

# Using a Multimedia Case Study Approach to Communicate Information Technology Concepts at the Graduate Level

## —The Impact of Learning Driven Constructs<sup>1</sup>

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### ABSTRACT

Learning-Driven Factors, constructs that show the intrinsic value of the instructional materials to the end-user, have been found to be fundamental in improving a learner's higher order cognitive skills needed to communicate technical concepts like those in Information Technology (IT). Communicating IT concepts at the graduate level could be a difficult albeit challenging task when faced with a heterogeneous class made of students with varied backgrounds in IT. One tool that has been identified as helping students understand complex technology concepts is multimedia instructional materials. This research investigates the perceptions of graduate business students on

improvement of their higher-level cognitive skills when they participated in a multimedia based case study that involved making a multi-million decision to implement a new POS system at the Chick-fil-A food chain. Two groups of students participated in an experiment where they analyzed the case study and made their recommendations. One of the groups was made of graduate business students with at least three years of work experience in the IT area. The other group was made of graduate students at a traditional university, most of whom had no previous work experience in the IT area. Two questionnaires measured their perceptions on the improvements achieved on different con-

structs.

Using the Analysis of Variance (ANOVA) procedure, the perceptions of the two groups of graduate students on the impact of the learning-driven constructs and higher order cognitive skills when using multimedia case studies were solicited. These results show that multimedia instructional materials were found to be very helpful in understanding technical issues. In particular, they were more effective for graduate business students with no previous work experience if they included learning-driven factors such as challenging the participants, providing self-learning opportunities, making it possible to learn from others, and enhancing learning interest.

### Introduction

It is an established truism that the continuous spread of Information Technology (IT) has transformed the way we live and do things. Such transformation has been commonplace among graduate students at most institutions of higher learning, especially in the West. Current research on the influence of electronic communication technologies such as electronic mail, World Wide Web, electronic journals, bibliographic databases, and online card catalogs suggest that they broaden academic research communities and change the ways graduate students and researchers work (Covi, 2000). For example, a recent study on the interaction of graduate students with IT to enhance their work performance was con-

ducted using 28 graduate students and their advisors in four disciplines at eight U.S. research universities. The findings from the study suggest that all the graduate students used IT in various ways to enhance their performance, regardless of their previous and existing patterns of work and resource use in their disciplines (Covi, 2000).

There has been emphasis over time on preparing students to graduate from schools with good decision-making skills and higher-level cognitive skills so as to enhance their performance in the real-world work environment. Educators have, therefore, invested much to prepare students to be successful as they go on to enter the work force, enabling them to become productive, responsible members of society by providing an education that encompasses good decision-making skills

needed to be qualified managers (King, 2000). The need for qualified managers with good technical skills is well documented in job postings and academic literature. These technical skills usually include a good understanding of technical issues related to a given line of business. Communicating highly technical issues to the managers in a way they can comprehend has been an issue of concern in both academia and industry (Lim and Benbasat, 2000). Researchers state that to prepare students to be successful as they go on to enter the workforce it is critical to provide them an education that encompasses higher-order cognitive skills such as reasoning, problem identification, criteria specification, integrating, interrelating, and problem solving (King, 2000; Guzdial and Soloway, 2002).

Preparing graduate students for the

workforce with an education that develops the students' higher-order cognitive skills posits a major challenge to the instructor. In fact, previous research shows that student learning is the primary purpose of teaching (Larkin-Hein and Zollman, 2000). The question "how do you teach or communicate technical Information Technology (IT) concepts to a heterogeneous graduate class made of technical and non-technical students?" is a challenge to both the instructor and to the students, given the very analytic and critical nature of graduate students. One tool that has been identified as helping instructors communicate difficult technical concepts in the field of Information Technology and Engineering is multimedia case studies (Raju and Sankar, 1999; Mbarika, et al., 2001; Mbarika, 1999). Researchers disagree over what impact multimedia has on a person's higher-order cognitive skills improvement (Dillon and Gabbard, 1999; Mbarika, 1999). Therefore, given the complex technological decisions that graduate business students have to deal with in their careers, the question "does multimedia case studies enhance graduate business students' higher-level cognitive skills?" posits as relevant and interesting.

This paper answers this question by reporting the results of an experiment conducted with graduate business students. A case study that incorporates a real-world information technology decision was chosen as the basis of the study. This case study, supported by a multimedia CD-ROM that included videos and photographs from the company in question, brought the problem alive to the audience. Two groups of graduate students, one group with previous work experience in some area of IT and the other group with no previous IT work experience, participated in an experiment where they analyzed the case study and made their recommendations. Two questionnaires measured their perceptions on the improvements achieved on different items. Research questions were developed and investigated using the Analysis of Variance (ANOVA) approach. The results of the experiment reveal significant findings on the ability of multimedia instructional materials to improve higher-level cognitive skills of graduate students. This leads to some recommendations.

## Impact of Multimedia Learning Driven Constructs on Higher-Order Cognitive Skill Improvement: Literature Review and Research Questions

Previous research has established learning-driven constructs as important in explaining the impact of multimedia in improving higher-order cognitive skills. We built on the previous work by Mbarika et al., 2001, which argues that variables such as learning-driven factor might explain why higher-level cognitive skills improved. Therefore, the learning driven factor derived from past literature (Hingorani et al., 1998; Mbarika et al., 2001) were included in our research.

Learning-Driven Factor is composed of constructs that show the intrinsic value of the instructional materials to the end-user. For example, the constructs of learning interest, challenging, self-reported learning, and learning from others measure the end-user's perceived intrinsic achievements due to the experiment. Each construct was measured by multiple items and these items were adopted from the Hingorani et al., (1998) study. The constructs are defined below.

- **Learning interest** was used to evaluate how much the case study drew students' interest during and after the experimental sessions.
- **Challenging** was used to evaluate whether the case study successfully brought real life problems to the classroom, was helpful in learning difficult technical and management concepts, and was helpful in transferring theory to practice.
- **Self-reported learning** was used to evaluate whether the case study improved students' understanding of basic concepts and whether the students learned to identify central management and technical issues.
- **Learned from others** was used to evaluate whether the students learned from one another by valuing other students' point of view or by interrelating important topics and ideas.

### Higher-Order Cognitive Skills

Higher-Order Cognitive skills relates to the perception that an individual has acquired an adequate portfolio of skills

to make a decision within a specified period of time. It implies an improved ability to identify, integrate, evaluate, and interrelate concepts within the case study and hence make the appropriate decision in a given problem-solving situation. This construct was derived from Hingorani et al. (1998) study and includes the following items: identify, integrate, evaluate, confident, interrelate, connect, decision-making, and problem-solving.

Higher-Order Cognitive skills isn't a new concept. Described as early as the 1950s, it entered the general education literature as a way to enhance learning. This concept has been re-emphasized in the last decade, especially in nursing and medical education. Higher-Order Cognitive skills is purposeful, outcome-directed thinking that's based on a body of scientific knowledge derived from research and other sources of evidence. Its approach is broader than merely seeking a single solution to a problem. It involves identifying options or alternatives, such as nursing interventions, and then selecting one that's best for meeting the desired outcome. In other words, the outcome directs and gives meaning to the task.

Anyone can learn critical thinking, but it's a long-term development process that must be practiced, nurtured, and reinforced over time. For example, in the field of Nursing, the expert critical thinker uses the following six essential cognitive skills (Ignatavicius, 2001).

1. Interpretation involves clarifying meaning, such as determining the significance of laboratory values, vital signs, and physical assessment data. It also includes understanding the meaning of a patient's behavior or statements.
2. Analysis is determining the patient's problems based on assessment data. At times, the actual problem can't be validated initially, but several possibilities or arguments can be identified.
3. Evaluation is identifying expected patient outcomes and assessing whether or not they're met. If not met, the nurse ascertains why.
4. Inference is about drawing conclusions. For example, the nurse determines when a patient's health status improves or declines through careful monitoring.

5. Explanation is the ability to justify actions. The nurse implements interventions based on research or other sources of evidence.

6. Self-regulation is the process of examining one's practice and correcting or improving it if necessary.

Considering the impact of learning-driven constructs on improving students' higher-order cognitive skills using multimedia case studies, our research questions are summarized as thus:

- What are the perceptions of graduate students on the impact of learning-driven constructs and higher order cognitive skills when using multimedia case studies?
- Are there any differences in perceptions, of graduate students with previous work experience compared with graduate students with no previous work experience on the impact of learning-driven constructs and higher order cognitive skills when using multimedia case studies?

Table 1 summarizes the constructs and items that were used to measure the constructs and factors used in this study.

Construct	Items
Self Reported Learning	Improved my understanding of basic concepts, learned new concepts, learned to identify central management and technical issues. (Hingorani et al, 1998)
Learning Interest	Discussed technical and managerial issues outside of class, did additional reading on technical and managerial issues, did some thinking for myself about technical and managerial issues. (Hingorani et al, 1998)
Learned from Others	Learned to value other students' point of view, learned to interrelate important topics and ideas. (Hingorani et al, 1998)
Challenging	Successful at bringing real life problems to the classroom, challenging, helpful in learning difficult topics, helpful in transferring theory to practice. (Hingorani et al, 1998)

**Table 1: Constructs and items used to measure learning-driven factor**

### Research Methodology

The research questions were approached by administering a field experiment in two classrooms and at two different major southeastern universities. This section describes the instructional

materials, the experimental design, the subjects, the instrument, and the analysis procedures used in this study.

A case study, Chick-fil-A, was developed by working with the Chick-fil-A fast food restaurant chain in order to bring

### Instructional Materials

#### Development of a Case study to Bring Technology Concepts to the Classroom



**Figure 1: Chick-fil-A Point of Sale Terminal (with a graphical user interface).**

real-world technology concepts to classrooms. (Sankar and Raju, 2000). The case study illustrates the decision faced by Chick-fil-A, as it moves from its current Point-of-Sale (POS) system to a choice between two operating systems, one based on Windows NT and the other on Windows CE. Since the Chick-fil-A chain operates over 700 stores, this changeover represents an approximately \$3.2 million investment due to the differences in costs between implementing the two POS systems. Concepts covered include operating systems, central processing units, network design and layout, telecommunications, thin versus fat clients, system development cycles, project management, decision making, and cost/benefit analysis.

Mike Erbrick, Director of Restaurant Information Systems at Chick-fil-A, was given the responsibility of transitioning the restaurant's point-of-sales (POS) systems from a proprietary EPROM based system to a newer system. Since Chick-fil-A had over 700 corporate owned stores, this changeover had about a \$3.29 million investment impact stemming from the difference in prices between implementing various POS systems. This difference could be as high as \$15,000 per outlet, depending on the system chosen and the store layout.

Within its more than 700 outlets, Chick-fil-A averaged about 8 POS systems per store compared to two or three systems used by other quick-service restaurant chains. The number of POS systems gave rise to additional confusion for the people cooking because they could get six to eight orders at a time on the Kitchen Display System (KDS) screens. This meant that the system had to be extremely efficient and scalable to meet the needs of individual stores. Perhaps most importantly to the store owners using the system, which is compensated by sales figures and net income, was that the sales data be relayed to Chick-fil-A's corporate headquarters accurately and reported back to each store in a timely manner.

An internal project team called the Operations Council, consisting of Roger Blythe, Brent Ragsdale, Jon Bridges, Mark Walker, Sandi Moody, Mike Erbrick, and Ken Oliver, came up with recommendations for Tim Tassopoulos, Senior Vice President of Operations, and

Buck McCabe, Chief Financial Officer for Chick-fil-A. The Operations Council offered two recommendations for the next generation point-of-sales system to be used in all Chick-fil-A restaurants. The first option given was the selection of an intelligent POS based on Windows NT/95- that was robust, fault tolerant and database-driven. The second option given was the alternative of a "thin" POS based on Windows CE that was fast with memory-resident programs and data and noted for being a strongly resilient system after lock-ups. The price difference between the two was \$5,000 per store depending on the size and layout of the store.

The team was challenged to evaluate the options with respect to operational usability, technical architecture, programming effort involved, environment, 5 year total cost of ownership, and business issues.

The case study was followed by an assignment for the students:

Chick-fil-A was forced to choose a new direction for point-of-sales (POS) terminal systems since they were unable to continue purchasing their traditional systems. The manufacturer of its then current systems (known as EPROM systems) forced this compelling situation upon the upper management of the quick-service

restaurant chain. This manufacturer of the EPROM systems was no longer willing to produce the POS systems in use at the current price that it was offering to Chick-fil-A. The offer to continue purchasing these traditional systems was made to Chick-fil-A if they were willing to pay an inflated amount of money- costs for these legacy systems were expected to be about as much as the latest technology offered by the manufacturer and its competitors. Therefore, Chick-fil-A was presented with three options from the technology available at the time the decision was made:

- (1) Continue purchasing and using the EPROM technology POS systems.
- (2) Purchase and implement POS systems that were based on Windows CE technology.
- (3) Purchase and implement POS systems that were based on Windows NT technology.

The students participating in the case were assigned with the task to decide what direction Chick-fil-A should pursue. They were given the three choices above. They were required to choose between the three options and support their decision and present their findings in class (Figure 2).



**Figure 2: Case Study presentation session at LSU.**

## Incorporation of Multimedia Elements in the Chick-fil-A Case Study

A CD-ROM was created in order to show the problem to students (Sankar and Raju, 2000). The students were shown the problem visually, the technological issues concerning the POS system were presented in a video, and the students were given specific assignments to tackle in groups of four. Videos and pictures of the POS system and related components, in addition to discussions on operating systems issues (Windows CE versus Windows NT), led the students to the problem. The visual presentation included a live video on components of a POS system. Photos, animation, and videos were used to cover concepts of operating systems, central processing unit (CPU), random access memory (RAM), and EPROM. Videos, audios, photos, and animation augmented the student's ability to grasp the technical materials and made it possible to apply decision-making theories. For example, students were able to visualize the internal components of a PC and POS system rather than only read about these concepts from a textbook. The main screens used in the case study are shown as Appendix A. The students were given the option to either play the video or read the text version of the case study related to that screen.

The students were provided with a tools section that provided the basic competency materials that were needed to analyze the technical issues involved in the decision-making scenario. Animation, videos, and photographs explained the technical concepts and made it easy for students to comprehend the concepts of POS, CPU, RAM, EPROM, Operating Systems, etc.

### Experimental Design

A field experiment was conducted in two graduate business classes. One of the classes was made of executive graduate students with three or more years of work experience. These students were part of Credit Card Processing Company and the class was offered by a Southeastern University that admitted only students from this company into the class. The other class was made of graduate business students in an MBA class at another major

southeastern university. The students involved in this experiment were, therefore, separated in different physical locations and the students had no known interaction. The students were not told that the multimedia case study would be run at the other university. This further assured no interaction among the students from the two universities. Both graduate classes covered concepts in Information Technology Management. Historically both classes were taught through the traditional lecture mode using a textbook. Since the purpose of the experiment was to compare and contrast effectiveness of the multimedia instructional materials, the multimedia CD-ROM case study was made part of the course structure.

For both graduate classes, the students were given access to the CD-ROM in a computer lab and as mentioned earlier, they had minimal interaction and were never told before the experiment, what the other group would be doing during the class time.

### Subjects

A total of eighty-eight students participated in the experiment conducted during the period Fall 2000 through Fall 2001 semesters. Of the eighty-eight students, 21 were executive business students with three or more years work experience and 67 were traditional, full time graduate students most of whom had no previous work experience.

### Instrument

Two questionnaires were designed to elicit responses related to the items defined in Table 1. The questions were similar to those used in earlier studies (Hingorani et al., 1998; Mbarika et al., 2001) thereby reinforcing construct validity. The students were asked to evalu-

ate the effectiveness of the method in understanding a typical issue faced by a manager on a 5-point Likert scale (1 indicating an extremely negative rating and 5 an extremely positive rating). The questionnaire had items that measured the four Learning-Driven constructs of *learning interest*, *challenging*, *self reported learning*, *learned from others* and one construct of *higher-order cognitive skills improvement* (Table 1).

The students completed the questionnaires and submitted it along with their written comments. Cronbach alphas were computed for each construct to identify whether the items belonged together within a construct. There are several opinions on acceptable levels of Cronbach alphas. For example, Nunnally (1967) proposes an alpha of 0.80 and higher, while Treacy (1985) suggests a value of 0.70 or higher. Since all the constructs were based on previous studies and since this is an exploratory study, we expected the values of Cronbach alphas to be well above 0.70.

### Analysis Procedure

Since all four Learning-Driven constructs of *learning interest*, *challenging*, *self reported learning*, *learned from others* and the one construct of *higher-order cognitive skills improvement* could be correlated, it was appropriate to use the Analysis of Variance (ANOVA) procedure to obtain mean comparisons between the graduate class with previous work experience and the graduate class with no previous work experience.

### Results

The Cronbach alphas were computed for each construct (Table 2). The alphas were 0.86 for *self reported learning*, 0.81

Construct	Cronbach Alpha
Self Reported Learning	0.86
Learning Interest	0.81
Learned from Others	0.76
Challenging	0.84

**Table 2: Constructs and their Cronbach alphas**

for learning interest, 0.84 for challenging, and 0.76 for learned from others. The alpha for higher-order cognitive skills was 0.91. These substantially high values of alphas assured us that the items under these constructs coalesced adequately to measure the constructs. Scaled values for the constructs were computed by averaging the responses across the items identified as best representing the construct. The descriptive statistics for each of the constructs, differentiated by graduate business students with previous work experience and by graduate business students with no previous work experience, is shown in Table 3.

### Identification of differences in Perceptions of the graduate students on the Learning-Driven constructs and higher-order cognitive skills improvement

We used the ANOVA procedure to identify differences in perceptions of the graduate students with previous work experience and those of graduate students with no previous work experience on the impact of the learning-driven constructs and higher-order cognitive skills improvement. Table 4 presents results of the ANOVA.

### Findings and Implications

The results lead to the following findings:

- Graduate business students with no previous work experience perceived slightly more improvements in higher-order cognitive skills and in all constructs that constitute the Learning-Driven factor, than graduate business students with previous work experience.
- Both groups perceived an improvement in higher-order cognitive skills and in all constructs that constitute the learning-driven factor.

Graduate business students with no previous work experience reported better higher-order skills improvement (3.77 versus 3.24) when they used the multimedia CD-ROM compared to graduate business students with previous work experience. In addition, they reported that higher improvements in learning-driven factor. Comparison of the constructs under this factor shows that the graduate

	Mean and s.d. (grad. students with previous work experience)	Mean and s.d. (grad. Students with no previous work experience)
Higher Order Cognitive Skills Improvement	3.24 (.94)	3.77 (.61)
Self Reported Learning	3.28 (1.04)	3.77 (.64)
Learning Interest	3.27 (.94)	3.73 (.69)
Learned from Others	3.43 (1.02)	3.85 (.63)
Challenging	3.27 (1.01)	3.81 (.61)

**Table 3: Descriptive Statistics for graduate business students with previous work experience and graduate business students with no previous work experience**

Source	Sum of Squares	df	Mean Square	F
Self Reported Learning	3.787	1	3.787	6.629*
Learning Interest	3.356	1	3.356	5.858*
Learned from Others	2.951	1	2.951	5.338*
Challenging	4.592	1	4.592	8.775**
Higher Order Cognitive Skills Improvement	4.512	1	4.512	9.112**
*p < 0.05; **p < 0.01				

**Table 4: Analysis of Variance on the Perception of Graduate Students on Learning-Driven Constructs and Higher Order Cognitive Skills Improvement.**

business students with no previous work experience perceived higher values than graduate business students with previous work experience (self reported learning: 3.77 versus 3.28; learning interest: 3.73 versus 3.27; learned from others: 3.85 versus 3.43; and challenging: 3.81 versus 3.27). In this regard, among graduate business students with no previous work experience, multimedia was more successful in bringing real-life problems to the classroom, teaching technical topics, and transferring theory to practice. A student commented:

*I learned about the importance of an operating system, and how many areas of IT are affected. I had no idea the operating system determines the*

*type of Internet connection or the speed of rebooting. I feel a lot more comfortable with my knowledge of operating systems.*

Another student further commented:

*I learned how to evaluate different information system devices. I learned the differences between NT and CE and how to show advantages and disadvantages of the two systems in order to make decisions that will advance Chick-fil-A. I learned that the decision of which system to pick had a great impact on the company's technological and business advancement. The information was a lot more interesting and easy to learn when put in a real-life scenario rather than in text*

-book form.

These results imply that in order to improve the performance of graduate business students it might be important to incorporate multimedia instructional technologies so that the technical problems are brought out live and interactively.

As mentioned earlier, there were slight differences in perception of the graduate students on the impact of the Learning-Driven constructs: self-reported learning, learning interest, learned from others, and challenging. The means of the constructs under this factor (as shown in Table 3) are all above 3.0 showing that both groups of graduate students perceived improvement in Learning-Driven factors. In this regard, multimedia improved the graduate students' understanding of basic concepts, new concepts, and identified central management and technical issues from the case study. This confirms the finding from Ehrlich & Reynolds (1992) study where they state that multimedia provides an opportunity to reach people with different learning styles, and different skill levels, while also offering the potential to reduce the learning curve and accelerate the learning process.

These findings also agree with the Jonassen's (1989) study which states that multimedia is attention-capturing or engaging to use. Another important fact concerning enhancing learning interest is that the students discussed technical and managerial issues outside of class after the case study sessions. Furthermore, the students learned from their group members by discussing and interrelating important topics and ideas. One graduate student commented:

*During our case study especially, I learned how to listen to everyone's ideas and to give my own. Then we worked as a team to decide what we were going to do. I also learned that you don't need a technical background to understand the material. For example, before our case study, I didn't know anything about the NT or CE, but now I have a good idea of what they can do.*

A reason for the improved perception of the business students might be because it challenges their multiple senses and fosters teamwork. Woolf and Hall (1995) believe that the multimedia approach challenges students to want to learn.

DiPasquale and McCabe (1993) argue that multimedia makes students really sit up and focus on what's going on.

## Conclusion

This study evaluates the effectiveness of multimedia instructional material for conveying a technical decision to graduate business students. These findings show that designers of multimedia instructional materials need to include materials that will help enhance these four constructs (self reported learning, learning interest, learned from others, and challenging) when building multimedia instructional materials that focus on graduate student learning. These findings could be applicable to graduate classes that have students with diverse backgrounds and that need to learn technological concepts that would otherwise be difficult to communicate using the traditional textbook teaching approach. Since student learning is the primary purpose of teaching (Larkin-Hein and Zollman, 2000), it should, therefore, be worthwhile for universities and other institutions of higher learning to invest in multimedia instructional materials to communicate technical IT concepts for the graduate classes such as those that constitute MBA and Masters in Information Systems / Technology programs.

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## Appendix A

### Screens from Chick-fil-A Case Study CD-ROM

Case: [Dropdown] Tools: [Dropdown] Assignment: [Dropdown]

## Introduction



The evolution of Chick-fil-A's POS systems

Mike Fricker, Director of Restaurant Information Systems at Chick-fil-A, was given the responsibility to "handle" the restaurant's point of sale (POS) systems from a proprietary ETRON based system to a newer system. Since Chick-fil-A has over 700 corporate owned stores this project over time about a \$8.29 million investment (project planning from the different prices between implementing various POS systems). This difference could be as high as \$5,000 per outlet depending on the system chosen and store layout. With a total of over 700 outlets, Chick-fil-A averaged about 8 POS systems per store compared to two or three systems used by other fast-service restaurant chains. The number of POS systems gave rise to additional confusion for the people working because they could get six to eight orders at a time on the Kitchen Display System (KDS) screens. This made it difficult for the system to be extremely efficient and scalable to meet the needs of individual stores. Perhaps most importantly to the store owners using the system with area compensated by sales figures and net income, was that the sales data belonging to Chick-fil-A corporate headquarters instantly and reported back to each store in a timely manner.

An internal project team called the Operations Council consisting of Roger Rhyne, Brent Bagdikian, Jon Bridges, Kirk Walker, Sand Woody, Mike Fricker and Ken Gilver. The Operations Council was set up with recommendations for Tim "Assassoulis" Santa Via, President of Operations, and Susk McCann, Chief Financial Officer for Chick-fil-A. The Operations Council offered two recommendations for the next generation point of sale system to be used in all Chick-fil-A restaurants. The first option given was the selection of an multi-gen POS based on Windows NT/95 that was robust, multi-tenant and database-driven. The second option given was the alternative of a "thin" POS based on Windows CE that was fast, with memory-resident programs and data, and noted for being a strongly resilient system after one year. The price difference between the two was 30,000 per store depending on the size and layout of the store.

The team was challenged to evaluate the options with respect to operational usability, technical architecture, programming effort, method, environment, 5 year total cost of ownership, and a risk-reduction.

Case: [Dropdown] Tools: [Dropdown] Assignment: [Dropdown]

## Central Processor Units

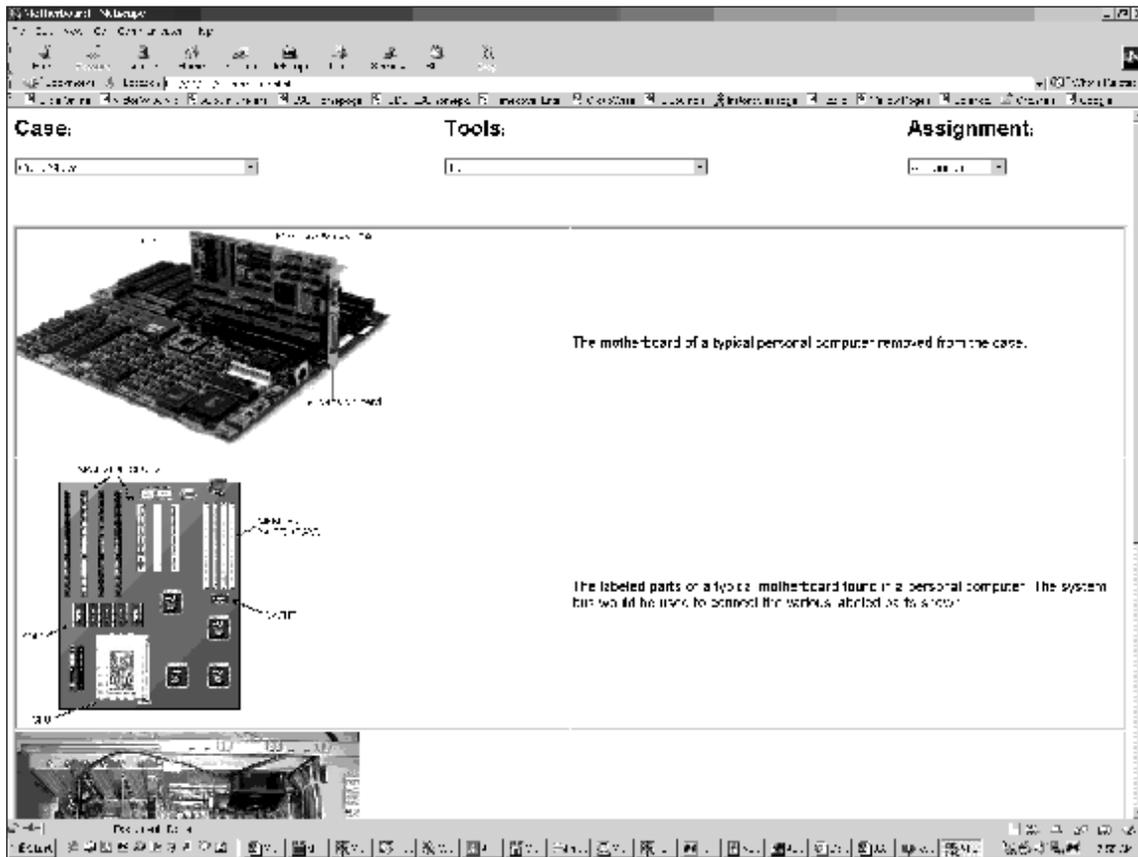
CPU chips are centrally located on the motherboard of a computer and are in close proximity to the memory chips in a computer. These chips are removable and can be upgraded with more powerful (faster processing) chips. Upgraded chips must be compatible with the computer's motherboard, otherwise they will not function.

CPU chips are typically run cooled in their original layout. Heat sink chips and first introduced in 1987 by Intel, have up to 7,500,000 transistors located on a thin white water (see 3.3 Processor Chips). CPU chips are electrical in nature and generate heat during normal operation. This heat must be dissipated to protect the chip from other components within a computer. Often, a cooling fan located on the end of the board removes the heat, however this is not always necessary for computers using applications that are not processor intensive that may also be removed from a computer by a cooling fan located on the computer case fan itself. This is a lot of heat! Fans are used to cool the processor and for the passive use of heat sink. View a video illustrating the installation of a water cool chip. Chips perform various tasks by design, some tasks being more complex than others. Since the manufacturing of these chips is costly, it is important to use a chip that is minimally suited to a particular task.

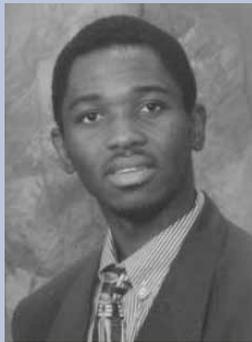
Manufacturers of CPU chips use MHz, or millions of cycles per second, to measure the speed of CPUs. Generally, the greater the MHz of a chip, the faster it will be able to perform calculations.

There are many manufacturers of processor chips. Some of the most common manufacturers are IBM, AMD, and Intel among others. In 1999, CPU chips were in the "6th generation" of manufacturing. The first CPUs operated at 4.77 MHz in early 2000 6th generation processor chips operated at more than 700 MHz and were capable of performing hundreds of millions of calculations each second at a cost around \$30 per chip.





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