number and severity of operational problems, was used at SU to evaluate the level of reliable operation. A high OP measure indicates unacceptable operation of the notebook computer and the CAD software and a low OP measure indicates a low level of operational problems. Significant operational problems as indicated by the OP variable would be indicative of premature
implementation of a new technology thereby incurring the risk of a number of organizational systems level problems and large negative reactions from students and faculty.

This research indicates that the notebook computers used in the CAD classes at SU operated well as measured by the OP variable. Of 145 student responses to question 12 (see Figure 6) during the eight years of the study, 93.9% indicated that their computer and software operation was adequate and only 2 students (both in the early period) reported that their notebook computer never operated acceptably. This level of acceptable operation did not significantly change between the year groups evaluated. The student comments in this research also indicate acceptable operation with several written comments claiming that the student actually perceived better operation than that expected in a conventional computer laboratory. Faculty survey comments indicated they found the student notebook computers operated well with the CAD software, and they perceived the level of reliable operation had improved during the eight years of the study. A significant positive correlation was detected by this research between operational problems and the student perception of learning indicating that students that experienced better computer operation also perceived learning more in the notebook computer classes. Further analysis of this relationship as part of research question 4, did not detect a significant relationship in the mean variation between these variables, however the lack of observed power (.585) should be noted. There was no significant relationship detected between the level of operational problems and the student preference for notebook computer classes, the amount of out of class operating time or the economic impact measures. The
operational problem metric therefore indicates that, as early as 2001, student owned
notebook computer operation, including the more demanding requirements of CAD
content, was reliable.

**Implementation Timing**

The determination of proper timing for the implementation at SU was a
significant concern for those faculty members responsible for the initiative. Of
primary importance was whether the CAD software was capable of operating reliably
within the hardware capabilities of the notebook computers available at the time of
implementation. A series of annual experiments using available notebook computer
hardware was conducted by the faculty over several years prior to 2001. In addition
annual evaluations of student attitudes regarding the acceptability of a notebook
computer requirement were performed by the faculty. Only when a suitable level of
student support and proper operation had been verified on affordable notebook
computer hardware was the request for the pilot program submitted to the SU
administration.

The results of this research, as reflected by the intersection of the *Preference
for Notebook Computer Instruction, Economic Impact, and Operational Problems*
variables indicate that the timing of the pilot implementation was appropriate at SU.
Students throughout all eight years indicated a high level of support for the
requirement and a similar level of support was received from the faculty involved.
The metrics of this research indicate that the operation of the notebook computer
when operating the CAD software used was not problematic even as early as 2001.
The research also indicates that while student cost complaints were a constant, the
fact that the number of these negative comments were significantly less than the number of positive comments when coupled with the finding that students typically spent more than necessary for their computer, indicates an acceptable economic impact to students resulted from the requirement.

Recommendations for Further Research

The value of the research presented in this study could be expanded by a number of additional research activities using the SU pilot survey implementation data or studies on similar implementations at other institutions. Of critical interest and importance is the determination of actual learning impact of notebook computer classes with student performance measured objectively using concurrent classes with duplicate content and similar student populations. While such a comparative measure was not possible at SU using the pilot class data, the research finding that students in the pilot program preferred notebook computer instruction significantly more than they perceived learning more in such classes is notable. In addition, the research review presented in this study shows that while learning improvement is a frequently stated goal of educational leaders implementing notebook computer based instruction, the conclusive measure of any improvement is notably lacking in published research.

This research shows that the cost of a notebook computer is only a perceived concern for students. While technology costs have decreased as performance of the equipment has increased, this research disclosed that students typically spent significantly more on their notebook computer than required during all eight years of the SU pilot program. One possible reason for this could be that the once the student was able to find financial support for a basic notebook computer, the additional
incremental cost to add extra features that the student desired was not significant. Another possible reason would be that some students do not experience the expense of their computers directly because the cost has been covered by parents or loans. Such students may be more willing to add the expense of unneeded features. Additional research designed to determine why students spent more than necessary when required to purchase computer equipment would be insightful.

An additional cost-based area of further interest would be to determine why those students who have paid more than necessary for their computer, frequently identify cost as an area of concern as they did during this study as part of their comments. Further research directed toward determining how the cost of a notebook computer as a source of dissatisfaction for students compares to a negative student viewpoint based on other educational expenses would be informative. Since a negative cost reaction is a likely reaction to the introduction of other new technologies, it would be useful for educational leaders to be able evaluate if a negative cost reaction was significantly greater than the negative cost reaction such students have toward any educational expense.

The ability to operate the CAD software without open laboratory limitations is an important positive factor as evidenced by the student comments collected in the SU pilot program. Based on the educational benefits that result from more practice, casual exploration or the opportunity to use solid modeling for applications other than class assignments, this research included a measure of out of class operating time as a student response. What remains undetermined however is a direct comparison of the out of class operating time for notebook computer students to the time that those
students would have spent operating the software in an open computer laboratory. While it is logical to expect that additional flexibility identified as important by students would produce greater out of class operating time, additional research could confirm this relationship and allow more insight as to the basis of any learning benefit observed.

This research seems to indicate that the amount of out of class operating time decreased somewhat during the eight years of the SU pilot implementation. While not reaching a level of statistical significance, a decreasing trend in the level of out of class operating time would merit additional research. Possible reasons behind a gradual reduction in out of class operating time by students during the SU pilot implementation include (a) improvements in notebook computer operation allowing students to complete assignments in less time, (b) improvements in CAD software making required operations more intuitive and therefore easier to learn, or (c) students taking the class with prior experience in solid modeling software that allows them to extend their knowledge more readily. Since additional operating time has been established by this research as very important to student learning, additional research exploring why it seems to have decreased at SU would be useful.

The low level of observed power present in many of the statistical evaluations included in this research would indicate that it is possible that significant findings were present but not detectable using the SU data. Additional research using similar metrics with larger student populations could determine if, in fact, significant relationships exist among these metrics for notebook computer implementations. Additional research could also expand upon the evaluations provided by the SU data.
For example it would be useful to determine (using a student population of adequate size) if allowing students to select and purchase their own notebook computer rather than forcing them to use a specific make and model impacts the degree of negative cost reaction expressed by students. If providing students the opportunity for some degree of choice in obtaining their computer can be shown to help minimize the negative reaction to the cost, this factor could be used by educational leaders to design notebook implementations that could be completed more easily.

Leadership Recommendations for Technological Advancement

The findings of this research, while based on a single successful implementation at SU, can be useful to higher educational leaders at other institutions that are considering implementing a notebook computer requirement or other implementation of new technology. As predicted by organizational theorists such as Senge (1990), organizations frequently resist change and leaders that recognize the need for change must be careful in the way that they plan its incorporation. New technology which inherently involves added cost and operational risk requires exceptional care in this planning. The results of this research offer the following recommendations for leaders meeting the challenge of implementing new technology.

1. Higher educational leaders implementing new technology which constitutes an additional expense for students should expect cost resistance. This research identified that students cited cost as a negative factor far more often than any other negative factor. The research also shows however that the requirement was very popular with students and that they typically spent more than required to obtain their computer. Therefore leaders should not assume that a
negative cost reaction alone equates to an unsuccessful implementation. Leaders must look at other metrics that do more than detect a negative student cost response. Factors such as student satisfaction and the economic impact of the additional expense should be evaluated to determine if student resources are actually over-extended. In many cases it is likely that students would express a negative reaction to any additional cost independent of the benefits received.

2. Implementations of new technologies should consider the finding that students greatly value flexibility in where and when they choose to learn. The research presented establishes that students valued the flexibility of the notebook computer initiative at SU significantly more than any other positive factor associated with the implementation. This finding indicates that technologies that provide students with additional learning flexibility will be valued by students and this can produce satisfied students even when additional cost is a concern. Leaders therefore should expect that new technologies that provide additional student choice and flexibility will be more readily accepted.

3. The timing involved in implementing new technologies is dependent upon the maturity of those technologies. Early implementers of notebook computer instruction often experienced operational problems that occasionally became a significant source of student dissatisfaction (Grau, 2006). The implementation at SU was sensitive to the capabilities of available notebook computer equipment when operating CAD software and the faculty responsible for initiating the requirement at SU delayed the implementation of the pilot
program until they were reasonably certain that the required CAD software would work acceptably on notebook computers. It should be noted however that several individuals and stakeholders in the decision at SU were convinced that the operational capabilities of the computers used were not capable of operating solid modeling CAD software. Higher educational leaders must evaluate the timing of implementing new technologies to ensure that the technology available is capable of reliable operation, but should not wait for an organizational consensus. It is important that leaders accept that any implementation includes a degree of risk and include a measure of operational reliability to be used in directly monitoring how well the new technology is functioning.

4. Higher educational leaders should note from this research that more expensive equipment does not automatically equate to better operational reliability. The eight years of the SU study indicate that students who paid more for their notebook computers did not exhibit any improvement in the performance of their equipment. Since cost is an established concern for students, leaders should take special efforts to ensure that any implementation of new technology does not require unnecessary expense. It is recommended that a list of minimum requirements be established and enforced and that within those requirements, maximum flexibility for competitive sourcing be maintained.

5. Higher educational leaders should be cautious when using an improved level of learning to justify the implementation of new technologies. This research
indicates that students can and will separate learning improvement from other positive factors. For this reason leaders that justify the implementation of new technology based on improved learning should ensure that post implementation metrics include measures that can directly and objectively establish that a learning improvement has resulted. If such a metric is not possible as in the case of this research, leaders should include other indirect metrics such as out of class use and student perception of learning to provide some indication that learning has been improved.

Summary of Discussion

This research examines the pilot implementation of student owned notebook computers within a CAD-based curriculum at one 4 year institution in the Midwest. It examines survey data collected during the first 8 years of an implementation tracking a number of variables over time. The class survey data was taken from a short self-administered exit survey taken by students completing a CAD class utilizing solid modeling software once each academic year from 2001 through 2008. This information had been collected as part of the program implementation and evaluation process, but was never carefully analyzed. The survey content provided the ability to evaluate a number of variables over time and to use this information to explore the characteristics and inter-relationships between five quantitative variables developed from the student survey responses. In addition, student written responses developed from two open ended survey questions add insight and depth in interpreting the survey information. In order to evaluate the intentionality of the notebook computer implementation from a faculty viewpoint and to evaluate the student survey
responses, a separate, more contemporary survey of faculty with classroom experience in the class evaluated is included.

The research presented in this study is based on a conceptual foundation of leadership and organizational theory as well as learning theory. It is intended to provide a number of benefits for higher educational leaders involved in the implementation of student owned notebook computers or similar new technologies with CAD based curriculum receiving the greatest potential benefits. This research is significant in its quantitative content in that most prior studies have been qualitative in nature. In addition the eight year longitudinal scope of this research greatly exceeds the duration of any prior research effort directed at the implementation of notebook computers and is therefore unique in documenting and evaluating its variables and their inter-relationships over time. The research is also unique in its evaluation of the severity of the economic impact experienced by students when required to purchase a notebook computer. Finally this research is significant in its evaluation of the use of notebook computers for three dimensional CAD classes.

The central focus of this study is the resolution of six research questions. The analysis of these questions indicate that no significant changes occurred over the three year groups of the study for measures of the student preference for notebook computer instruction, student self-evaluated perception of learning, economic impact and operational problems with the notebook computer. The analysis did indicate a significant decrease in the amount of out of class operating time. A significant correlation was found to exist between the student preference for notebook computer instruction and the student perception of learning; however the determination of a
highly significant difference in these measures establishes that they are differentiated. A lack of statistically significant inter-relationships was found for the five quantitative survey variables during the three year groups comprising the eight years of the study. An analysis of the most important positive and negative factors relating to the notebook computer requirement detected no significant changes over time for the most commonly expressed positive and negative student perceptions in terms of either the number or nature of those comments.

Even though a statistically significant change over time in the study metrics as well as their inter-relationship is not established, the research provides a number of useful observations relating to its variables. These observations and measures obtained from the class survey data are found to be consistent with the conclusions and opinions expressed by SU faculty members with direct knowledge of the pilot implementation.

First, students were found to strongly prefer notebook computer classes over conventional computer laboratories and they believed that they learned more in notebook computer classes throughout the eight year period. Comparatively however students indicated that they preferred such classes significantly more than any perceived learning benefit.

Second, this research indicates, based on the evaluation of student survey comments, that the flexibility to use their notebook computer to complete class assignments at a time and place of their choosing was highly valued by students. The research also shows that CAD students participating in the pilot program reported
spending an average of 2.19 hours working on their laptop outside of class for each hour of class.

Third, the analysis of financial impact of the SU notebook computer implementation indicated that students spent an average of $631 more than necessary to obtain their notebook computer while citing excessive cost impact as the most commonly expressed negative factor involved in participating in the pilot implementation.

Finally, computer operation as evaluated by this research established that students who paid more for their computer did not experience improved operational reliability for the extra expense and that nearly all students thought that their notebook computers worked acceptably throughout the eight years of this study.

The notebook computer pilot implementation described in this research represented a landmark event for SU in early 2001. It required the involvement of a number of elements of the SU organization and therefore involved a variety of motivations. The central driving force behind the pilot program was a relatively small group of faculty motivated by the need to provide their students with software skills critically and immediately needed as an entry requirement to their careers as mechanical designers. While the implementation provided a means to bypass a number of organizational barriers to achieving this end, its educational justification was based on improving (or at least not degrading) student learning. It is also important to note that at the time the pilot implementation began in 2001 notebook computer costs were higher and their capabilities much more limited than they are at this time. There was significant risk that the demanding graphical processing
requirements of the CAD software required would exceed the capabilities of the
notebook computers available when limited to those computers within the financial
resources of the students impacted. This organizational and technological backdrop
motivated the creation of the student survey instrument and was responsible for the
metrics included in the survey.

In retrospect the results of this research indicate that the timing of the pilot
implementation was appropriate at SU. The research also indicates that after its
successful start, CAD instruction using student owned notebook computers continued
to enjoy both student and faculty support throughout the eight years of the study. It is
notable however, that after nearly ten years of successful operation, the pilot program
has yet to be extended into a university wide requirement at SU. The positive results
of the program have however have served as an impetus for a number of other
academic programs at SU with similarly motivated faculty to implement notebook
computer requirements; all of which continue successfully to this day. It is the hope
of this researcher that this study can provide similar support and insight to the faculty
and administrators at other institutions when implementing notebook computers as
well as other new technologies in the future.
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Appendix A

Example Student Survey
STUDENT SURVEY - PDET 322  WINTER 2004

About the course

1. Overall, how do you feel about conducting this course using laptops, compared to computer lab based class.

1 2 3 4 5 rather use the laptop rather use the computer lab

2. For each hour of class, about how much out of class time did you spend using PRO-E? _______ hours

3. How much did you learn using laptops compared to a normal CAD course taught in a computer lab?

1 2 3 4 5 learned more with laptops would have learned more in a lab

About the software

4. Have you used PRO-E for modeling other than class assignments? YES NO

5. Do you feel the PRO-E class has improved your position in the job market? YES NO

6. Are you interested in taking an advanced PRO-E class? YES NO

About your hardware

7. What is the Manufacturer ______________ and Model ______________

8. Did you get your laptop NEW for this course YES NO

9. About how much did you spend to get your laptop?

10. Where did you obtain your laptop? Computer Store ___ Internet ___ Other ___
**Miscellaneous Items**

11. How much did you use your laptop for purposes other than PRO-E?

<table>
<thead>
<tr>
<th>Purpose</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word Processing</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Playing games</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Internet</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

12. Describe your laptop PC's operation running PRO-E

<table>
<thead>
<tr>
<th>Operation</th>
<th>Worked well</th>
<th>Some Problems</th>
<th>But adequate</th>
<th>never</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Problems</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Unacceptable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>worked/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13. How important is it for students to have the option of selecting a laptop of their choice?

<table>
<thead>
<tr>
<th>Importance</th>
<th>Very Important</th>
<th>Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

**Your Recommendations**

14. For a student considering entering the PDET program, do you think the laptop PC requirement is a;

<table>
<thead>
<tr>
<th>Factor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A positive factor</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Not a factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A negative factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

15. Overall do you think that PDET classes using student owned laptop PCs are:

<table>
<thead>
<tr>
<th>Idea</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A good idea</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>A bad idea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please explain your answer.

16. Are there any changes you would recommend regarding laptops for future classes?
Appendix B

Example Faculty Survey
STUDY OF FACTORS IMPACTING THE IMPLEMENTATION OF
COMPUTER BASED CAD INSTRUCTION

You are invited to participate in a research project entitled a “Longitudinal Study of Factors Impacting the Implementation of Notebook Computer Based CAD Instruction”. This research is designed to examine the experiences of the faculty and students involved in CAD instruction using student provided notebook computers. The data being examined for this study was obtained from those students that completed the course PDET 322 between the Winter semester of 2001 and Winter semester 2008. The study is being conducted by Dr. Louann Bierlien-Palmer from the Department of Educational Research and Leadership at Western Michigan University and Richard Goosen as part of a doctoral dissertation.

This survey asks you to provide written responses to 15 questions and it is anticipated that your response will require approximately one hour to complete. You may choose not to answer any question and simply leave it blank. If you chose not to participate in this survey, you may return it blank in its entirety. Returning the survey will indicate your consent for use of the answers you provide. If you have any questions, you may contact Dr. Palmer at 269-387-3596, Richard Goosen at 231-591-2635, the Human Subjects Institutional Review Board (269-387-8293) or the vice president for research (269-387-8298).

As a faculty member with direct experience in teaching the PDET 322 class, your participation in this study will be used to enhance the interpretation and understanding of student responses to a series of survey questions presented as part of each class during the period of this study. The results of this study, which seeks to evaluate a number of relevant factors involved in implementing the use of student provided notebook computers for CAD classes, will be used to document and analyze the implementation experience of the PDET 322 classes over an extended period of time as a means to improve future implementations of new technology within higher education.

I am requesting that you add a written response to the following 15 questions presented in this document and then return it to me via email within the next two weeks. Your responses will be used to provide an alternate faculty perspective of the student responses collected for this study. Your participation in this interview is appreciated and voluntary. Your responses will be used as part of this study anonymously, without identifying you or the university.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board as indicated by the stamped date and signature of the board chair in the upper right corner. You should not participate in this project if the stamped date is more than one year old.
1. Identify the amount of experience you have had teaching PDET 322, the notebook computer based solid modeling class that is the subject of the proposed research.

2. Based on your classroom experience teaching PDET 322, describe how you believe that students taking the PDET 322 class would respond to the following survey question. Also please provide any insight that you can add explaining why you think that the students in your PDET 322 classes would have provided this response:

   **Overall, how do you feel about conducting this course using laptops, compared to computer lab based class.**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>rather use the laptop</td>
<td></td>
<td></td>
<td></td>
<td>rather use the computer lab</td>
</tr>
</tbody>
</table>

3. If you can do so, please describe any changes that you have noted since 2001 (the initial year that PDET 322 students were required to provide and use their own notebook computer) in **student preference** for notebook computer based classes relative to classes conducted in conventional desktop computer based laboratories.

4. Based on your classroom experience teaching PDET 322, describe how you believe that students taking the PDET 322 class would respond to the following survey question. Also please provide any insight that you can add explaining why you think that the students in your PDET 322 classes would have provided this response:

   **How much did you learn using laptops compared to a normal CAD course taught in a computer lab?**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>learned more with laptops</td>
<td></td>
<td></td>
<td></td>
<td>would have learned more in a lab</td>
</tr>
</tbody>
</table>

5. Describe any changes since 2001 that you have noted in the **amount of learning that students believe they achieve** in CAD classes requiring them to supply and use their own notebook computer relative to the amount of learning they believe they achieve in CAD classes taught in conventional computer laboratories.

6. Based on your classroom experience teaching PDET 322, describe how you believe that students taking the PDET 322 class would respond to the following survey question. Also please provide any insight that you can add explaining why you think that the students in your PDET 322 classes would have provided this response:
For each hour of class, about how much out of class time did you spend using PRO-E? _____

hours

7. Describe any changes that you have noted in the amount of out of class operating time for students taking PDET 322 since 2001.

8. Based on your classroom experience teaching PDET 322, describe your perception of the financial difficulty that students experience in obtaining a notebook computer to use in class.

9. Describe any changes that you have noted since 2001 in the financial difficulty that students experience in obtaining a notebook computer to use in class.

10. Based on your classroom experience teaching PDET 322, describe how you believe that students taking the PDET 322 class would respond to the following survey question. Also please provide any insight that you can add explaining why you think that the students in your PDET 322 classes would have provided this response:

Describe your laptop PC's operation running PRO-E

<table>
<thead>
<tr>
<th>Worked well</th>
<th>Some Problems</th>
<th>never worked/ Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Problems</td>
<td>But adequate</td>
<td></td>
</tr>
</tbody>
</table>

11. Since 2001 describe any changes that you have noted in the amount and severity of operational problems experienced by students in using notebook computers for the PDET 322 class.

12. At the time that students were initially required to provide a notebook computer for the PDET 322 class, there were a number of reasons (both for and against) identified by those involved in the institutional decision to implement this requirement. What do you remember about the rationale used to support the initial implementation of this requirement?

13. Please feel free to add any additional observations regarding the benefits or drawbacks resulting from requiring students to provide a notebook computer for CAD classes such as PDET 322.
14. Please indicate if your observations regarding the benefits or drawbacks resulting from requiring students to provide a notebook computer for CAD classes such as PDET 322 have changed since 2001.
Appendix C

Human Subject Institutional Review Board Approval Letter
Date: June 8, 2009

To: Louann Bierlein-Palmer, Principal Investigator
    Richard Goosen, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number: 09-06-04

This letter will serve as confirmation that your research project entitled “Longitudinal Study of Factors Impacting the Implementation of Notebook Computer Based CAD Instruction” has been approved under the exempt category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: June 8, 2010
Appendix D

Student Comments - Survey Questions 15 and 16
Format of Recorded Responses

Student number – Survey Year

Question 15 response to:

<table>
<thead>
<tr>
<th>Question 15 response to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Overall do you think that PDET classes using student owned laptop PCs are:</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>A good idea</td>
</tr>
<tr>
<td>Please explain your answer.</td>
</tr>
</tbody>
</table>

Question 16 response to:

<table>
<thead>
<tr>
<th>Question 16 response to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. Are there any changes you would recommend regarding laptops for future classes?</td>
</tr>
</tbody>
</table>

Student Responses - Spring 2001 - Early Group

1. W01 Positive
   15. Since computers are so prevalent, on engineering curriculum based on the computer (in upper level classes) is very attractive
   16. n/a

2. W01 Negative
   15. Many students just can’t afford to buy a laptop. And considering that laptops are normally 2x more expensive than a desktop and then cost a lot to upgrade
   16. No

3. W01 Positive
   15. Good idea but you need to standardize. Ex O.S Windows 2000
   16. Worked well under the given conditions, a modeling program is necessary

4. W01 Negative
   15. Majority of students already own a desktop, so added cost of an additional computer is useless unless it can offer more than a desktop
   16. more help when PC problems occur.
5. **W01**  
15. *Negative*  
   New lab in SWAN would have been adequate. We already paid for the course, just like every other class, no $3500 extra purchases in those classes  
16. Work out a Pro E class that can be held in SWAN lab  

6. **W01**  
15. *Both*  
   It is a good thing to have but it would be nice to get some extra financial aid to help with the cost  
16. n/a  

7. **W01**  
15. *Neutral*  
   NO! I don’t want to explain it  
16. Not really  

8. **W01**  
15. *Negative*  
   This semester was a very expensive one. Students with financial problems may find it difficult to find money to cover all expenses. Classes in labs often can get help when running into problems on homework and when using owned PC they often are stuck  
16. I guess, the hardest part about Pro E for me way thinking in 3d way, which is something I have never done. I am sure that their will be future students with the same problems. Maybe, start off slower and explain how to think 3-d how datums are used in more detail.  

9. **W01**  
15. *Neutral*  
   The more it is used the more students will think it is a good investment, if office 2000 programs could easily be obtained, that would be a plus  
16. Add the Pro-E class, and use it in a pro type environment  

10. **W01**  
15. *Positive*  
   More freedom outside class  
16. n/a  

11. **W01**  
15. *Positive*  
   If you need to buy a computer a laptop is a good choice. You don’t need to spend a lot of money to get one that will run this program either.  
16. n/a
12. W01 Neutral
15. Depending on the financial stand point of student
16. Maybe more time spent on using software and commands

13. W01 Neutral
15. I think it may be a good idea in some cases when a student can afford to buy a laptop
16. n/a

14. W01 Positive
15. Don’t have to worry about the computer lab being open since its not open on the weekends
16. n/a

15. W01 Both
15. It’s a good idea as long as that laptop will be used in a majority of classes, $2000 for one class is pretty hard to handle, but the cost would be easier to handle if I saw the application of it in other classes
16. I would like to see the choice of computers that can be purchased through the school on the tuition plan. It is a school expense and I think tuition would be well spent on it. Basically see if school loans would be willing to pay for the laptop.

16. W01 Negative
15. Can they afford it. Can they get it serviced if it breaks
16. n/a

17. W01 Positive
15. I feel that using PCs in PDET classes will be a helpful tool when we get into industry
16. No

18. W01 Positive
15. Helped me become more efficient w/ my time
16. No, Very good. A+, more pizza parties
19. W01  
15. This gives the student access to the software, no matter what time it is. Like most students I do most of my work when the labs are not open. This eliminates a major problem for me.
16. Keep the number of students in each lab to 10-15 people. The more interaction with the teacher the better

20. W01  
15. If laptops were free it would be a great idea, however expenses are very high.
16. Not so late at night

21. W01  
15. It allows us to spend a little more time on our work
16. n/a

22. W01  
15. If it gets broken, the PC was their own, not somebody else’s. The student finding his/hers own PC also gives the student the ability to work within ones budget.
16. No, because it will be slower paced and easier for students to learn

23. W01  
15. n/a
16. Use the laptop more in other classes

24. W01  
15. n/a
16. n/a

25. W01  
15. It is a large expense, but if it pays off in the job market its worth it
16. No, those are the main problems

26. W01  
15. Its helpful, but it is a rather large expense for an average college student
16. n/a
27. W01
   Positive
   15. Its good because you can take your work with you
   15. n/a

28. W01
   Positive
   15. No computer lab issues with time and availability
   16. n/a

29. W01
   Positive
   15. For me, I use my laptop for everything, its my personal computer, so it is hard to maintain and keep up to par
   16. n/a

30. W01
   Positive
   15. The compute and programs are always there with you, you don't need to rely on a computer lab
   16. I don't foresee any problems besides those

31. W01
   Positive
   15. It's a good idea. It gives students and teachers more flexibility. forces them to learn to use a computer.
   16. n/a

32. W01
   Both
   15. For me it was a way of establishing credit and making payments. It was tough getting the money around, but it had a positive affect
   16. Having a plan for students that are not able to afford buying a laptop and can qualify for financial aid.

33. W01
   Positive
   15. Its good because you don't have to be at "school" to do your work which could be a problem if you don't live around here and go home on the weekends
   16. Smaller classes. (More than just 1 option for days of class)
34. W01
   15. Can’t afford it!
   16. Use a Swan Desktop

Student Responses - Spring 2002 - Early Group

1. W02
   16. I really liked having my own laptop but it put a big dent into my financial aid, since my parents don’t contribute anything
   17. n/a

2. W02
   16. Good idea as long as there is more than one class that you use your laptop mainly for.
   17. No

3. W02
   16. It gives the student time to do their work at home of anywhere else w/out making them wait for a computer lab to be opened
   17. No none at all

4. W02
   16. These let you do your homework at anytime instead of having to go somewhere else (i.e. computer lab) where those computers are randomly going down
   17. n/a

5. W02
   16. Students can take their work home and expand on the things they learned in class
   17. No

6. W02
   16. Very nice to have a computer at hand anytime you need it, labs are very hard to use when needed.
   17. The requirements maybe a little higher
7. W02  
   16. It is nice to be able to draw when the mood hits me, or when an idea is burning. With having the lap-top my lab hours were 24-7  
   17. Nope

8. W02  
   16. Not sure  
   17. Yes

9. W02  
   16. Biggest concern is cost, however the Pro-E software savings was nice, but when it expires then what.  
   17. n/a

10. W02  
   16. I didn’t have to go to a computer lab to do homework  
   17. None at this time

11. W02  
   16. Helps keep students neat and organized  
   17. No

Student Responses - Spring 2003 - Early Group

1. W03  
   15. They’re a good idea because you can do your work when you want and wherever you want  
   16. None

2. W03  
   15. Good to use at home, great investment  
   16. n/a

3. W03  
   15. Yes, because then everything on your laptop is all your own. You don’t have to worry about other peoples files being on it  
   16. No
4. **W03**
   - **Positive**
     - 15. Allows you to have a portable station for every class
     - 16. No

5. **W03**
   - **Neutral**
     - 15. n/a
     - 16. n/a

6. **W03**
   - **Negative**
     - 15. Too much money
     - 16. School pays or use school computers

7. **W03**
   - **Negative**
     - 15. A laptop is a big purchase you should be able to angle it towards your needs!
     - 16. None

8. **W03**
   - **Positive**
     - 15. Helps learn better because you can do work at home at your leisure
     - 16. No

9. **W03**
   - **Positive**
     - 15. It was nice to be able to pick up where I left off at home rather than pack up and go to the computer lab
     - 16. Not really, maybe more class periods

10. **W03**
    - **Positive**
      - 15. It lets you work on it even when labs are closed or full
      - 16. It lets you work on it even when labs are closed or full

11. **W03**
    - **Positive**
      - 15. It is theirs and they can use the software at home
      - 16. No

12. **W03**
    - **Positive**
      - 15. Gives you great versatility as a student, use the lap top for everything.
        Since its “yours” you want to use and learn it more
      - 16. None
13. W03
   15. You can work at home @ own pace
   16. No

Positive

14. W03
   15. It lets you work on projects anytime you want to
   16. Get wireless network in the building

Positive

15. W03
   15. Its nice being able to work on projects where ever and whenever you want
   16. n/a

Positive

16. W03
   15. It is an extremely handy thing to have. I use it for all of my courses and
       would be much worse off with out it.
   16. Maybe talk to a computer source and build a standard system for reference
       of to buy

Positive

17. W03
   15. You can sit at home and work on projects at any time of the day
   16. No

Positive

18. W03
   15. Its inconvenient to have to buy one, but once you have it you can see its
       much better than using a computer lab. You learn more and it’s a good
       investment
   16. Just make sure Pro-E is loaded first. Before games or music

Both

19. W03
   15. I like it cause you don’t have to go to a lab to do homework, but I kinda
       didn’t like buying one
   16. Nope

Positive

20. W03
   15. I used the laptop a lot for other classes, its handy to use. I also purchased it
       for work, I diagnostic tool for testing equipment with it. I learned a lot with
       lap top by using it a lot
   16. No

Positive
21. W03 Neutral
   15. n/a
   16. n/a

22. W03 Positive
   15. You get to choose the computer you like as well as being able to work out of class. This is especially helpful to people who commute
   16. No

23. W03 Positive
   15. So you can work on it at your own time, and explore on your own
   16. No changes

24. W03 Positive
   15. It lets you learn the material during class, then apply yourself when you are convinced
   16. Wireless networking in classroom, optional lab

25. W03 Positive
   15. It allows for access to software @ home, for people who have further to travel
   16. None

26. W03 Negative
   15. Sometimes its hard to afford a laptop, even w/ credit students don’t have much money
   16. Maybe include the price into tuition so the financial aid will be more

27. W03 Positive
   15. Yes because it allows you to work more at your own pace
   16. No

28. W03 Positive
   15. Yes because if you ever needed to do a group project, everyone has their own computer
   16. Nope
29. W03  
15. It is easier to take it home with you instead of going back to a lab  
16. No – just keep minimum requirements for lap top

30. W03  
15. Yes, because I use PRO-E for stuff other than in class, giving me even more experience  
16. Better working help files

Student Responses - Spring 2004 - Intermediate Group

1. W04  
15. I use it for all my classes and I can take it with me any where  
16. n/a

2. W04  
15. Its nice to work at home  
16. Nope

3. W04  
15. I was in CDTD last 2 years and enjoyed using the lab but it is nice to have a computer to take home and complete assignments at home.  
16. Discount

4. W04  
15. Extra expense for very little added convenience and some extra problems  
16. Make it an option, not required

5. W04  
15. The flexibility is great, however the older laptops that have stability issues are a concern  
16. n/a

6. W04  
15. Well, the computers were a good idea but with the way the computers tend to have problems and it adds a huge headache to the situation. I like it for other reasons but not sure that it should be a requirement there should be a lab then have it as an option for your computer either laptop or desktop
16. Make an effort to be sure that the laptops will be able to function at a proper speed, other than that its ok but would rather have a lab then have it installed on a computer of our choice i.e. laptop or desktop. Thank you

7. W04  
15. It lets you take your work home and the computers in the lab are slow  
16. n/a

8. W04  
15. Depends  
16. n/a

9. W04  
15. Because you can take it home using it for other applications. Don’t have to worry about lab hours, if you have problems you can take your whole system to your inst office  
16. No! Everything looks and works great

10. W04  
15. Able to take home to work on assignments  
16. n/a

11. W04  
15. The laptops did help with other courses – not just solid modeling – but nothing that could not be done on lab stations. My opinion is that the courses should be taught in a lab environment. If students choose to buy lap tops then that will benefit them individually  
16. n/a

12. W04  
15. I think that students are already paying a lot for there education and with going to school full time and other bills, money is hard to come by.  
16. No

13. W04  
15. Laptops can be used outside class and you don’t have to rely on the labs.  
16. Not that I can think of
14. W04  
15. Compared to the computers in the lab, I definitely liked using my computer.  
16. No  

Student Responses - Spring 2005 - Intermediate Group  

1. W05  
15. N/A  
16. No  

2. W05  
15. It is a touch expensive, because laptop it required for this class only. If other classes/programs required laptops. I would feel more justified in initial purchase  
16. No  

3. W05  
15. The computer labs are slow and have many glitches. But it doesn’t seem worth it to buy a laptop for just this class  
16. Be able to get on the Network  

4. W05  
15. I like the lab setting and the computers run better, but the freedom is nice  
16. n/a  

5. W05  
15. It’s good to be able to do work at home where you feel more comfortable  
16. No  

6. W05  
15. n/a  
16. n/a  

7. W05  
15. Allows the freedom of being able to use the computer at any time  
16. Maybe try to find discounts for students through the school  

8. W05  
15. No problems with copying data to another media  
16. No
9. W05
   15. n/a
   16. n/a

10. W05
    15. *Positive*
        yes, it is a lot easier to do homework and readily accessible
        16. No

11. W05
    15. *Neutral*
        Your not defiling college owned computers
        16. Maybe recommend a brand/model which has farred well with pro-E

12. W05
    15. n/a
    16. n/a

13. W05
    15. n/a
    16. n/a

14. W05
    15. *Positive*
        Good so I can explore on my own, do more then class work on pro-E
        16. No

15. W05
    15. Both
        It was a little bit of a financial burden, but good to have
        16. Get a group rate!!! If ordered through the class

16. W05
    15. *Positive*
        Then you can do homework when time permits
        16. No

17. W05
    15. *Positive*
        Owning a laptop saves wear on university computers and assures you that
        your own computer is taken proper care of
        16. No
18. W05  
15. Being able to work at my own pace and on my own time was nice. I never had to worry about getting into the computer lab  
16. n/a  

19. W05  
15. There are computer labs on campus, why do we need a new one? It would have been better to spend a grand on books for other classes.  
16. Tell the students before they enter the program.  

Student Responses - Spring 2006 - Recent Group  

1. W06  
15. As students we already have enough to pay for. Also generally students already own a desktop computer  
16. The use of the laptop has been invaluable; however, more warning of the requirement of on would have been appreciated  

2. W06  
15. n/a  
16. n/a  

3. W06  
15. For the basic pro-E class, laptops are not needed  
16. n/a  

4. W06  
15. Different operating systems cause problems, not major, but can be inefficient at times. Different editions and processor speeds runs software differently, and minor inconveniences seem very reoccurring. Being a college student is expensive enough, for some people this might turn them away from the program due to cost.  
16. If laptops are rerequired, a major discount through a company would be extremely helpful. Going to school costs enough for a person. A joint contract through the school and a computer company would be ideal. I am pretty sure that Northern Michigan University issues laptops to their students.  

5. W06  
15. You can take your work everywhere and don’t have to worry about coming to the lab at night to finish work
16. Make them aware before they have the actual class, that require a laptop that they need a laptop with the first day

6. W06
   15. Laptops are a good idea for the class, but I am below low income and had to pull another loan to purchase my laptop
   16. Get the school to help students out in affording a laptop. See about a class discount or some thing in that nature

7. W06
   15. You can have all your own things on your computer and take your work anywhere, and have not have to worry about what is on your computer
   16. No

8. W06
   15. Can take home to work on and be able to do other things with the computer
   16. No

9. W06
   15. n/a
   16. n/a

10. W06
    15. It allows the student to use Pro-E when and where they want
    16. n/a

11. W06
    15. Its nice to use it whenever you want but they are a pain to carry around
    16. No

12. W06
    15. I like it because its mine, no one else uses it possibly moving or deleting files, messing with setting, etc. . .
    16. Finding a way to make it easier to purchase a laptop if a student does not get a lot of financial aid, they are just sort of hanging in the wind to purchase one
13. W06
   15. It allows you to work wherever you want to.
   16. No

14. W06
   15. n/a
   16. n/a

15. W06
   15. I think it adds versatility, a more professional outlook, and an easy way to complete work
   16. No, not really, personally, I am all for it

Student Responses - Spring 2007 - Recent Group

1. W07
   15. You get to work at home
   16. No

2. W07
   15. Can work on material whenever you have free time at home, less constraints on time
   16. Learn how to use Pro-E in Windows Vista

3. W07
   15. You can use and work at home or wherever you please
   16. n/a

4. W07
   15. Some student may not have the money for a good laptop. Pro-E runs better without crashing and the new vista has a problem with Pro-E, but you know that
   16. n/a

5. W07
   15. n/a
   16. Don’t buy a Dell
6. W07  
   Positive  
   15. You don’t have to worry about school’s computer breaking  
   16. Nothing  

7. W07  
   Neutral  
   15. n/a  
   16. n/a  

8. W07  
   Positive  
   15. Ability to take it home for homework  
   16. Reimbursement for part of it?  

9. W07  
   Positive  
   15. As a commuting student having my own computer with Pro-E is much easier than finding time on campus to use a lab  
   16. n/a  

10. W07  
    Positive  
    15. Allows students to work at their own pace.  
    16. No  

Student Responses - Spring 2008 - Recent Group  

1. W08  
   Positive  
   15. I love that I can do my h/w on my own time. I did not like the last two years when I had to go to a lab at only a specific time to do my h/w  
   16. n/a  

2. W08  
   Positive  
   15. If you fall a bit behind you can do your work in your room and not have to spend countless hours in a lab. You can just work on you assignments whenever.  
   16. Make sure your laptop isn’t outdated  

3. W08  
   Positive  
   15. I can work/practice things outside of class which makes it easier and more comfortable to do assignments  
   16. n/a
4. W08
   Positive
   15. Each year the laptops will be new and student purchased; unlike the CAD lab upstairs which is extremely slow and outdated. This increase productivity.
   16. No

5. W08
   Negative
   15. It is only good if the student owns a laptop. I think it should have been more clear that this was a laptop course during registration.
   16. Make sure students know it is a laptop course prior to registering for it

6. W08
   Positive
   15. It gives students more freedom, personally I do all my homework late at night when the labs are not available
   16. No

7. W08
   Both
   15. I think that having laptops for class is very useful. It can be a problem for those who already own desktops because laptops are expensive
   16. Possibly have 1 or 2 spare systems so students whose laptops breakdown and must be sent away have a computer to use during class

8. W08
   Positive
   15. Allows the students to do work outside of class on “their” own time without having to worry about open lab hours, lab computer problems, open lab computers, etc.
   16. Find a manufacturer that gives a reasonable discount specifically to students (computer that is discounted, must be able to perform)

9. W08
   Both
   15. Yes, but you should throw some $$ to the students tuition or be like on all savings from not having a lab or hardware
   16. If there is a non-traditional PDET student (IE graduating weld Engineer student taking ProE) make sure they know they are fully aware of the need for laptop when not able to take lab time class.

10. W08
    Positive
    15. I believe that it is a good idea for PDET students to own their own laptop pc. This way the students have ability to use the CAD system whenever and where- ever their at.
    16. Not regarding laptops but a smoother operating CAD system would be nice
11. W08
   15. If the student owns the PC then they will respect it more and if they can
take it home then they can do there work and not spend hours in lab
   16. Nothing it works now, don’t fix it

12. W08
   15. Without having a laptop you would have to schedule time to use a
computer lab then make sure it open. With having a laptop I can work on ProE
anytime I want
   16. Make a discount with a company so computer is cheaper

13. W08
   15. Laptops let you have access to the software at all times, so you can work
on things at home and get through the material in a more timely fashion. You
can also explore the software on your own and figure out some pretty cool
stuff
   16. No

14. W08
   15. Take work home easier, less likely someone will delete on steal files.
Convenient on weekends
   16. If required maybe not buy the computers for each student but budget an
amount giving to each student to purchase their computer

15. W08
   15. I can work out of house anytime I want
   16. No
Appendix E

Faculty Survey Responses
1. Identify the amount of experience you have had teaching PDET 322, the notebook computer based solid modeling class that is the subject of the proposed research.

Faculty 1 Response

I have been teaching the PDET 322 course for approximately nine years. The majority of the sections have been laptop based instruction. I have taught multiple sections in several semesters and for different programs.

Faculty 2 Response

Researcher’s Note; Faculty member #2 did not answer this question. This faculty member taught the first notebook computer based class in Winter 2001 and taught an advanced mechanical analysis class using notebook computers and the same CAD software evaluated from Winter 2002 through Winter 2008.

2. Based on your classroom experience teaching PDET 322, describe how you believe that students taking the PDET 322 class would respond to the following survey question. Also please provide any insight that you can add explaining why you think that the students in your PDET 322 classes would have provided this response:

Faculty 1 Response

Overall, how do you feel about conducting this course using laptops, compared to computer lab based class.

<table>
<thead>
<tr>
<th>1*</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>rather use the laptop</td>
<td>rather use the computer lab</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The vast majority of the students believe that they spend more time using the software because they are not tied to a computer lab. They have the opportunity to do their homework when they choose, not just when the lab is available. 1

Faculty 2 Response

Overall, how do you feel about conducting this course using laptops, compared to computer lab based class.

<table>
<thead>
<tr>
<th>1*</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>rather use the laptop</td>
<td>rather use the computer lab</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The students preferred laptops for the convenience of being able to use the CAD program at any time and in any location (rather than the often inconvenient availability of a desktop computer lab on campus). Also, any normal classroom could
be used for the class, the benefit being a better room layout for teaching/learning (computer lab rooms are usually difficult to teach and move around in). 1

3. If you can do so, please describe any changes that you have noted since 2001 (the initial year that PDET 322 students were required to provide and use their own notebook computer) in student preference for notebook computer based classes relative to classes conducted in conventional desktop computer based laboratories.

Faculty 1 Response

The general initial response back in 2001 was that it was another expense incurred and was not well received. Most students did not have a laptop and had to purchase one. The system requirements were such that they had to spend more for the then high end models.

The majority of students today are coming into the program with laptops. Most of the units far exceed the system requirements of the software.

Faculty 2 Response

Over this time period, laptop computers became increasingly more powerful and the students were able to run CAD programs on them with fewer problems and re­installs. Also, student access to basic programs, e.g. Microsoft Office, enabled them to study and complete assignments outside of the normal desktop computer lab. The students became receptive to these improving capabilities and conveniences and now feel that this type of learning more closely typifies a real employment environment.

4. Based on your classroom experience teaching PDET 322, describe how you believe that students taking the PDET 322 class would respond to the following survey question. Also please provide any insight that you can add explaining why you think that the students in your PDET 322 classes would have provided this response:

Faculty 1 Response

How much did you learn using laptops compared to a normal CAD course taught in a computer lab?

1 learned more with laptops 2* 3 4 5 would have learned more in a lab

Because they were not under the time constraints associated with the traditional lab environment, the student were able to spend more time working through issues with the software and felt they were able to gain a greater understanding of its command structure.
Faculty 2 Response

How much did you learn using laptops compared to a normal CAD course taught in a computer lab?

1 2* 3 4 5
learned more would have learned
with laptops more in a lab

Learning was increased due to the greater availability (24 hours/day) of the software for the class.

2
5. Describe any changes since 2001 that you have noted in the amount of learning that students believe they achieve in CAD classes requiring them to supply and use their own notebook computer relative to the amount of learning they believe they achieve in CAD classes taught in conventional computer laboratories.

Faculty 1 Response

I have noticed that I am able to cover more material in the laptop sections than in the lab sections. The students in the laptop section feel as though they have a greater opportunity to work through their issues, thus gaining a greater understanding of the software. Lab students feel as though they rush through to get the assignments done before lab is over.

Faculty 2 Response

Same answer as question 4 above. As laptop computers have become more powerful, students probably believe that their learning has increased because the software can do more and they spend more time using the software. However, learning the software and being able to apply software to a given engineering problem are two different things, and I believe that most students cannot differentiate between the two.

6. Based on your classroom experience teaching PDET 322, describe how you believe that students taking the PDET 322 class would respond to the following survey question. Also please provide any insight that you can add explaining why you think that the students in your PDET 322 classes would have provided this response:

Faculty 1 Response

For each hour of class, about how much out of class time did you spend using PRO-E? __2-3__
hours

Faculty 2 Response
For each hour of class, about how much out of class time did you spend using PRO-E? _2__

hours

Two hours based on the amount of homework and project assignments from the class. Extra time also spent learning the program.

7. Describe any changes that you have noted in the amount of out of class operating time for students taking PDET 322 since 2001.

Faculty 1 Response

The students are choosing to spend more time out of class today than in 2001. Again, allowing more time for instruction in class.

Faculty 2 Response

I know that in addition to the regular class assignments that many of the students “played” with Pro/E, which helped these students learn the program better and faster. The students that did not “play” lagged behind the others and required more direct teacher intervention during class. As the program increased in complexity with each new version release, the out of class time also increased for the top students, while others chose activities that were less educationally related.

8. Based on your classroom experience teaching PDET 322, describe your perception of the financial difficulty that students experience in obtaining a notebook computer to use in class.

Faculty 1 Response

Initially, this was the biggest issue that students expressed concern over. Today, it is almost a non-issue. Some students even express gratitude over the requirement because it allows them to use financial aid to acquire their system.

Faculty 2 Response

Student-owned laptops are now almost “expected” by them and their parents when they head for college. I think that financial difficulty applies to only a small percentage of the students. Also, the students entering the PDET program are aware beforehand that a laptop is expected, so I assume that they and their parents or other financial providers plan for the purchase of a laptop.

9. Describe any changes that you have noted since 2001 in the financial difficulty that students experience in obtaining a notebook computer to use in class.

Faculty 1 Response
The price of laptops has changed significantly since 2001. The students used to pay 2-3 thousand dollars for a system that would just meet or barely exceed the requirements of the software. Today even the basic laptops for 8-9 hundred far exceed the system requirements.

Faculty 2 Response

Financial problems have become minimal over time. Students/parents expect to purchase a laptop for college, and the cost is lower every year.

10. Based on your classroom experience teaching PDET 322, describe how you believe that students taking the PDET 322 class would respond to the following survey question. Also please provide any insight that you can add explaining why you think that the students in your PDET 322 classes would have provided this response:

Faculty 1 Response

Describe your laptop PC’s operation running PRO-E

<table>
<thead>
<tr>
<th>Worked well</th>
<th>Some Problems But adequate</th>
<th>never worked/ Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Problems</td>
<td>1</td>
<td>*2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

We still experience the occasional issue with student laptops, but it is usually due to extracurricular activities. The Vista operating system also seems to be a little unstable.

Faculty 2 Response

Describe your laptop PC’s operation running PRO-E

<table>
<thead>
<tr>
<th>Worked well</th>
<th>Some Problems But adequate</th>
<th>never worked/ Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Problems</td>
<td>1</td>
<td>*3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Many students (especially at the beginning of the laptop requirement) experienced some problems, but most of them were minor. These were usually related to settings within Pro/E and/or Microsoft Windows. Over the years these problems have pretty well been eliminated, but averaging over time since 2001 results in a “3” rating.

11. Since 2001 describe any changes that you have noted in the amount and severity of operational problems experienced by students in using notebook computers for the PDET 322 class.

Faculty 1 Response
In the beginning, we used to spend a fair amount of time with PTC tech support working through issues.

Now, Most of the issues we have can be solved by me or Professor Goosen.

The number of issues has dropped significantly. I have even had semesters where no issues were prevalent.

**Faculty 2 Response**

Over time, the problems have become fewer and of lower severity. It is extremely rare now to have a situation where the laptop and/or program either will not start up initially or crashes during use. In the event that this occurs, the PDET program has backup laptops available for student use.

12. At the time that students were initially required to provide a notebook computer for the PDET 322 class, there were a number of reasons (both for and against) identified by those involved in the institutional decision to implement this requirement. What do you remember about the rationale used to support the initial implementation of this requirement?

**Faculty 1 Response**

By going with the laptops, we can use the same classroom for both traditional and CAD instruction through the use of power access ports in the tables, and wireless connections.

Students would be responsible for the care and maintenance of the laptop, thus reducing the burden on Ferris technical support.

**Faculty 2 Response**

1. The ability for students to work on assignments at any time and in any location.
2. The course could be taught in a normal classroom rather than a dedicated computer lab.
3. Being independent of the computer consortia on campus (e.g. BTC).

13. Please feel free to add any additional observations regarding the benefits or drawbacks resulting from requiring students to provide a notebook computer for CAD classes such as PDET 322.

**Faculty 1 Response**
The students state they use the laptop for so much more than just the CAD course.

The benefit from an instructional standpoint is the ability to cover the material in a more thorough manner, and to cover more topics. Due to the reduction in performance issues, and the increase in system performance, I have been able to add additional topic areas into the course.

Faculty 2 Response

I have not observed any drawbacks related to laptop usage/requirement. Most students already own a laptop, and in the event of major problems the PDET program has backup laptops available. The benefits have been interwoven in previous answers above.

14. Please indicate if your observations regarding the benefits or drawbacks resulting from requiring students to provide a notebook computer for CAD classes such as PDET 322 have changed since 2001.

Faculty 1 Response

The increase in performance of the systems has been the biggest change. Initially it was difficult to get some of the laptops to run properly. We struggled to get topics covered and systems to model properly.

Today, system problems are a rare occurrence. When they do occur, it is usually solve by a simple software reload.

The biggest issue I see today is the students rebooting/reloading their operating systems. This requires us to reload the software. It is not difficult to do so, just mildly disruptive.

Faculty 2 Response

No. I was in favor of the laptop proposal initially and still support it fully.
Appendix F

Additional Student Survey Information
4. Have you used PRO-E for modeling other than class assignments?  

<table>
<thead>
<tr>
<th>Year</th>
<th>Yes</th>
<th>No</th>
<th>N</th>
</tr>
</thead>
<tbody>
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<td>2001</td>
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<tr>
<td>Total</td>
<td>83</td>
<td>65</td>
<td>148</td>
</tr>
</tbody>
</table>

Table F1

Response Summary - Question 4
5. Do you feel the PRO-E class has improved your position in the job market?  YES  NO

Table F2

*Response Summary - Question 5*

<table>
<thead>
<tr>
<th>Survey Year</th>
<th>Yes</th>
<th>No</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>33</td>
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<tr>
<td>2006</td>
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6. Are you interested in taking an advanced PRO-E class?  

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Response Summary - Question 6
Table F4

Response Summary - Question 7

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8. Did you get your laptop **NEW** for this course

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10. Where did you obtain your laptop?  Computer Store  Internet  Other

Table F6

*Response Summary - Question 10*

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<th>Other</th>
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13. How important is it for students to have the option of selecting a laptop of their choice?

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Table F7

Response Summary - Question 13

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14. For a student considering entering the PDET program, do you think the laptop PC requirement is a:

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Table F8

Response Summary - Question 14