VISUAL COMPUTER SIMULATION IN INSTRUCTION OF APPAREL PRODUCTION

by

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ABSTRACT

The two main purposes of this study were to explore ways in which object-based visually interactive computer simulation can be an effective learning environment in which to teach apparel production management, and to further the development of software for instruction in apparel production planning.

Since students enrolled in apparel design programs typically manufacture only one of each design, there is no link between the design of a garment and the cost of production on a larger scale - a critical link in industry. Setting up assembly lines in the classroom to teach production concepts would be impractical. Visits to production sites are useful, but stop short of allowing students to design and test alternative production strategies. Computer simulation provides a safe, efficient, cost-effective tool for teaching basic production concepts and solving problems related to production costs.

Prototypes of a visual computer simulation and a spreadsheet simulation were developed to teach apparel production layout design and costing. The effectiveness of the simulations were compared, using the nonequivalent control group quasiexperimental design approach. The researcher realized that ANCOVA was the appropriate statistical test to analyze the data as it was shown that the initial differences in mathematical ability of the two groups was statistically significant.

The study was conducted over one month. At the beginning of the experiment, instruments to identify students' thinking and learning styles and a pretest were administered to all subjects. Subjects in the experimental group were assigned the visual computer simulation exercise while subjects in the control group were assigned the computer spreadsheet exercise. Each group was allowed one-and-one-half hours to complete the assigned exercise, working in pairs. An achievement test pertaining to the mathematical content of the computer exercises and drawing of a production scheme, was administered to both groups as a posttest.

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Students in the group that received the visual computer simulation treatment achieved a higher adjusted mean score on a test of production costing and scheduling, although not statistically significant, than the students who received the computerized spreadsheet treatment. The analyses indicated that there may be a directional relationship between students identified as visual learners who used the visual computer simulation and achievement on a test of production costing and scheduling as there was a significant increase in adjusted posttest scores. The analyses also indicated that there may be a trend in students identified as active learners who used the visual computer simulation and achievement on a test of production costing and scheduling as there was a significant increase in adjusted posttest scores. The analyses also indicated that there may be a trend in students identified as active learners who used the visual computer simulation and achievement on a test of production costing and scheduling as there was an increase in adjusted posttest scores.

Feedback from the students was overwhelmingly positive. Many students indicated that they were not strong in mathematics, but the visual simulation helped make the process more real to them; the calculations made sense. The enthusiasm displayed by the students and the surprisingly deep nature of the discussion that followed convinced the author that this teaching strategy was worth the effort and has considerable future potential.

In conclusion, the visual simulation can be used in the classroom to supplement instruction in apparel production management. Implications for future research include: testing the software with a larger sample and randomizing their distribution into groups; and probing more deeply into the nature of object-based simulation as a teaching/learning strategy. Planned extensions for the simulation include student configurable layouts and the typical production problems of employee absenteeism and machine breakdowns.

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Chapter 1

INTRODUCTION

Statement of the Problem

The purpose of this study is to explore ways in which object-based visually interactive computer simulation can be an effective learning environment in which to teach apparel production management.

The study is motivated by the need to provide college students, enrolled in an apparel design program, with realistic experiences relevant to the work place. The author's quest is for a dynamic, visual, sophisticated, flexible, extensible, learner-friendly and cost-effective teaching/learning environment.

Rationale

Students enrolling in apparel design programs enter because they are attracted by the idea of producing fashionable clothing. Most of the students have previously completed senior matriculation home economics and art courses, but very few have completed a senior mathematics course (See Appendix A; Miller, 1991). Therefore, it appears that these students are more inclined toward the artistic than the mathematical. However, in commercial clothing manufacture, issues related to production management arise leading to the all important question of cost. Cost-effective production requires well planned budgets, organized plant layouts, precise scheduling, efficient production methods, accurate costing and effective quality control. Knowledge of and ability to manage a production setup will strategically place the students in an empowering position within the apparel industry (Hudson, 1989). This study will focus on the management of garment assembly, and the subsequent costs, within an apparel design facility.

Employers expect that entry-level professionals are capable of integrating and applying their educational and training experiences to the demands of the workplace (Steinhaus, 1989). However, students have limited opportunity to experience realistic occupational responsibilities in their college courses. In apparel design programs students typically manufacture only one of each design, completely missing the opportunity to study mass production techniques and their costs. Consequently, many fine designers and technicians graduate from these programs only to fail in business or be overlooked for promotions because of their lack of ability to supervise mass production and optimize costs. It has been found to be difficult to set up assembly lines in the classroom to teach these concepts, and visits to production sites are of limited value. Onthe-job training opportunities are also limited.

According to Alan Kay (1984), one of the leaders in computers in education, objectbased visually interactive computer simulation is a new field that promises tremendous opportunities for education and training. This medium can be used to model an existing environment, incorporating factors that address the learning process and the learner by allowing the learner to participate in creating the learning environment. The user then, not the medium, is, to some extent, controlling the learning experience.

Where realistic learning experiences relevant to the work place are required, developers of object-based models claim that this medium should provide an effective learning environment (Bell & O'Keefe, 1987; Page, Berson, Cheng, & Muntz, 1989). Object-based computer models can provide the one-to-one correspondence needed between elements manipulated by students and elements in the real world.

Since the introduction of microcomputers in the late 1970s and the subsequent development of computer-based learning (CBL), computers have captivated teachers and learners from preschool to all fields of post secondary education. In spite of warnings for caution that the computer may not be the panacea to all that ails in education and amidst constant controversy of the potential danger to one's health when exposed to a computer for extended periods of time, computers have pervaded nearly every school in North America. Microcomputers have made computing power accessible to everyone and to the extent that they are now used in business, industry and even personal services,

educational institutions must pursue these trends if education is to play "an integral part in shaping future industrial and sociocultural developments" (Randhawa & Hunt, 1986 p. 82). Sheldon (1988) found that the apparel industry is greatly increasing its use of computerized equipment, and therefore, strongly advocated the use of current technology in apparel design programs if designers are to function effectively.

Increased efforts to use microcomputers to aid in facilitating the teaching and learning processes during the 1980s stimulated numerous studies on computer effectiveness as a learning strategy. Results are controversial; ranging from computers having positive effects, to being as effective as traditional modes, to displaying negative effects (Bresler & Walker, 1990). Encouragingly, student testimonials reveal an overwhelmingly positive attitude toward using computers in the classroom (Bennett, 1991; Rieber, Boyce, & Assad, 1990; Stead, 1990).

The most popular forms of CBL have been "drill and practice" and "simulation". Exercises using drill and practice present users with a stimulus, elicit a response and provide immediate feedback. Advantages to this type of instruction include allowing students to: work independently at their own pace; review or repeat a lesson as often as they wish, receive immediate feedback; and start and stop when they please. This medium is excellent for questions requiring mathematical calculations and is also used in a variety of other contexts.

Computerized instructional simulations are more complex. Briefly, summarized, a computer-based simulation can be defined as a model that imitates some portion of a hypothetical or existing situation designed to capture the essential elements of the environment with the use of graphics, colour, and animation such that implications and consequences can be determined when a course of action is applied (Bell & O'Keefe, 1987; Gredler, 1986; James, 1986; P. Smith, 1986). A major advantage for students is the opportunity to build on their knowledge through exploration and problem-solving in an environment that replicates the one in which they will work. Advantages for teachers

are that situations can be consistently replicated and presented in a variety of ways, an infinite number of times (P. Smith, 1986).

Much of the criticism of the use of CBL is related to software development failing to incorporate learning principles, drill and practice interaction restricted to entering numbers or words and simulations constrained by static graphics and text, or minor animation. However, the widespread use of computers in the classroom is relatively new, but evolving at a rapid rate, and will, therefore, require considerable time and effort on the part of software developers and educators to further exploit the promised potential of the medium. Recent educational research studies on computer simulation recommend that more research is needed in the development of innovative interactive computer simulations in a variety of instructional situations (e.g. Baek & Layne, 1988; McCaskey, 1989; Rieber et al, 1990). Concerns and limitations to the technology are addressed by these researchers, who also provide recommendations regarding factors that could enhance the effectiveness of the software.

An alternate approach to traditional CBL suggested by Seymour Papert (1991), a pioneer in the exploration of a "constructionist" approach to educational research and practice, claims that computers have the capacity to alter the learning process by shifting from the typical instructional mode of attempting to transfer knowledge to students, to students producing their own knowledge. This is a powerful and challenging concept.

The features of "interactive video" are also being explored in classrooms. Interactive video consists of a videodisc or videotape player controlled by a computer program. Educational videos can show a process with real images at a speed appropriate to the viewer, including examples of altered conditions, but the user interaction with the video via a computer offers an exciting form of non-linear learning by allowing users to access different sections of the video.

If, however, simulations are effective learning environments, why are object-based visually interactive computer simulations not being more widely used in education and

training? One of the major reasons is that the programming language SMALLTALK, the widely accepted leader in multiple object-based programming languages, has only recently become available (Thomas, 1989). In many cases, the potential flexibility of systems like SMALLTALK can only be achieved on powerful and expensive hardware. Development of computer simulation for instructional purposes is still "leading edge", as researchers seek to expand authoring systems into "expert systems" that will decrease program design time for subject experts, and be cost-effective. With the price of hardware decreasing and its sophistication increasing, and as object-based programming research evolves, there is reason to believe that applications will become more accessible to educators. Empirical evidence, anecdotal observations and testimonials on the effectiveness and enjoyment of object-based applications as teaching/learning environments rely on case studies in areas such as the military, aviation and applied engineering where implementation costs may not be as limiting a factor as it is in most colleges. Educational studies that are still in progress are emerging in the literature (See Borne & Girardot, 1991; Fenton & Beck, 1989; Riley, 1990; Steed, 1992), but more empirical findings and case studies that focus on analyzing and validating the performance of prototypical applications of object-based computer simulations in educational settings are now needed.

A survey of post secondary clothing and textiles instructors revealed that the increased use of computers in the apparel industry in the 1980s has led to an increased use of computers in post secondary clothing and textiles programs (Knoll, 1989). However, the computer usage was more in the area of word processing rather than subject-specific coursework. Results of the study showed that 49 percent of the participants selected apparel production as the area in which the most growth in computer usage would be seen. Knoll (1989) recommended that more computer coursework must be implemented if graduating students are to function effectively in the apparel industry. The review of the literature includes a review of current research describing the use of computers in the apparel industry and the use of computers to teach apparel production.

In short, the two main purposes of this study are:

- to contribute to our understanding of how object-based visually interactive computer simulations create dynamic learning environments; and
- to further the development of software for instruction in apparel production planning.

Hypothesis and Related Questions

To explore the effectiveness of an object-based visually interactive computer simulation the following hypothesis was developed:

Adjusted mean posttest scores for apparel design students trained using a visually interactive computer simulation will be significantly different on a test of production costing and scheduling than for students trained on a computerized spreadsheet simulation.

It was expected that students using the visual computer simulation would score higher on a test of achievement related to the material presented than students using a more traditional computerized spreadsheet. The visual simulation has the potential to provide a richer, more exciting learning environment with the use of graphics, colour and animation as opposed to a static display of rows and columns. Both treatments allow for active rather than passive involvement for the learner by inviting the student to make selections and elicit responses, but the visual simulation is more active as it invites students to link and activate screen objects.

To link learning environments to accepted learning theories, the following questions were also examined:

 Is there a relationship between students who are identified as higher visual learners, the treatment administered and achievement on a test of production costing and scheduling? 2. Is there a relationship between students who are identified as higher active learners, the treatment administered and achievement on a test of production costing and scheduling?

Definitions of the Terms

Concepts which are central to this study are: *learning theory, learning style, visual learners, active learners, learning environment, production management, computer simulation, visual, interactive, object-based, computer spreadsheet* and *effectiveness.* This section will define the terms as they will be used in this study.

Learning theory is an attempt by psychologists and educators to provide insight into the processes of learning. In the context of education, events are designed to change the meaning of experience for students. The learning theories adopted by object-based systems developers include Papert's (1991) "constructionist theory" of building one's own knowledge in one's own way, Dewey's (1938/1963) philosophy of "learning-by-doing" and Ausubel's "meaningful learning theory" whereby the learner must choose to relate incoming information with previously learned material (Novak & Gowin, 1986). The review of the literature will construct a theoretical framework linking accepted learning theories with visually interactive computer simulation to show that the use of this medium to teach production management training is a worthwhile endeavor.

Learning styles, a component of learning theory, are the ways in which individuals are able to think and learn most effectively. Goldman-Segall (1991) takes the position that it is the learner who comes "to the subject from a variety of perspectives and thinking styles" and that "it is the responsibility of the educator to provide experiences within the subject matter which open the curriculum " to the learners such that they can "make what they learn their own" (pp. 235, 236). Hughes invites educators to become more aware of students' individual styles and how to "open educational opportunities" (cited in Guild & Garger, 1985, p. v) to everyone. For instance, it is important to people identified as

visual learners to "see" objects and activities in order to learn, while for individuals identified as *active learners*, it is necessary for them to be "physically active" in some way to facilitate learning (Reinert, 1976).

A *learning environment* is the sum total of all the factors that are brought to bear by the conditions surrounding the student. Regarding the computer as a learning environment, it can provide interaction, graphics, colour, sound, text and animation. Papert (1980) and others refer to this environment as a "microworld".

Production management is the controlling of the process of producing finished goods. The production division of an apparel firm plans and executes the conversion of fabric into cost-effective finished garments within appropriate time constraints while striving to maintain harmonious labour relations (Glock & Kunz, 1990).

As previously stated, a *computer simulation* is a computerized model that imitates some portion of a hypothetical or existing situation. It is designed to capture essential elements of an environment such that changes in the environment can be affected by student responses (Gredler, 1986; James, 1986; P. Smith, 1986).

Visual applications are dynamic, presenting information using pictures, animation and colour as well as traditional displays of tables and charts. Visual presentations can, on one hand, allow users to more efficiently interpret large amounts of complex information ("a picture is worth a thousand words"), or on the other hand, open that one image to multiple interpretations.

Interactive refers to the communication between the user and the computer. The user interacts with the computer application used in this study by clicking on graphical objects with the mouse. Interaction with a computer is generally limited to stimulus-response activities; true interaction between a computer and user has yet to be achieved since there are many more new issues to be explored (Kay, 1990).

Object-based refers to the use of computer screen "objects" in the form of icons designed to look like real world objects that have individual and general properties.

These computer screen objects can react to one another as a result of sending "messages" from one object to another. Users can intervene at any time to "interact" with such a model by pressing keys or activating mouse buttons. Turkle and Papert (1991) suggest that these objects are part of a cultural shift towards an acceptance of concrete ways of thinking. These objects are a step toward the idea of agents acting together to produce intelligent behaviour in a society, as postulated by Minsky (1986). The objects used in the simulation designed for this study are not agents as defined by Minsky, since the overall effect is not an intelligent system, but merely a simulated system. Kay (1984) envisioned an agent acting as a "librarian" to assist users by "threading" its way through extensive data bases; "a persistent 'go-fer' that for 24 hours a day looks for things it knows a user is interested in and presents them as a personal magazine" (p. 8).

A *computer spreadsheet* is a rectangular array of columns and rows divided into cells similar to a paper spreadsheet used by an accountant. Each cell has a "value rule" that specifies how its value is to be determined. Every time a value is changed anywhere in the spreadsheet, all values dependent on it are recomputed instantly and the new values are displayed.

Effectiveness will be measured by the differences in pretest and posttest scores within and between experimental and control groups.

Significance of the Study

Knowledge Claim:

This study will show that an object-based visually interactive computer simulation designed to facilitate the learning process is a more effective learning strategy than a computerized spreadsheet for design students.

Value Claims:

The simulation used in this study will provide a practical solution for instructors who need resources to teach apparel production management. It will provide an extensible prototypical computer simulation that can be used in the classroom.

Knowledge of and ability to manage a production setup and use a computer will strategically place the learner in an empowering position within the apparel industry.

This study may lead to further research of software applications in various domains to show that object-based visually interactive computer simulation can promote effective teaching/learning where not traditionally used.

This study will have implications for computer-assisted learning in general, since the findings could assist in determining which factors are useful in enhancing students' performance in other applications of computer-assisted learning.

Limitations of the Study

Since intact classroom groups will be used for this study and the sample size available is small, the generalizability of the findings are limited to the participants in the sample group.

The programming language used to create the software for this experiment was a betatest model, or prototype, with minimal documentation. Therefore, the programmer was limited in the development of the model since many of the features of the programming language were not as yet working to their anticipated capacity.

Although a highly visual learning environment was desired, it was decided to limit this study to object-based computer simulation. The incorporation of interactive video could be the basis of a future study.

Summary

An object-based visually interactive computer simulation was chosen as the teaching/learning strategy for production management training, in this study, because it is useful for demonstrating processes evolving in time. It can take several days to complete a production run of a particular garment; a computer simulation can model the situation and execute it rapidly. Simulations can be designed to allow users to alter the conditions to ask "What if..." questions and then rerun the simulation to view the results. The visual component allows the user to actually see the different factory configurations or production parameters modelled and can choose the one that best optimizes resources (See Appendix B).

A spreadsheet application was used as a comparison in this study since spreadsheets are currently used in the apparel industry to plan production schedules, project costs and provide updated information throughout the production process. The expected difference in the two applications is that the visual simulation will allow the user to "see" the whole (virtual) picture, whereas the spreadsheet requires the user to make hypothetical connections between what is displayed in the spreadsheet and what is happening on the factory floor.

It was necessary to create the simulations as existing computer simulations related to garment production planning and costing were designed for practitioners in the field of production planning, not for use in the implementation of teaching/learning strategies. The software design attempted to address a variety of learning styles.

It is anticipated that the students will find the visual computer simulation used in this study to be intrinsically interesting. Hopefully, this research will be an inspiration for future probing as to why this medium is a rich format that guides learning and provides a foundation for further software development in apparel production training.

Chapter 2

REVIEW OF THE LITERATURE

Introduction

A common thread found to be woven throughout most of the current literature on computer-based learning (CBL) was an attempt by researchers to address the learning process; the analysis of how information is perceived, organized, reorganized, stored and applied. Papert (1991) and his colleagues at MIT have been using the computer with children in schools for over two decades to study how one learns and how one thinks about one's learning. In the context of typical classroom settings, many of the earlier studies on CBL were generally only quantitative in nature, reporting on the effectiveness of the medium in terms of achievement in comparison to traditional modes of instruction such as lecture and laboratory (Bracey, 1987). Since the late 1980s most studies on CBL not only reflected on the effectiveness in presenting instructional content provided by the medium, but addressed a sincere desire to contribute to the knowledge on learning processes and how to use this knowledge to improve students' learning capabilities (for example, Bresler & Walker, 1990; Fenton & Beck, 1989; Goodyear, 1991; Kay, 1991; Riley, 1990; Steed, 1992).

To explore the potential of object-based computer simulation as a teaching/learning environment, it was appropriate to first investigate psychological research which suggest some of the factors that influence learning.

This review of the literature begins with a discussion of learning theory and is followed by an evolutionary approach in the development of CBL from the introduction of the microcomputer to computer-based simulations, culminating with students creating their own powerful learning environments. The final section is an analysis of the literature related to the apparel industry to show that using computer simulation for learning production management skills is a worthwhile endeavor.

Learning Theory

Learning is a natural phenomenon which transposes the quality of our experiences as we move from a state of not knowing to a state of knowing. Learning something new changes behaviour in terms of the way in which we think, feel and act about things (Gowin, 1981). Learning is a process that leads to gaining knowledge or understanding of a subject, or the acquisition of skills as a result of study, experience or teaching (Oxford, 1976). Minsky (1986) stated that "*no one understands how we learn to do*" (p. 21) the things that we find strange at first, but once mastered seem "mere common sense" (p. 21). Learning theory is an attempt by psychologists and educators to provide insight into the processes of learning to assist in developing meaningful instructional environments.

The literature on CBL relates to two theoretical learning models: behavioral psychology or cognitive science. The earliest examples of CBL, usually in drill and practice format, used a behavioral, stimulus-response, (question and answer) approach to learning and did not refer to mental processes. With the shift in instructional software design to a cognitive approach (Tennyson, 1990), current CBL research focuses on "how" learners transform information into knowledge, and in some instances, "how" learners think about their learning, is also addressed.

In a cognitive context of education, events are designed to change the meaning of experience for students. Two key elements in this process are: the teacher who intervenes with meaningful material, support, guidance and feedback; and the learner who chooses or does not choose to grasp the meaning and learn it (Hartley & Lovell, 1984). If a student chooses to learn, learning becomes an active reorganization of the student's existing pattern of meaning; that is, the learner makes connections between what is to be learned and what is already known. Novak and Gowin (1986) consistently concluded that educational experiences that did not motivate learners to grasp the

meaning of the learning task failed to give the learners confidence in their abilities and did nothing to enhance their sense of mastery over events.

Malone (1984) prescribed the interaction of three elements for an intrinsically motivating instructional environment; challenge, fantasy and curiosity. Students who are intrinsically motivated to learn something tend to spend more time and effort learning, feel better about what they learn, and use it more in the future (Malone, 1984).

The fact that different people learn in different ways and at different rates is an extremely important concept in the planning of teaching/learning environments. Some people find that they can learn by reading. Others are more apt to learn something if they can see how it operates. Some people learn best by hearing about something and others "learn by doing".

Montessori (1914/1966), an early proponent of "learning by doing", used a didactic approach to learning (instructing in a systematic, yet pleasurable manner). Montessori (1914/1966) used to advantage the natural restlessness of children by showing them with few or no words precisely how to move their bodies to perform a particular task, for example, tying a bow and other forms of fastening clothing. She then gave the children an opportunity to practice the techniques they have been shown. "Once a direction is given to them, the child's movements are made towards a definite end, so that he himself grows quiet and contented, and becomes as an active worker, a being calm and full of joy." (p. 21) Dewey (1938/1963), another early advocate of learning by doing, illustrated an educational strategy that combined experience, experiment, purposeful learning and freedom, to form a philosophy within a framework of a progressive organization of subject-matter. In the 1960s, Carl Rogers (1969) abstracted the principle that significant learning is acquired through doing, and that the only learning that significantly influences behaviour is self-discovered and self-appropriated.

This concept of "learning by doing" is strongly upheld by the leading educators of the technological revolution (diSessa, 1986; Kay, 1984; Papert, 1980). Papert, a disciple of

Piaget, advocates that true knowledge is only acquired through experience, and that involvement in "constructing" one's learning environment can be a powerful motivating force. Learners need to be allowed to explore, but at the same time require an external stimulus, direction and guidance (Goodyear, 1991; Lawler, duBoulay, Hughes, & McLeod, 1986; Papert, 1980).

Papert's theory of "contructionism" was influenced by Piaget's "constructivism" theory. Both theories focus on children learning by reconstructing their previously acquired knowledge in the building of their own models to solve problems. The two theories differ, in that Piaget was interested in how children's mental faculties evolved at certain stages of their life regardless of their environment (Ackerman, 1991), whereas "Papert 's research focuses on how knowledge is formed and transformed within specific contexts" (p. 272) related to the world in which the learner lives. Also, Piaget was mainly interested in how one constructs an internal stability in the way that one thinks about one's world, whereas Papert is more interested in the dynamics of how one's thinking changes (Ackerman, 1991) and does not consider age as a relevant factor in his theory. Papert (1991) claims that when children program they are teaching the computer to think, embarking on an exploration about how they themselves think. Programming transforms the process of learning while learning becomes more active and self-directed (Papert, 1980, p. 21).

According to the "right brain - left brain" theory, both the right and left hemispheres of the brain are involved in equally complex higher cognitive functioning of the brain, each side specialized for different modes of thinking (Edwards, 1979). However, most of our educational system has been designed to cultivate the verbal, rational left hemisphere, while the other more visual, more creative half of every student's brain has been left neglected (Edwards, 1979). In a changing world of environments with "virtual" simulations in many fields, it may be necessary to provide settings in which students can experience shifting from one hemisphere to the next, and to encourage them to do so. The optimal educational environment leads the learner to not only retain knowledge, but to build upon it (Kay, 1984). To meet the challenges of their future, students must learn to learn and to accept learning as an ongoing process, an integral part of their lifestyle. Bruner emphasized (cited in Martin & Hearne, 1990) that learning must also be transferable to situations that are similar to the learning environment, therefore, teachers must "select the kind of present experiences that live fruitfully and creatively in subsequent experiences" (Dewey, 1938/1963, p. 29).

The questions educators face are best summarized by Novak and Gowin (1986). How can educators help individuals to reflect upon their experience and to construct new, more powerful meanings? How can a curriculum be built that will provide learners with the basis for understanding why and how new knowledge and skills are related to what they already know, and give them the affective assurance that they have the capacity to use these new tools in new contexts?

The following sections take the position that computers are being used to impact on learning by addressing the learner and the learning process.

Introduction of Computers for Learning

How can instruction be designed in a way that captivates and intrigues learners as well as educates them? (Malone, 1984, p. 68)

One response to Malone's quest is that "The microcomputers of today are the culmination of a long search for better and more efficient ways of getting things done." (Lockhard, Abrams, & Many, 1990, p. 4)

The introduction of microcomputers in the late 1970s led to an exploitation of computer potential in the business world with data processing, word processing and spreadsheet applications leading what appeared to be a revolutionary approach to speed and efficiency in business oriented tasks. Educators have since been searching for their Lotus 1-2-3. What, then, has been happening in education since the early forms of computer-based learning (CBL) were introduced in the late 1970s?

The first drill and practice forms of CBL were criticized as being nothing more than electronic page turners that allowed for only minimal responses from the learner. Since CBL was new, there was perhaps an over emphasis of concern with automation, therefore, overlooking the positive features of the medium. This form of instruction, designed to supplement rather than replace lectures and laboratories, does have a number of advantages and has not been totally discarded even in the 1990s. Advantages include: individualized instruction and practice; repetition; feedback; and usually does not require the presence of a teacher. This form of individualized instruction, along with the computer's ability to test, grade and keep records, enables teachers to work with those students who need extra attention. Also, these early programs initiated research on CBL which has led to the development of a wide variety of educational software in every field.

At the same time, researchers in education were taking a cognitive science approach to the use of computers. Papert and others studied children's learning and thinking processes with children who used the computer language LOGO to program computers. The recognizable "turtle"-like object and the commands it can be given: FORWARD, BACK, LEFT and RIGHT, are all familiar body movements that children use as starting tools to explore and build their own objects with.

Lawler (Lawler et al, 1986) described "playing turtle" where he and a six year old child moved away from the computer, and pretending to be the turtle, acted out directions that they wanted the turtle to take. This was a chance for the child "to connect his knowledge of himself, his own body and its movement with the new knowledge he is learning" (p. 22). The child was then able to return to his LOGO drawing of a moonscape and program the number of steps and direction of the turns that he had acted out, to get the screen turtle to form the shapes that were desired. When Lawler first

worked with the child he could not arouse the child's interest when he read to him about how to use the program, but as soon as they experimented with the program on the computer, the child became interested. This example supports the theory that some learners need to be actively involved in their learning experience in order to learn.

LOGO is used in classrooms to teach programming as well as mathematical concepts. It is conceivable that LOGO inspired the contemporary approach to programming whereby programming is not a goal in itself, but an opportunity for students to program models which become vehicles for the transmission of knowledge in a specific subject area (Harel, 1988).

A study that summarized the major research done since 1975 on the effectiveness of CBL in improving students' learning showed that the effectiveness of CBL has increased steadily since 1975 (Bennett, 1991). The three most overriding conclusions to this study were that: students liked using the computer for instructional purposes; using the computer as a supplement to regular instruction increased student achievement; and students learned more quickly when using the computer as a supplement to instruction.

Computer-Based Simulation

If an instructional aim is to assist in building models of the real world in the mind of the student (James, 1986), then it would appear from some of the research presented here that computer simulation could be a solution at least some of the time. Some of the research on the development and use of educational microcomputer simulation, which is the subject of this study, will be described here. This section outlines the potential of the medium, describes some of the elements found in good instructional design, cites studies that explored the use of computer-based simulations in education and addresses some of the problems and concerns related to the design and implementation of the medium.

The Potential of Computer-Based Simulation

Gredler (1986) summarized that a simulation used in instruction provides (1) an environment (a model of a realistic setting in which a problem is presented); (2) opportunities for student responses; and (3) a set of outcomes (changes in the environment affected by student responses). Students' previous knowledge can be built in to the model as a stimulus to encourage attainment of higher cognitive levels (Goodyear, 1991). Simulations are usually less expensive than providing students with the actual environment, and whenever desired, simulated situations can be consistently replicated, presented in a variety of ways, an infinite number of times (P. Smith, 1986).

Simulations can incorporate Malone's (1984) elements of an intrinsically motivating instructional environment: challenge is met by allowing for a variety of outcomes that can be learner controlled; by deviating from reality, fantasy is incorporated; and curiosity can be aroused by progressively increasing the complexity of the tasks as the student successfully completes each task. A powerful learning situation is created by environments that allow students to attain goals through discovery of new skills and knowledge (Papert, 1980). Simulations provide this opportunity for learners to explore and problem-solve by asking "What if ... " questions (Kay, 1984). Prompt feedback to the learners on their actions frees them to take risks and experiment with decisions. By allowing for student manipulation of the environment, simulations generally lead to involvement with the subject matter.

The capabilities of computer-based simulations go beyond providing these problem solving and exploratory teaching/learning environments. Computer-based simulations are used in contexts where performing the necessary activities might otherwise be morally implicating, time-consuming, very complex, dangerous or expensive (James, 1986). For example, the cost of designing bridges, experiencing engine failure, performing tests on animals, the number of variables in the design of a manufacturing setting or modelling geological processes are often impractical to explore in real life (James, 1986).

Computer-based simulations can optimize the function of the computer. The modelling of a realistic situation is dynamically presented in a two-dimensional window. It can be pictorial and animated, modelling processes instead of static concepts. Computer-based simulations are programmed to allow the models to operate according to a combination of rules and random processes (Walker, 1983). Student involvement is attained by controlling the computer simulated world using the keyboard or a mouse. Effects of responses can be viewed immediately. This type of environment enables students to learn abstract relationships more easily than by reading or being told them (Walker, 1983). Metaphors are being used in computer simulations to guide students from the familiar to the unfamiliar. It is this metaphorical approach combined with the interactiveness of the medium that provide students with the leverage needed to react to a multiple of possible outcomes (Kay, 1984). The kind and amount of knowledge gained need not be predetermined by an outside agent; it can be constructed by the student. Students are, therefore controlling their own learning experience.

Even with the qualities accredited to computer-based simulations, educational software has its problems and limitations. Much of the existing software lacks sophistication to deal with complex situations. In many instances teachers who use computers in the classroom have become frustrated with them, as existing programs do not adequately meet their needs. Generally, educators have neither the time nor the inclination to become programmers, so they have had to rely on computer programmers who are not necessarily educators. Even when programmers do consult educators, the process of creating software is still time consuming and therefore costly. Additional barriers in using computers in education include the cost of hardware, training, equity, leadership, support, cultural bias, inconclusive evidence that learning has been improved, fear of the

unknown and social/psychological issues that have been raised in relation to extended use of computers.

Computer-Based Simulation in Education

In spite of the concerns associated with computers there is an abundance of literature on computer-based simulation in education. The simplest forms of computer-based simulations were designed using text, the next level of sophistication incorporated spreadsheet applications and most contemporary simulations include colour, graphics or animation.

A text-based computer application, that simulated an MS-DOS environment to teach the use of DOS commands, was used as an enhancement to previously existing course materials in a management information systems course and to provide an opportunity for students to become active participants in their learning. Results of the study showed that students with a higher level of computer usage performed better on course assignments and quizzes than students with a lower level of usage. It was concluded, therefore, that active involvement in one's learning appears to be an enhancement to the learning acquired (Atkinson & Burton, 1991). This conclusion is consistent with Bennett's (1991) findings.

Computer spreadsheets imitate an accountant's paper ledger of rows and columns. Cells represent each figure in the rows and columns, and as one cell is altered the others respond according to the specific direction they have been given. As well as recording the past, this medium can be used to forecast the future by inputting data and asking "What if . . ." questions. It would appear that computer spreadsheets are a powerful form of simulation.

Stead (1990) used a computer spreadsheet simulation application, "Running the British Economy", to provide an opportunity for students to experience problem-solving and to study the capabilities of simulations as learning environments. If one accepts that

learning is the process of redefining previous knowledge, then Stead (1990) recommended that students be provided with sufficient background knowledge prior to introducing them to the simulation. Two limitations to the medium that this study unveiled were: (1) that models might present discrepancies due to change over time (e.g. change in interest rates); and (2) the potential for information-overload. The simulation did, however, capture the students' interest and they found it to be a pleasurable learning experience, "not normally a salient feature of economic courses" (Stead, 1990, p. 115).

A spreadsheet software package, designed for chemical engineering students, was used to simulate chemical processes in a chemical plant (Gilabert & Gavalda, 1990). The students had considerable success in solving problems by analyzing the computer generated calculations, and it was found that the students who were exposed to the simulation for six hours rather than three were the most positive about the simulation (Gilabert & Gavalda, 1990).

Humans and computers communicate through a contact surface referred to as an "interface" which is most often equated with the software displayed on a computer screen (Laurel, 1990). Components of interface design include pointing devices, windows, menus, colour, graphics and animation. As software sophistication has increased so has the need to address the "user-interface" so that the potential of the software can be exploited. Colour, graphics and animation should illustrate the important features of the material being presented (Baek & Layne, 1988). The following studies show ways in which colour, graphics and animation have been used to enhance the learning process in instructional software design.

It is essential that the use of colour be appropriate to its purpose since colour is an important communication aid in computer output (Thorell and Smith, 1990). Colour usage in computers, rather than monochrome, is preferred because colour images more closely represent the appearance of real images and when used appropriately, enhance the location, grouping, coding and memory of images (Thorell & Smith, 1990). Colour is a

primary factor in drawing attention to a computer program, can affect the users emotions and it has been shown that the use of colour can be used to enhance learning.

Thorell and Smith (1990) identified a number of uses of colour in educational computer applications. Colour coding is used on maps when trying to identify specific features. Spreadsheets and graphs use colour to highlight and group complex information. Colour aids in the visualization of the iterations of shapes derived from recursive mathematical equations called fractals. In simulations used to show production tracking in a manufacturing setting, moving targets are better identified if they are in colour. In complex manufacturing displays, colour can be used to identify the various elements of the system.

Computer graphics are visual outputs in the form of graphs, charts and pictorial representations, as opposed to alphanumeric information. Graphs reveal data by showing a range of values against a scale. It is often easier to interpret data from a properly designed visual representation of the numbers than from a list of numbers. Computer graphs can be produced more quickly on a computer than by hand, and once created are easy to alter and reuse.

For a construction project, engineering students used a spreadsheet model which automatically computed and generated a resources requirement schedule in graphical form when the predetermined activity start times were input. Students claimed that they could better understand the concepts behind job scheduling techniques when they were freed from the tedious task of manually computing the volume of computations required in a construction project. They spent their time doing higher level learning by analyzing the results shown on the graph (Premachandra, 1991). Peck and Pargas (1991) supported the use of graphing data for analysis in operational settings due to the volume of detail that needs to be assessed.

Graphing can be applied to a variety of subject areas; consumer purchasing patterns

can be graphed and used to forecast future market trends, and geological processes can be graphed to show change over time,

Computer graphics are also pictorial representations, either as icons that are simple symbolic representations, or as objects with sufficient detail to be recognized as real objects. Spencer (1991) focused on "pictorial representation" in teaching materials. He found that "decorational" graphics had no effects while "representational" graphics used in educational media and methods could aid recall, comprehension and understanding. He also found that the most effective methods of instruction included individualized learning that provided diagnostic and remedial feedback combined with media that addressed both the verbal and image systems of the brain (Spencer, 1991). This supports the previously mentioned "right brain - left brain" theory of learning. Spencer (1991) also found that the computer is most successful when tutoring or interactively simulating real world events, and that simple line illustrations are as effective as more complex, realistic representations. This supports James' (1986) claim that an attribute of simulation is the opportunity to remove unnecessary complexities found in reality to allow the student to concentrate on the fundamental process under study.

Sachter (1991) found that students gained a mastery of spatial concepts by coordinating both rotation and perspective using a 3 - D computer graphics program. Since the students needed certain mathematical knowledge in order to create and rotate images on the computer they were also learning mathematics as they actively applied the mathematical concepts needed to develop the desired spatial relations between the objects on the computer screen.

In computer-based simulations graphics can be static objects in which the image remains constant, or dynamic objects which can be seen in operation with the use of animating techniques. A simulation to study the relationship of the visual effect of animation in a lesson on Newton's Law of Motion, gave students control over an animated starship by allowing them to manipulate the direction and frequency of forces acting on the starship (Rieber et al, 1990). Students who used the animated graphics found them to be helpful in their learning and "fun practice". In comparison, students using static graphics or no graphics said that the lesson should have included pictures and graphics with examples of movement to enhance their ability to grasp the concepts and aid in the retrieval and reconstruction process on a posttest.

Peck and Pargas (1991) stated that techniques such as animation are inappropriate when simulating a large, complex environment, such as a an entire factory, because the viewer cannot comprehend how an operation is progressing while watching an animation that incorporates a lot of detail.

Problems inherent in the software used in most of the examples cited include limited opportunity for student or teacher input to the systems in order to vary a model's parameters and limited opportunity for students to really experience results of their actions. Riley (1990) found that students gained a general impression of a hydrological system when they used a dynamic computer simulation which provided an opportunity for them to vary the model's parameters to study the effects of rainfall. However, the students had difficulty in explaining the behaviour of the system. The study also identified some of the problems with the design of the software and suggested to the researcher that students might learn more or understand better if they researched and developed their own computer models (Riley, 1990).

Some of the contemporary literature focuses on providing students with an opportunity to create their own models in place of existing controlled models (Borne & Girardot, 1991; Fenton & Beck, 1989; Goodyear, 1991; Harel & Papert, 1991; Riley, 1990; Steed, 1992). Student model making is especially prevalent in subjects requiring an understanding of the functions and changes over time found in "dynamic systems". Riley's (1990) and other educators' realization that important learning comes through experience and discovery takes us back to Papert's (1980) constructionist theory. A major deterrent in the use of student model making to date is the current lack of an
authoring system that is flexible and easy to master in a short period of time. The next section will look at the research on developing the tools needed to produce powerful computer-based simulations.

Producing Powerful Computer-based Simulations

"The power of computer simulation is that it allows interaction to take place. At anytime, the simulation may be halted and changes made to the parameters, or reports viewed to assess how the simulation is proceeding" (Harlock, 1989, p. 22). In a manufacturing setting, for example, if a bottleneck is identified, then workcentres or machine operators can be moved, and the effects of the changes can be determined on the next run of the simulation. This activity allows for experimentation with the opportunity for users to see, almost immediately, the consequences of their actions. How can this type of simulation be produced?

Object-oriented programming languages are powerful enough to develop models that can provide a one-to-one correspondence between a real world object and a computational object (Kay, 1984). Object-oriented refers to the use of computer screen "objects" in the form of icons designed to look like real world objects that have individual and general properties. These computer screen objects can react to one another as a result of sending "messages" from one object to another. Users can intervene at any time to "interact" with such a model by pressing keys or activating mouse buttons.

LOGO, developed by Seymour Papert (1980), is the simplest and most widely known of the object-oriented environments. The language is built on a "turtle" metaphor. The readiness with which a young child can comprehend the "turtle-ness" of a small triangle that can be made to move and draw lines is testimony to the power of an appropriate metaphor. LOGO is, however, limited in that it uses only one object. A desire to expand LOGO capabilities to a broader range of activities motivated work on BOXER (diSessa & Abelson, 1986). Other environments, most of which are still in their developmental stages, have the capacity to bring a multiple of objects into play.

SMALLTALK is the leader in multiple object-based programming languages. It is a powerful tool for developing interfaces and interactive environments (Borne & Girardot, 1991). However, it is a complex language and, therefore, takes considerable time to learn. This type of authoring language usually requires a programmer to produce courseware. An authoring system is a layer on top of the underlying language that is designed to be more accessible to nonprogrammer subject experts. Some of the authoring systems act like templates and others provide a variety of predesigned tools that can be manipulated by the user.

REHEARSAL WORLD was implemented in SMALLTALK (Finzer & Gould, 1984). The programmable components (analogous to the cells in of a spreadsheet) use theatrical user-interface metaphors. The user sends messages to performers, telling them to do specific tasks (display a message, calculate a number, retrieve data). The emphasis in this environment is that it is graphical, allowing for visual programming so that nonprogrammers can create software easily and quickly.

Alternative Reality Kit (ARK), an animated programming environment implemented in SMALLTALK, was based on a "physical objects" metaphor (Smith, 1986). The objects have velocity and mass. For example, the laws of gravity are presented in the form of concrete objects. The primary motivation for this project was to simplify perplexing abstractions. This provides an alternate strategy for teaching principles that are not easily grasped.

Alan Kay's Vivarium Project (cited in Rose, 1987) developed and explored a computer program that allows children to create their own exploratory plant and animal environments. One purpose of this project was to assist children in becoming a part of their learning experience by building and investigating their own microworlds. Using PLAYGROUND, an object-oriented programming environment implemented in SMALLTALK /V and C, children constructed simulations by creating objects in the shape of animals, gave each of their artificial animals "laws" to obey, let them loose in an artificial environment and then observed their behaviours (Fenton & Beck, 1989). These objects are a step toward the idea of agents acting together to produce intelligent behaviour in a society, as postulated by Minsky (1986). To make programming easier, PLAYGROUND uses a syntax that closely resembles the syntax of a natural language.

Goldman-Segall (1991a) created and used a "unique multimedia research environment called *Learning Constellations*" (p. 467) which combines videodiscs and a specifically designed HyperCard (computer) application, developed for researchers to build theories from video-based data. HyperCard-based applications are developed in HyperTalk, a computer language that is relatively easy to learn and use. HyperCard simulations are currently being developed and verified in educational settings (Guimaraes & Dias, 1992).

The growth of microworlds is now evident in commercial systems that reflect the vision and research of the early 1980s. There are many object-oriented products available today. "The suitability of a language for modelling is a measure of its ability to support the creation and execution of objects that represent the objects being modelled." (Morton, in press) Some examples of object-oriented products that have been used to develop manufacturing simulations are mentioned here.

CINEMA, an authoring system written in the SIMAN simulation language, uses graphics to produce animated systems with problem solving potential (Systems Modeling Corp., 1988). Legault (1992) used a simulation model developed with SIMAN/CINEMA to experiment with a modular production system to assist a dress manufacturing company in its decision to invest in equipment and training in order to implement the production system. Steed (1992) described three types of simulation construction kits that are designed to assist users in developing their own simulations and facilitate dynamic systems thinking; DYNAMO, STELLA and EXTEND. SIMFACTORY, implemented in PC-SIMSCRIPT was designed to provide a standard tool for realistic factory analysis without programming (CACI, 1987). Harlock (1989) developed one of the first production simulations specifically for clothing manufacture using the SEE WHY simulation tools program.

AUDITION (Synaptec Holdings Ltd., 1990), the programming language used for this study, is a PC-based object-oriented computer modelling environment that extends REHEARSAL WORLD's theatrical paradigm. The objects in a simulation are "Performers" with independent intelligence that co-ordinate their activities by sending and receiving messages, called "Cues", on platforms called "Stages". Through its visual interface, AUDITION provides a menu of options from which the types of Performers used in the simulations are created and then customized. AUDITION follows the 'nounverb' style of object-oriented programming. The basic idea is that the programmer tells An Object to do This Action using These Arguments. Processes can be explicitly scheduled using a Scheduler which schedules events at a particular point in time. Time is managed by an Event Monitor. Statistical support includes both the ability to generate random numbers from various distributions for input to a simulation and support in analyzing data that is generated by a simulation. Reporting is provided by Graphs, Gauges and Spreadsheets.

Although the programming tools described here are intended to be easy-to-use, many are still at the prototypical stage and, therefore, are not necessarily easy to master. Also, creating an effective simulation requires rigorous thinking in the design of the model and to make the model function within the software system (Steed, 1992). Research in object-oriented programming environments is ongoing.

Computer Simulation in Apparel Production and Student Need for Production Management Skills

To compete with the increasing influx of low cost imported apparel, North American apparel manufacturers need to reduce costs (Shelton & Dickerson, 1989; Warfield, Barry,

& Anderson, 1986) by improving production efficiency (Forney, Rosen, & Orzenchowski, 1990; Sheldon, 1988). Also, consumers have become more sophisticated in their preferences for high quality and variety in fashionable apparel which requires enormous flexibility in production (Friese, 1986; Hallem, 1990). Solutions are being found in the use of computers in all areas of the apparel manufacturing business from sales orders processing to the scheduling of production lots and tracking of work-inprogress.

Retailers face a number of problems in dealing with imports, such as lengthy lead time, inability to control quality (Warfield et al., 1986) and limited opportunity to reorder items that are selling well. As North American manufacturers have the advantage of close proximity to domestic markets, they are combating imports with the use of "Quick Response" (QR). QR is a computerized system that links retailers with manufacturers and manufacturers with suppliers.

QR has become a way of thinking that is revolutionizing the garment industry (Staff, 1987). It now incorporates computer-aided design (CAD), computer-aided manufacturing (CAM) and computer-integrated manufacturing (CIM). The feature articles in top trade publications for the apparel industry (for example, Bobbin, Readywear, & Apparel Industry) regularly focus on apparel industry innovations, suggesting that, "the computer is the ultimate weapon to address the changing demands on apparel manufacturers" (Turner, 1990). Most companies using computerized production systems have reduced fabric waste, increased productivity and improved garment quality which has increased their ability to compete (Forney et al., 1990; Walsh, 1989).

Along with buying new equipment to compete in the current market place, apparel manufacturers have also had to consider changing their way of doing things. Although the traditional "bundling system", where each machine operator is responsible for one step in the construction of the garment as bundles of garment pieces move from one

machine operator to the next, is still being used in production, many apparel companies are now using a "modular system" to produce smaller lots, especially repeats, quickly enough to respond to the demands of the retail stores (Legault, 1992). Modular manufacturing refers to the conceptual approach of having machine operators work as a team, whereby, each operator is required to do a number of different tasks as needed and garment pieces rather than bundles move through the system. Research results show that using the modular system has increased production planning flexibility, labour efficiency, throughput times, net productivity and morale as well as an improvement in quality (Hill, 1992).

Interestingly, the first seeds of data processing machines were planted in the textile industry by Jacquard, in 1790, who constructed an automated loom controlled by a series of punched cards to weave fabric. This technology is still used today in modern textile plants.

Computer systems specific to the apparel industry were introduced in the late 1960s (Tray, 1986). However, computer simulation, although used in manufacturing throughout the 1980s, is new to the clothing industry (Harlock, 1989), especially in a visual form. Most existing interactive simulations are in the form of a computerized spreadsheet. A computer simulation is a relatively inexpensive risk-free opportunity that can shorten response time by solving manufacturing problems at the production planning stage.

The first minicomputer system for pattern grading and marker making was installed in Vancouver in 1982 with five more installations in 1985. Now that more reasonably priced systems that run on microcomputers are available, the number of companies using computers for manufacturing components of their businesses has increased to about twenty.

Rapid changes in the apparel industry directly impact upon the educational and training requirements of apparel design students. Apparel manufacturers need entry-level

designers who can communicate with production personnel and be able to adapt to constant changes in job performance demands (Scheres-Koch, 1988; Sheldon, 1988).

"An employee who can accurately *cost a garment* is a tremendous asset ... Efficient companies *cost* a garment soon after the sample is completed for assistance in weighing its merit as a potential addition to the line." (Hudson, 1989, pg. 131) These skills are required in all aspects of apparel manufacturing from the design and merchandising through to the production management department. Opportunities should exist within the curriculum that build on students' existing knowledge to assist them in the construction of new learning experiences so that they can gain confidence before entering the work force.

Many apparel design programs across the continent are responding to the changing employee qualification requirements of apparel manufacturers by implementing computer related learning activities. Instructors of design programs, who are using computers to teach, are pioneers in the development of computer-assisted learning modules for apparel design; few appropriate commercial products exist. Most of the research on the use of computers in apparel design programs can be found in the annual meeting proceedings of the International Textile and Apparel Association (ITAA; previously called the Association of College Professors of Textiles and Clothing: ACPTC). Knoll (1989) summarized the research on computer use within the academic body of post secondary clothing and textiles from 1980 to 1987. By 1985 Miller and Dejonge's students were using Auto CAD to create garment design variations, input patterns, grade patterns and create markers (cited in Knoll, 1989, p. 41). The number of research presentations on computer use in post secondary apparel design programs has dramatically increased since 1987. ITAA annual meetings now include a "special topics" session" on computers. Also, a special conference (Holloway & Ledwith, 1989) a special journal (Rabolt, 1990) and a special resource display at the 1991 ITAA annual meeting were dedicated to computer use in apparel design programs. Computers are now used to

teach a wide variety of topics in apparel design, including: garment design; textile design; pattern making; pattern alterations; pattern grading; marker making; merchandising math; and retail store layout planning.

Four studies directly related to this study were identified in the ACPTC and ITAA general meeting proceedings. Ford, Kunz and Glock (cited in Knoll, 1989, p. 49) and Miller (1991) customized the spreadsheet software program, Lotus 1-2-3, to teach apparel costing and concepts of the production process. At the Apparel Computer Integrated Manufacturing centre, established at the University of Southwestern Louisiana in 1988, students use state-of-the-art industrial CAD/CAM systems to study production planning (Im, 1991). The fourth study described the role of the Textile Clothing Technology Corporation (TC²); a non-profit resource centre for the American apparel industry and educators that provides training in costing and production management (Fraser, Christman, Else, Hughes, & Glock, 1989). TC² has developed a number of visual interactive computer-based simulations on several different apparel production systems using SIMAN and CINEMA software development tools. However, these simulations were designed for practitioners in the field of production management, not for use as teaching/learning strategies.

O'Riley (1988) stated that textile and clothing instructors are continuously looking for new and better ways of enhancing students' visual thinking and communication skills. Her research focused on using a visual computer program in apparel design to encourage students to think and communicate visually.

To stay abreast of changes in the industry, in 1989, the Fashion Design and Technology Program at Kwantlen College added computer-aided pattern grading and marker making to the curriculum using an industrial CAD system. Garment costing is an integral component of the program whereby students use a spreadsheet application that includes general categories such as materials, production, and overhead to establish the wholesale and retail costs of a specific garment. However, a guide to industrial

production costs is supplied to the student. The student does not actually divide the design into its individual components to determine the production cost, which in a manufacturing setting is based on the number of pieces to be sewn, the amount of time for each operation and the wages for the machine operators. To compensate for this deficiency, an option course that includes Time-and-Motion studies that provides students with an opportunity to learn how costing of individual operations is arrived at, was recently added to the curriculum. It was anticipated that students will have a better understanding of production costing upon completion of this course. However, they will not have had the opportunity to "experience" the production flow of mass producing one style followed by another, as it is done in an industrial setting.

Several design and clothing and textiles programs across Canada have incorporated computers into their curriculum. For example, to teach garment design, pattern making, grading or marker making, colleges such as Ryerson Polytechnical Institute and LaSalle College use industrial CAD systems and the Universities of Manitoba and Alberta are using programs developed with Auto CAD.

Summary

From the discussion on learning and learning theory, it would appear that the optimal educational environment leads learners to want to learn by providing opportunity for: discovering and building on their personal and scholastic experiences; becoming familiar with the ideas of others; being intrinsically motivated to grasp meanings; learning by doing; being involved in choosing their learning experience; shifting from one hemisphere of the brain to the other; relating the subject matter to their own purposes; transferring knowledge to similar environments; and learning how to learn as an ongoing process.

Studies cited, reflected these elements of the learning process in a variety of computer-based learning environments, thus, suggesting that the medium provides a

positive learning environment. In addition to addressing the learning process, the use of colour, graphics and animation has expanded the potential to produce dynamic computerbased simulations that are intrinsically captivating. Object-based authoring systems are the current technology used to produce powerful computer-based simulations.

There have been many technological changes in the activities of the apparel industry. There is reason to believe that changes in all industries will continue at a fast pace. It is therefore necessary that students become skilled learners. To provide students with an opportunity to "experience" the production flow of mass producing one style followed by another, as it is done in an industrial setting, a visually interactive computer simulation on production management will be implemented and its effects as a teaching/learning strategy will be compared with a computerized spreadsheet simulation. The simulation addresses issues cited in the review of the literature; students will have the opportunity to build on their knowledge through interactive exploration and problem solving in a visual environment that replicates the ones in which they will work.

The analyses of this study will argue that a dynamic, sophisticated computer-based simulation can provide an effective teaching/learning environment, to teach mathematical concepts to students who tend to be more inclined toward the artistic than the mathematical.

Based on the review of the literature, it is anticipated that this study will provide a practical solution for instructors who need resources to teach apparel production management and contribute to the implementation of computer-assisted learning environments in apparel design programs. It is also hoped that this research will contribute to the research and development of visual computer-based simulation and provide further insight into factors that enhance student learning.

Chapter 3

METHOD AND PROCEDURE

The purpose, research questions, selection of the subjects, treatments, laboratory setting and procedures, design of the study, instrumentation, pilot project and data collection and analysis are described in this chapter.

Purpose of the Study

The purpose of this study is to explore ways in which object-based visually interactive computer simulation is an effective learning environment in which to teach apparel production management.

An object-based visually interactive computer simulation was chosen as the teaching/learning strategy for production management training, in this study, because it is useful for demonstrating processes evolving over time. It can take several days to complete a production run of a particular garment; a computer simulation can model the situation and execute it rapidly.

A spreadsheet application was used as a comparison in this study since spreadsheets are currently used in the apparel industry to plan production schedules, project costs and provide updated information throughout the production process.

Research Questions

The data gathered were used in a statistical analysis to test the following hypotheses:

Research Question 1

H₀: The adjusted mean posttest scores for apparel design students trained using an object-based visually interactive computer simulation will not be significantly different on a test of

production costing and scheduling than for students trained on a computerized spreadsheet simulation.

> $\mu_{X1}' = \mu_{X2}'$ $\mu_{X1}' =$ experimental (visual simulation) group $\mu_{X2}' =$ control (spreadsheet simulation) group

H₁: The adjusted mean posttest scores for apparel design students trained using an object-based visually interactive computer simulation will be significantly higher on a test of production costing and scheduling than for students trained on a computerized spreadsheet simulation.

 $\mu_{X1}' > \mu_{X2}'$

Two further questions, with the alternative hypotheses being non-directional since the direction of the results were unpredictable, were also tested.

Research Question 2

H₀: The adjusted mean posttest scores for apparel design students identified as higher visual learners will not be significantly different on a test of production costing and scheduling from the lower visual learner group.

 $\mu_{vH}' = \mu_{vL}'$ $\mu_{vH}' = higher visual learners group$ $\mu_{vH}' = lower visual learners group$

H₁: The adjusted mean posttest scores for apparel design students identified as higher visual learners will

be significantly different on a test of production

costing and scheduling from the lower visual learners group.

 $\mu_{\rm VH}' \neq \mu_{\rm VL}'$

Research Ouestion 3

H₀: The adjusted mean posttest scores for apparel design students identified as higher active learners will not be significantly different on a test of production costing and scheduling from the lower active learners group.

 $\mu_{AH}' = \mu_{AL}'$ $\mu_{AH}' = higher active learners group$ $\mu_{AL}' = lower active learners group$

 H_1 : The adjusted mean posttest scores for apparel design students identified as higher active learners will be significantly different on a test of production costing from the lower active learners group.

Since research question one has a directional H_1 a one tailed test can be used. However, for questions two and three, a two tailed test must be used.

Selection of Subjects

This study was undertaken at Kwantlen College in Richmond, British Columbia, Canada. Kwantlen College is a community college, located in the south Fraser region of the lower mainland, that offers a range of courses and programs. The researcher is an instructor in Kwantlen's two-year Fashion Design and Technology Program. Participants in the study were students enrolled in one of the courses in this program.

The participants were recruited from fifty-five first-year college students enrolled in two sections of a Development of the Apparel Industry course taught by the researcher. Students received a covering letter and consent form to sign (See Appendix C). The study was in the context of the material normally covered in the course with the posttest making up ten percent of the final mark for the course. Marks were not affected if a student chose not to participate in the study. All fifty-five students agreed to participate, however, three students were eliminated from the study because they missed one or more of the components of the study.

Intact classes were used for the study rather than randomly assigning the students to two groups so that the normal course of events was maintained. A coin was flipped to determine which group of students would receive which treatment. All of the participants were offered the opportunity to use the simulation that they did not use in the study after the experiment was completed.

Treatments

There were two treatments given; a visual computer simulation (See Appendix D) and a spreadsheet computer simulation (See Appendix E). The two computer simulations used for this study were designed and developed by the researcher using a beta-test version of the AUDITION computer language (Synaptec Holdings Ltd., 1990).

It was necessary to create the simulations since existing computer simulations related to garment production planning and costing were designed for practitioners not for use in the implementation of teaching/learning strategies.

AUDITION is a PC-based object-oriented computer modelling environment based on a theatrical paradigm. The objects in a simulation are "Performers" with independent intelligence that co-ordinate their activities by sending and receiving messages, called "Cues", on platforms called "Stages".

Through its visual interface, AUDITION provides a menu of options from which the types of Performers used in the simulations are created and then customized using AUDITION's Model Editor. AUDITION follows the 'noun-verb' style of object-oriented programming. The basic idea is that the programmer tells <u>An Object</u> to do <u>This Action</u> using <u>These Arguments</u>. The cue representing the action to be performed is sent to the object. The object concerned is known as the receiver and the action as the cue. The receiver is, therefore, the 'noun' and the cue the 'verb'.

Along with the customizing of Performers and the invoking of cues from the Performers' Behaviour Editor, simulation modelling in AUDITION requires two more facilities: scheduling and statistical support. Processes can be explicitly scheduled using a Scheduler which schedules events at a particular point in time. Time is managed by an Event Monitor called MainEvents. A cue to MainEvents resets its clock at zero and starts it running. Another cue stops a simulation clock once MainEvent's clock reaches a given time. Statistical support includes both the ability to generate random numbers from various distributions for input to a simulation and support in analyzing data that is generated by a simulation. Reporting is provided by Graphs, Gauges and Spreadsheets.

The visual computer simulation (experimental treatment) developed is a prototype to teach apparel production layout design and costing to fashion design students. Colour graphics display a simulated factory layout that includes gauges, graphs and a costing sheet to show the flow of goods and the associated costs. Garment designs are divided into their individual components to determine the production cost which, in a manufacturing setting using the progressive bundling system, is based on the number of pieces to be sewn, the amount of time for each operation and the wages for the machine operators.

Students use the simulation by selecting options from menus with a mouse. There are three options which are progressively more complex in design: (1) a basic skirt; (2) a skirt with side inseam pockets; and (3) a skirt with side inseam pockets and a back vent (See Appendix B). Selecting a scenario displays a layout of a factory floor with sewing machines representing the steps in the construction of the garment. Selection of option two will display one more sewing machine than option one and selection of option three will display two more machines than option one to show that more complex designs require more machinery and more operators which will, therefore, increase the total cost of the garments. A spreadsheet in one corner of the screen displays the average times for completing each step. Each sewing machine has two gauges which rise and fall with the flow of parts in and out of the workstation. A graph in another corner of the screen monitors aggregate production. Each run is different because the underlying model is a simulation driven by probabilities (as opposed to a more deterministic simple spreadsheet). Students can stop the simulation at any time and restart. A "help" option provides assistance with the use of the program and the mathematical calculations required.

The spreadsheet computer simulation (control treatment) developed is the same as the spreadsheet component of the visual simulation (See Appendix F).

Laboratory Setting and Procedures

The covering letter accompanied by the consent form was distributed and the consent form was collected during a regular class session one month prior to the experiment. The researcher read the covering letter aloud and gave the students an opportunity to ask questions related to the procedure.

The thinking and learning styles inventories and the pretest were administered at the end of three different regular class sessions in the regular classroom setting, two weeks prior to the experiment. Microprocessors (386 DOS based), colour VGA monitors and serial mice were required for the software used in this study. After considerable research into the potential computer facilities available to the researcher, eight appropriate hardware configurations were located in the Mass Communications and Journalism Program microcomputer laboratory at Kwantlen College. Advance assistance from the laboratory technician was needed to load and test the software. Timing for the experiment was based on the regular class time for the course, to allow for minimum disruption, and the availability of the computer laboratory.

Students were introduced to the topic on Mass Apparel Production and given a demonstration of the computer program in a two hour class preceding the experimental date. The experiment took place on Tuesday, November 19, 1991. Table 3.1 summarizes the treatment sequence. Each of the treatment groups were divided into two groups, and due to the time constraints and limited number of computers available, students worked in pairs at the computers.

Regular class time for the participants in the experimental group was Tuesdays and Thursdays from 8:00 a.m. to 10:00 a.m. Regular class time for the participants in the control group was Tuesdays and Thursdays from 1:00 p.m. to 3:00 p.m.

Table 3	Ta	ble	3.	1
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	<u>8:00- 9:30a.m.</u>	<u>9:30-11:00a.m.</u>	<u>12:00-1:30p.m.</u>	<u>1:30-3:30p.m.</u>	
Intact Classes	Experimental Group	Experimental Group	Control Group	Control Group	
No. of students	14	13	14	13	

Treatment Sequence

In the experimental groups, students took from one hour to one-and-one-half-hours to complete the exercise. In the control groups, students took from fifty minutes to oneand-one-half-hours to complete the exercise. Every student was able to finish the exercise assigned in the allotted time.

The posttest was administered one week after the experiment during a regular class session.

Research Design

The experimental design and procedures are summarized in this section. As well, potential threats to internal and external validity are discussed.

Nonequivalent Control Group Design

An experimental design was selected, for this study, as an initial approach in the examination of the use of a visually interactive computer simulation as a practical solution for instructors who need resources to teach production management. Since intact classes were randomly assigned to treatments, the nonequivalent control group quasi-experimental design approach as outlined by Campbell and Stanley (1963, pp. 47-50) was used. Random assignment of individuals to treatment groups was not possible and the sample size was small, therefore, analysis of covariance (ANCOVA) was determined to be the appropriate test to study the effect of the treatments (Campbell & Stanley, 1963). To measure the treatment effects, variations in class means from posttest results were analyzed by ANCOVA using a pretest means as the covariate.

At the beginning of the experiment, instruments to identify students' thinking and learning styles and a pretest were administered to all subjects.

Subjects in the experimental group were assigned the visual computer simulation exercise while subjects in the control group were assigned the computer spreadsheet exercise. Each group was allowed one-and-one-half hours to complete the assigned exercise. An achievement test pertaining to the mathematical content of the computer exercises and drawing of a production scheme, was administered to both groups as a posttest.

Table 3.2 shows a diagram of the research design.

Table 3.2

Outline of the Research Design

Experimental Group	01	X ₁	02
Control Group	01	X ₂	02

The following abbreviations are used in Table 3.2:

X represents exposure of a group to an experimental event of which the effects were measured; and *O* refers to the measurement used (Campbell & Stanley, 1963; pp. 6)

 O_1 - the covariate (pretest)

 O_2 - the posttest

 X_1 - the visual computer simulation

 X_2 - the spreadsheet computer simulation

Analysis of Covariance (ANCOVA)

The mean and standard deviation for pretest and posttest scores were calculated for both experimental and control groups.

To test the effect of the treatments, posttest results were analyzed by ANCOVA, using a pretest as the covariate; the mean scores obtained on the posttest were adjusted for the initial differences between the groups. Since the sample size was small and intact classroom groups were being used to conduct this experiment, ANCOVA was considered to be the appropriate statistical test (Campbell & Stanley, 1963).

ANCOVA was repeated to investigate whether visual or active learning styles mediated the experimental treatment.

Threats to Internal Validity

Campbell and Stanley (1963) state that the nonequivalent control group design controls for the main effects of several threats to internal validity: history; maturation; testing; instrumentation; selection; and mortality.

History is not likely to be such a threat since any event that might affect scores on the dependent variable would be experienced by both groups, and the duration of the study was only one week. However, since all members of the experimental group were treated in one session and all members of the control group were treated in another session, the possibility of intrasession history (events unique to either session) affecting the dependent variable should be considered when interpreting the results of the study.

Maturation is also not likely a threat since students were all at the same level in the program and the duration of the study was short. However, ages of the students vary, thus, the possible effects of students' past experiences related to the subject matter should be considered in the interpretation of the data.

Multiple testing is not likely to be a threat since both groups received the pretest; any influence on student posttest achievement would be the same for both groups. Furthermore, the pretest and posttest were not the same test, they were quite different. Instrumentation is not likely a factor since both groups received the same tests and both instruments for both groups were scored by the same person. To attempt to control for any scorer bias on the part of the researcher, students used the last four digits of their telephone number instead of their name on the tests. In addition, subject numbers for both groups were combined and listed randomly, and assignments for both groups were

combined and shuffled so that the researcher was unaware of specific treatment application in relation to the assignment being graded and recorded.

An analysis of variance revealed that there was a statistically significant difference in the pretest achievement score means of the two groups in this study. This difference was controlled by using the pretest means scores as a covariate in the analyses of the data. Therefore, selection is not a threat to the internal validity of this study.

Three students, two from the control group who missed the posttest and one from the experimental group who missed the treatment, were eliminated from the study. Since both treatment groups were expected to attend all sessions and the final sizes of the groups were similar it seems reasonable to assume that deletion of the scores did not influence the results due to one group being more conscientious. Therefore, mortality is also not a threat to the internal validity of this study.

Regression, considered to be a possible source of concern (Campbell & Stanley, 1963), is not a factor in this study as matching, to establish the pre-experimental equivalence of the groups, was replaced by ANCOVA.

Threats to External Validity

Campbell and Stanley (1963) suggest that potential threats to external validity of the nonequivalent control group design are the interaction of selection, maturation and history, interaction of testing and the treatment, interaction of selection and the treatment and reactive arrangements.

The questionable generalizability of the specific conditions which the experimental and control groups have in common, such as: type of program enrolled in; stage in the program at which the treatments are applied; program entrance requirements; intelligence of the subjects; and geographical region, should be considered in the interpretation of the results. The treatments for the study relate to subject matter specific to apparel design programs. Attempts at generalization of the effects are, therefore, limited to subjects enrolled in apparel design programs.

This study was conducted during the natural course of events for intact classes. Students had been informed and had consented to participating in the experiment, but they did not appear to be consciously aware of the event at the time that it was taking place. It is therefore unlikely that reactive arrangements pose a threat to external validity in this study.

Instrumentation

Each of the three types of instruments used in this study: the thinking and learning styles inventories; a pretest; and a posttest, are described in this section. Photocopies of each of the instruments administered to each of the participants in the study were retained by the researcher. The original documents were returned to the participants when all of the components of the experiment were completed and scored.

Thinking and Learning Styles Inventories

The thinking and learning styles inventories, selected from the existing literature, were used to provide some insight into the relationship between the thinking and learning styles of students enrolled in an apparel design program and their ability to cope with costing exercises.

The thinking styles inventory, *Knowing Yourself* - *Right or Left* (Wonder & Donovan, 1984), and the learning styles inventory, *Edmonds Learning Style Identification Exercise* (*ELSIE*) (Reinert, 1976;), are self-tests designed to assist in determining one's brain hemispheric dominance. The tests are based on the theory that either the right hemisphere of the brain, described as the visual-spatial, artistic side, or the left hemisphere of the brain, considered to be the verbal, rational side, dominates the ways in

which one is able to think and learn most effectively. This "right brain - left brain" theory assumes that knowing which side of the brain is dominant for each individual student can assist teachers and learners in developing learning environments that optimize each individual's brain preference.

Since both the thinking styles study (Wonders & Donovan, 1984, p. 31) and the learning styles study (Reinert, 1976, p. 162) reported good psychometric properties of all the test items, the two inventories were adopted for this study. These instruments were administered during regular class sessions on two different days, two weeks prior to the experiment. The participants were able to score and interpret their own responses. Scores were recorded by the researcher.

Pretest

A pretest was utilized to control for possible differences in mathematical ability between the classes in this study. The pretest consisted of (See Appendix G) arithmetic manipulations (seven questions; one mark each), simple word problems (five questions; one mark each) and the drawing of a floor plan for a production scheme (one question; three marks). There were 13 questions for 15 marks. The arithmetic manipulations involved multiplication and division of decimals, conversion of fractions to decimals and identification of largest fraction. Word problems included number of items, cost per item, total cost and rate, time production. Students were given twenty minutes to complete the test. All of the students completed the test, taking from 14 to 20 minutes.

The arithmetic manipulations and word problems for the pretest were modifications of items selected from the 1990 British Columbia Mathematics Assessment (Ministry of Education, 1990) for grades seven and ten. Since that study reported very good psychometric properties of all the items, the assembled pretest was considered to have acceptable psychometric characteristics. It was administered to the pilot group to assist in determining if it was an appropriate test for college level apparel design students. Scores

ranged from 10.5 to 13.5 out of 15 with a mean of 12.5. Students commented that they did not think that the test was too easy. The researcher decided that the test would be appropriate to use in this study to assist in estimating the mathematical ability of the study participants in relation to the type of mathematical calculations needed in production costing. Some minor changes, mostly related to presentation, were made to the pilot test.

The pretest was administered two weeks prior to the experiment during a regular class session and scored by the researcher.

An Item Analysis Test was computed using the pretest scores (Davis, 1964 pp. 281-285). A comparison of the responses of high-scoring and low-scoring participants showed that more of the high-scoring participants correctly answered all but one item (See Appendix H). The results indicated that most of the items discriminated to some extent between students who have considerable arithmetic-reasoning ability and those who have little. Most of the items were, therefore, considered relevant to the properties measured by the test as a whole.

Posttest

The posttest (See Appendix I) consisted of 10 word problems (one or two marks each for a total of twelve marks) and the drawing of a floor plan for a production scheme (one question; three marks) for a total of 15 marks. The questions in the posttest related to the content and type of arithmetic manipulations used in the computer exercises.

The posttest was reviewed by four of the pilot study participants. Time did not allow for a formal testing, and these students had used both simulations. Some minor adjustments were made to the posttest based on students' comments.

The posttest was administered one week after the experiment during a regular class session and scored by the researcher.

Scores on the posttest could vary based on the following two conditions: 1) what students learned in the treatment; and 2) general mathematical ability. Since mathematical ability could not be controlled by random assignment it was controlled by ANCOVA using a pretest of mathematical ability.

An Item Analysis Test was computed using the posttest scores (Davis, 1964 pp. 281-285). A comparison of the responses of high-scoring and low-scoring participants showed that more of the high-scoring participants correctly answered all of the items (See Appendix J). The results indicated that most of the items discriminated to some extent between students who have considerable knowledge or ability of the subject matter tested and those who have little. All of the items were, therefore, considered relevant to the properties measured by the test as a whole.

Pilot Project

The purposes of the pilot project were to: study the psychometric properties of the test instruments, which had been assembled by the investigator, and to edit and alter them to produce more reliable results in the main study; and to study the ease of use, comprehensibility, accuracy and students' feelings regarding the treatments.

Twelve second-year Fashion Design and Technology students were invited to participate in the pilot project. This group of students had previously studied garment production costing by selecting a standard sewing time from a chart that lists average sewing times for standard garment styles. The time selected is then multiplied by a given rate of pay per hour to arrive at a cost per unit. By this method the student does not actually divide the design into its individual components to determine the production cost, therefore, missing the opportunity to experience how design details can affect costs.

The pretest was administered to this group and scored by the researcher.

Students were then asked to work with the computer spreadsheet simulation. They found two programming errors, that the researcher was able to correct, and provided

positive feedback related to their feelings about using the simulation. They stated that they enjoyed doing calculations using the computer rather than paper and pencil exercises, and that the simulation allowed them to more easily see how costs are arrived at.

When the students were asked to work with the visual simulation they were asked to compare it to the spreadsheet simulation. Again, the feedback was positive. Students said that they preferred the visual simulation because it seemed more real. They also said that seeing the physical addition of more sewing machines on the screen for more complex designs gave them a better understanding as to why simplifying design details can often reduce production costs. Suggestions from the students for improvements to the visual simulation included providing an on-screen calculator, allowing students to use the computer spreadsheet to record their responses and having an animated icon to represent a floor supervisor. It is the intention of the researcher to incorporate each of these ideas into a future version of the computer program.

The posttest was reviewed by four of the pilot study participants.

Data Collection and Analysis

Calculations for the analysis were conducted with the assistance of the researcher's advisor, Dr. D. Bateson at the University of British Columbia Computing Centre, using the SSPS-X statistical package.

The level of significance used to accept the main treatment hypothesis and for rejecting the null hypothesis was set at .05, a commonly used probability level in educational research (Christensen & Stoup, 1986). For the exploratory hypotheses, the significance level was set at .01 since no conclusions will be drawn, but only suggestions for further research will be made. In this case, it was considered that falsely rejecting a true alternative hypothesis was of greater consequence than accepting a false null hypothesis.

Overview of Data

Individual scores for all participants on both the pretest and posttest as well as their thinking and learning styles inventory scores are listed in Appendices K and L.

The means for the pretest and posttest scores and the posttest adjusted means were calculated for both the experimental and control groups and for the entire sample (See Table 3.3) to provide an overview of the data prior to analyzing it for the effects of the treatments.

Table	3.3	Ś
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Summary Data of Pretest and Posttest

	Pretest Means	Posttest Means	Posttest Adjusted Means
Experimental Group	9.09	10.06	10.43
Control Group	11.25	10.78	10.40

Note: Maximum Score 15

The means for the thinking and learning styles inventories were calculated for both the experimental and control groups (See Tables 3.4 and 3.5) to provide an overview of the data prior to analyzing it for the effects of the treatments.

Table 3.4

Summary Data of Thinking Styles Inventory

	Means
Experimental Group	5.8
Control Group	5.6

Note:	Scale for Table 3.4	1	5	9
		left	balanced	right
		brain		brain
		dominance		dominance

Table 3.5

Summary Data of Learning Styles Inventory

	Means			
	Visualization	Written Word	Listening	Activity
Experimental Group	.52*	.15	-1.10*	-0.20
Control Group	.60*	-0.20	-1.08*	.80*

* ± 0.5 is considered significant

Summary

An experiment to determine differences in student achievement between a visually interactive computer simulation and a computer spreadsheet simulation on production scheduling and costing was designed and implemented.

Two further questions were also explored to investigate whether students' thinking and learning styles mediated the experimental treatment.

In this chapter the elements related to the design of the study were described. The next chapter will present the results of the study.

Chapter 4

RESULTS

This chapter includes a brief description of the statistical procedures used to analyze the data and deals with the disposition of the hypotheses stated in Chapter 3.

Calculations for the analysis were conducted with the assistance of the researcher's advisor, Dr. D. Bateson at the University of British Columbia Computing Centre, using the SSPS-X statistical package.

The level of significance used to accept the main treatment hypothesis and for rejecting the null hypothesis was set at .05, a commonly used probability level in educational research (Christensen & Stoup, 1986). For the exploratory hypotheses, the significance level was set at .01 since no conclusions will be drawn, but only suggestions for further research will be made. In this case, it was considered that falsely rejecting a true alternative hypothesis was of greater consequence than accepting a false null hypothesis.

Statistical Procedures

To test for any effects of the treatments, posttest results were analyzed by analysis of covariance (ANCOVA), using the pretest as the covariate. This statistical procedure increases the precision of the research analysis by removing the effects of initial differences that are considered important between the groups to identify more clearly whether mean differences among groups were likely to have occurred by chance (Tabachnick & Fidell, 1983) or can be attributed to the experimental treatment. In this case the initial differences of major concern had to do with general mathematics ability. Therefore, the mean scores obtained on the posttest were adjusted for initial differences, measured by a test of general mathematics ability, between the groups. Since the sample size was small and intact classroom groups were used to conduct this experiment,

ANCOVA was considered to be the appropriate statistical test (Campbell & Stanley, 1963).

Disposition of Hypotheses

In this section, the statistical tests of the hypotheses are described along with interpretations of the findings.

Research Ouestion 1: Treatment Differences

H_o: The adjusted mean posttest scores for apparel design students trained using an object-based visually interactive computer simulation will not be significantly different on a test of production costing and scheduling than for students trained on a computerized spreadsheet simulation.

 $\mu_{X1}' = \mu_{X2}'$ $\mu_{X1}' =$ experimental (visual simulation) group $\mu_{X2}' =$ control (spreadsheet simulation) group

H₁: The adjusted mean posttest scores for apparel design students trained using an object-based visually interactive computer simulation will be significantly higher on a test of production costing and scheduling than for students trained on a computerized spreadsheet simulation.

 $\mu_{X1}' > \mu_{X2}'$

An initial ANOVA on the unadjusted posttest scores indicated no significant difference between the experimental and control groups [F(1, 50)=.85, ns]. However, because the groups differed on the pretest scores [F(1, 50)=10.22, p < .01] with the

control group scoring significantly higher than the experimental group (means = 11.34 and 9.09), ANCOVA was performed, controlling for pretest scores. This ANCOVA again indicated no significant effect for group on the adjusted posttest scores [F(1, 49)= 0.0]. The pretest covariate produced a significant beta of .30, p < .05. The initial difference between the groups justified the use of the pretest in the analysis of covariance for testing the hypotheses in this study.

An increase from pretest to posttest for the experimental group was expected and achieved, but the increase was not statistically significant (9.09 to 10.06). The null hypothesis was accepted because the probability of this result occurring is greater than the alpha level set at .05 and can therefore be attributed to chance.

Two further questions, with the alternative hypotheses being non-directional since the direction of the results were unpredictable, were also tested. Since research question one has a directional H_1 a one tailed test was used. However, for questions two and three, a two tailed was used.

Research Ouestion 2: Visual Learning Style

H₀: The adjusted mean posttest scores for apparel design students identified as higher visual learners will not be significantly different on a test of production costing and scheduling from the lower visual learner group.

 $\mu_{VH}' = \mu_{VL}'$ $\mu_{VH}' = higher visual learners group$ $\mu_{VL}' = lower visual learners group$

H₁: The adjusted mean posttest scores for apparel design students identified as higher visual learners will be significantly different on a test of production

costing and scheduling from the lower visual learners group.

Students were divided into two groups on the basis of a median split of their scores on the visual learning sub scale of the learning styles inventory. The high and low visual learners were split approximately equally between experimental and control groups. To investigate whether a visual learning style mediated the experimental treatment, this factor was introduced into the ANCOVA reported above as a second factor. Table 4.1 shows that while neither the treatment group nor the visual learning style main effects were significant, the interaction of the experimental treatment group by visual learning style was significant.

Table 4.1

Source of Variation	SS	DF	MS	F	р
Pretest Covariate	29.18	1	29.18	3.97	.05
Group	.24	1	.24	.03	.86
Visual	2.54	1	2.54	.35	.56
Group by Visual	20.50	1	20.50	2.79	.10*
Within Cells	338.09	46	7.35		

Visual Learners Subgroup ANCOVA on Posttest Scores Controlling for Pretest Scores

* p≤.10

Figure 1 indicates that while low visual learners seemed to perform better on the control treatment relative to the high visual learners (controlling for pretest scores), high

visual learners in the experimental treatment group appeared to do better compared with the low visual learners in the experimental treatment.







Visual Learners Subgroup Posttest Adjusted Mean Scores

Research Ouestion 3: Active Learning Style

H_o: The adjusted mean posttest scores for apparel design students identified as higher active learners will not be significantly different on a test of production costing and scheduling from the lower active learners group.

$$\mu_{AH}' = \mu_{AL}'$$

 $\mu_{AH}' = higher active learners group$
 $\mu_{AL}' = lower active learners group$

H₁: The adjusted mean posttest scores for apparel design students identified as higher active learners will be significantly different on a test of production costing from the lower active learners group.

Students were divided into two groups on the basis of a median split of their scores on the active learning sub scale of the learning styles inventory. The high and low active learners were split approximately equally between experimental and control groups. To investigate whether an active learning style mediated the experimental treatment, this factor was introduced into the ANCOVA reported in the first null hypothesis as a second factor.

Table 4.2 shows that while none of the effects were significant, the interaction of the experimental treatment group by active learning style might indicate a trend.

Table 4.2

Active Learners Subgroup ANCOVA on Posttest Scores Controlling for Pretest Scores

Source of Variation	SS	DF	MS	F	р
Pretest Covariate	37.04	1	37.04	4.91	.03
Group	.13	1	.13	.02	.90
Visual	.93	1	.93	.12	.73
Group by Visual	15.09	1	15.09	2.00	.16
Within Cells	347.38	46	7.55		

Figure 2 indicates that while low active learners seemed to perform better on the control treatment relative to the high active learners (controlling for pretest scores), high active learners in the experimental treatment group seemed to perform better compared with the low active learners in the experimental treatment.





Active Learners Subgroup Posttest Adjusted Mean Scores

It should be noted that the relationship between the visual learning style and the activity learning style was uncorrelated [r(49) = -.10, p > .48]

Thinking and Learning Styles Inventories

Thinking Styles Inventory

For this brain preference indicator test, on a scale from one to nine, a person with a score of four to six is considered mixed dominant, a score of one is considered left brain

dominant and a score of nine is considered right brain dominant. The mean score for the experimental group was 5.8 with nearly 33% of the students scoring more than six. The mean score for the control group was 5.8 and, again, nearly 33% of the students scored more than six. The results suggest that the members of both groups are mixed dominant, but there is a tendency toward right brain dominance.

Learning Styles Inventory

For this inventory a mean score of ± 0.5 is considered significant. For the "visualization" category, the mean scores for both the experimental (.52) and control (.60) groups were significant in a positive direction. For the "listening" category, the mean scores for both the experimental (-1.10) and control (-1.08) groups were significant in a negative direction. For the "activity" category, the mean score for the experimental group (.-0.20) was not significant but, for the control group, a mean score of .80 was significant in a positive direction. For the final category, "written word" the mean scores for both the experimental (.15) and control (.-0.20) groups were not significant.

Since the visualization category, considered to be a right brain activity, was significant in a positive direction, and the listening category, considered to be a left brain category, was significant in a negative direction, the results suggest that the members of both groups show a tendency toward right brain dominance.

Summary

The researcher realized that ANCOVA was the appropriate statistical test to analyze the data as it was shown that the initial differences of the two groups was statistically significant.

Students in the group that received the visual computer simulation treatment achieved a higher adjusted mean score on a test of production costing and scheduling, although not
statistically significant, than the students who received the computerized spreadsheet treatment.

The analyses indicate that there may be a directional relationship between students identified as visual learners who used the visual computer simulation and achievement on a test of production costing and scheduling as there was a significant increase in adjusted posttest scores.

The analyses also indicate that there may be a trend in students identified as active learners who used the visual computer simulation and achievement on a test of production costing and scheduling as there was an increase in adjusted posttest scores.

An informal analysis of the data from the thinking and learning styles inventories suggests that both groups of students tend to be more right brain or visually oriented in their thinking and learning styles.

Chapter 5

SUMMARY, CONCLUSIONS, REFLECTIONS ON THE RESEARCH AND IMPLICATIONS

The purpose of the study, the procedures involved and the results are summarized in this chapter, followed by conclusions, some reflections on the research, implications for future research and implications for instruction.

Summary of the Study

The purpose of this study was to explore ways in which object-based visually interactive computer simulation is an effective learning environment in which to teach apparel production management to apparel design students who are more inclined toward the artistic than the mathematical. A review of the literature suggests that object-based visually interactive computer simulation provides a positive learning environment, has the potential to produce dynamic, intrinsically captivating simulations and can visually replicate the environment in which graduates will work. Therefore, it was hypothesized that students receiving an object-based visually interactive computer simulation treatment would score higher on a test of production costing and scheduling than students receiving a computer spreadsheet simulation treatment. Data were collected and analyzed to test this hypothesis. Two further questions were also examined:

- Will there be a significant difference in the adjusted mean posttest scores for apparel design students identified as higher visual learners and achievement on a test of production costing and scheduling compared to the lower visual learners group?
- 2. Will there be a significant difference in the adjusted mean posttest scores for apparel design students identified as higher active learners and achievement on a test of production costing and scheduling compared to the lower active learners group?

The Nature of the Study

Since intact classes were randomly assigned to treatments, the nonequivalent control group quasi-experimental design approach as outlined by Campbell and Stanley (1963, pp. 47-50) was used for this study.

Null hypotheses were formulated from the research hypothesis and the additional questions posed for the study, and were treated with an analysis of covariance (ANCOVA).

At the beginning of the experiment, instruments to identify students' thinking and learning styles, and a pretest to control for possible differences in mathematical ability between the two classes in this study, were administered to all subjects. Two weeks later, subjects in the experimental group were assigned the visual computer simulation exercise while subjects in the control group were assigned the computer spreadsheet exercise. Each group was allowed one-and-one-half hours to complete the assigned exercise. An achievement test pertaining to the mathematical content of the computer exercises and drawing of a production scheme, was administered to both groups as a posttest one week following the experiment.

To measure the treatment effects, posttest results were analyzed by ANCOVA using a pretest as the covariate; the mean scores obtained on the posttest were adjusted for the initial differences between the groups. ANCOVA was repeated to investigate whether visual or active learning styles mediated the experimental treatment.

Summary of Results

The level of significance used to accept the main treatment hypothesis and for rejecting the null hypothesis was set at .05 and for the exploratory hypotheses, the significance level was set at .01 since no conclusions will be drawn, but only suggestions for further research will be made.

ANCOVA was the appropriate statistical test to analyze the data as it was shown that the initial differences of the two groups was statistically significant.

An increase from pretest to posttest adjusted mean scores for the experimental group was expected and achieved, but the increase was not statistically significant (9.09 to 10.06). The null hypothesis was accepted because the probability of this result occurring is greater than the alpha level set at .05 and can therefore be attributed to chance.

The analyses indicate that there may be a directional relationship between students identified as visual learners who used the visual computer simulation and achievement on a test of production costing and scheduling as there was a significant increase in adjusted posttest scores.

The analyses also indicate that there may be a trend in students identified as active learners who used the visual computer simulation and achievement on a test of production costing and scheduling as there was an increase in adjusted posttest scores.

An informal analysis of the data from the thinking and learning styles inventories suggests that both groups of students tend to be more right brain or visually oriented in their thinking and learning styles.

Conclusions

In conclusion, this section will describe the limits of the study, examples of the learning theories outlined in Chapter 2 addressed in the experimental treatment (visual simulation) and uses for the visual simulation in apparel design programs.

Limits of the Study

A number of factors encountered in the research design and procedures might have affected the results obtained in this study. First, the considerably large difference between the two groups mean scores on the pretest was unanticipated and may need to be considered in future administrations of the treatment. Students in the visual computer simulation group obtained a mean score of 60.6%, compared to the control group mean of 75% on the pretest, which consisted of questions selected from a mathematics assessment for grades seven and ten. The results suggested that the mathematical ability of the experimental group was low and it could, therefore, be expected that any stimulus presented only once is unlikely to have a large effect. However, the mean score for the experimental group did increase on the posttest, which was a more difficult test than the pretest because it was designed for college level students. This result suggests that the visual computer simulation could have been a positive learning environment for many of the participants, but that students need to be exposed to the stimulus for several sessions. This is consistent with Atkinson and Burton's (1991) findings that students who used a computer simulation the most performed better on achievement tests than students who had little practice time.

Secondly, it could be argued that there was very little difference in the visual screen presentation between the experimental and control treatments since both simulations displayed the same spreadsheet. The researcher choose to have the control group use a computerized spreadsheet rather than a paper and pencil spreadsheet so that the "help" option incorporated into the simulations and learning to use the computer, especially the mouse, would not be considered intervening variables since both groups worked with the same conditions.

Thirdly, the effects on the results of the limiting factors associated with the visual computer simulation, since the programming language used was a beta-test model, the small sample size available for this experiment, and the use of intact classroom groups rather than randomized groups, are unknown. Therefore, the results are only generalizable to the participants in the study.

Finally, the effects on the results of potential threats to the internal and external validity of the study identified in Chapter 3: intrasession history; students' past experiences related to the subject matter; subject specific treatments; and the questionable

generalizability of the specific conditions which the experimental and control groups have in common, are also unknown, thus, contributing to the limited generalizability of the study.

Learning Theories and The Experimental Treatment

This section will describe how the visual computer simulation used in this study attempted to address aspects of the learning theories that were outlined in Chapter 2.

If simulations allow one to build on their previous knowledge, then it is necessary to ensure that each student has an appropriate knowledge base to build from prior to using a simulation (Goodyear, 1991; Papert, 1991; Stead, 1990). It was felt that the students who used the visual computer simulation in this study had an appropriate knowledge base since the simulation was administered after the students had been assigned a series of readings, had spent two, two-hour sessions discussing matters related to mass production and had viewed two video tapes on the topic. Also, since all of the students knew how to sew a basic skirt, there were a number of recognizable objects on the computer screen.

Papert (1991), Lawler et al (1986) and Goodyear (1991) advocated that support materials and the intervention of a facilitator are necessary to assist learners as they work with a computer program. For this study, students were provided with a demonstration, some written information to use as a reference and the teacher was present throughout the administration of the simulations.

The visual simulation encouraged students to be actively involved in their learning experience by requiring that they make selections in order to acquire the data they needed to solve problems and to run the simulation.

The visual simulation encouraged students to use both hemispheres of their brain; the spreadsheet and graph referred to mathematical elements and the user was required to make several computations, thus, addressing the left side of the brain, and the pictorial sewing machines with the garment bundles moving through the system gave a realistic,

visual representation of a manufacturing environment, thus, addressing the right side of the brain.

Many of the early advantages of computer-based learning were incorporated in the visual simulation. Students can use the simulation individually, receive immediate feedback to their responses, remediation is provided, the degree of difficulty is progressive and the amount of practice provided is infinite. Also, repetition is provided, but the data is always different so that the students have to compute each response. The intended use of the simulation is that it supplement other forms of instruction. This supports Bennet's (1991) and Spencer's (1991) findings that simulation was most effective when used as a supplement to other forms of instruction.

A number of the studies cited stated that colour, graphics and animation should be used to illustrate important features of the material presented (Baek & Layne, 1988; Spencer, 1991; Thorell & Smith, 1990). The simulation is a simple pictorial representation of a complex setting. The only aspect of the factory floor that is displayed on the computer screen is the layout of sewing machines for a specific garment style. The sewing machines are simple line drawings. Colour and animation are used to show the garment bundles moving through the system. A graph is provided for the user to quickly assess the number of garments being produced each hour. The simulation replicated an environment in which apparel design students will be expected to work. Determining the transferability of the learning gained from the use of the simulation was beyond the scope of this study. It was anticipated that the visual simulation would be intrinsically motivating due to the use of colour, graphics and animation. The simulation attempted to address Malone's (1984) elements of an intrinsically motivating instructional environment by incorporating: challenge, with the use of progressively more difficult problems to solve; fantasy, with the use of representational objects that replicated a small portion of a large system; and curiosity with three garment styles, or options, for the user to choose to work with.

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The visual simulation is only a prototype and as yet does not provide an opportunity for the teacher or the users to alter the parameters, or allow the users to create their own models. These components will be considered in future versions of the simulation.

Uses for the Visual Simulation in Apparel Design Programs

The visual simulation used in this study should provide a practical solution for instructors who need resources to teach apparel production management to students who tend to be more artistic than mathematical. It is an extensible prototypical computer simulation that can be used in the classroom to provide a flavour of the topic, especially for programs that are not able to offer courses dedicated to production management.

The visual simulation should also contribute to the implementation of computerassisted learning environments in apparel design programs. It could be incorporated into the curriculum in a variety of ways; a few suggestions are offered here. First, depending on the number of computers available, students could either run the simulation individually, in pairs or in small groups. If only one computer is available, the teacher could run the simulation, using an overhead projector so that all of the students could see the computer screen and either use the simulation as a demonstration or as a group problem solving session. Students could then use the simulation individually, either in class time or on their own time. Regardless of the way that the simulation is run, it could also be used as a point of departure for students to plan and build their own factory floor layouts on paper. It could also be used as a point of departure for further discussion of production costing and scheduling.

The visual simulation could be used to fulfill the need of textile and clothing instructors for new and better ways of enhancing students' visual thinking and communication skills as identified by O'Riley (1988).

In summary, the visual computer simulation appears to be a positive teaching learning strategy that can be used in the classroom as an integral component of the curriculum as a supplement to instruction on apparel production management, should be presented more than once during class time and should be available for students to use on their own time.

Reflections on the Research

An exciting opportunity to collect qualitative data arose while the students were working with the computer simulations. Students were required to work in pairs which allowed them to problem solve collaboratively through spoken language and gestures. Observation and record taking were not a part of the design of this study. However, the laboratory setting unexpectantly freed me from providing some of the usual individual assistance required because the students, with help from their partners, resolved their own operational problems, such as how to get the mouse to work and what to do next. Also, I was able to overhear and see some of what the students were thinking while they worked through the exercises. Consequently, I decided to use this opportunity to record some of the students' comments and actions.

Three incidents arising from the experimental (visual simulation) setting that could be used to develop a conceptual framework for part of a future study that investigates why this medium may be a rich teaching format that guides learning, are described here. The first scenario illustrates active involvement in the learning process, the second relates to math phobia and the third is an example of students' responses following the experiment.

Students used the visual simulation by selecting options from menus with a mouse. When a garment style was selected, the program displayed a layout of a factory floor with sewing machines representing the steps in the construction of the garment. Each sewing machine had two gauges which rose and fell with the flow of garment pieces in and out of the sewing station. I noticed that Jill, one of the students, was imitating the action of the two gauges attached to the on-screen sewing machines. With elbows bent, she alternated lifting each arm up and down as she swayed her body from side-to-side in

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time with the rise and fall of the flow of pieces. Jill appeared to be actively involved in her learning experience. Watching her reminded me of Papert's (1980) belief that students become the objects they study. In this instance, Jill was the garment pieces.

Another student, Anne, arrived late and was clearly flustered. She stated that she was embarrassed to be late, was intimidated by having to use a computer and disliked subject matter related to math. She refused the opportunity for a demonstration, saying that she should take the responsibility to catch up on her own. It soon appeared that she was unable to concentrate on the written instructions. She accepted the second offer of a demonstration. Twenty minutes later, she was moving through the exercise rapidly, with a smile on her face. Not having a partner, she discussed the activity with the two students sitting at the computer next to her. Anne later told me that she felt she understood the math involved in the exercise, a rare experience for her. Her test scores went from 5 out of 15 on the pretest to 13 on the posttest.

Other students indicated that they were not strong in mathematics, but the visual simulation helped make the process more real to them; the calculations made sense:

- Ruby, "Now I know exactly how the price of a garment is arrived at.";
- Andrew, "I hadn't realized before that every minute of sewing time can make a difference to the cost.";
- Rod, "I'm enjoying doing math using this program."; and
- Theresa, "I wish math had been taught this way in high school."

In a regular classroom setting the students in the experimental group are generally passive, requiring creative approaches from their instructors to motivate them to participate more actively. Worthy of note is that during the class following the visual computer simulation exercise, a number of students in the experimental group asked questions related to garment production which prompted voluntary discussions involving several students. Their questioning was more probing than questioning from the control group or from previous groups of students studying the unit on production management. Sherry asked, for example, "Isn't the rate of production only as fast as the slowest machine operator?" This question led to a discussion on how the average times for each sewing operation are arrived at and the concept of linear versus parallel processing. Subsequent questions led to a discussion that went beyond the scope of the simulation; to how bottlenecks, machine breakdowns and absenteeism will influence the production cost of garments.

Throughout the experiment both the control and experimental groups were deeply engrossed in their respective computer exercise. Several times when the researcher directed a question to a student, the student just looked up for a moment and smiled or nodded and immediately returned to work. All of the students in both groups were seen attempting to answer the questions asked in the simulation before they clicked on the cells in the computer spreadsheet that would reveal the correct responses. In most cases students were able to work out the correct response from the assistance provided in the simulation, but when they did not answer a question correctly they referred back to the help section and tried again.

Although the software was the learning pedagogy here, the process of the students' collaboration became a point of interest to me. The concept of collaborative learning using computers has recently stimulated a number of researchers to "pursue . . . research projects that study collaborative learning and other cognitive processes in situ" (Jackson, 1990, p. 65). Advantages of collaborative learning include maximizing the use of hardware and software by sharing, and students learning to help each other so that they can work more independently from the teacher. A deeper use of combining computers and collaborative learning techniques might be found in students using computer models to jointly discover concepts and meanings through discussion and criticism of each others point of view (O'Malley & Scalon, 1990). The findings here could be used as a base for the development of a conceptual framework on collaborative learning using computers as part of a future study.

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Feedback from the students in both groups was overwhelmingly positive. Certainly the novelty of the medium can be attributed to the interest and enthusiasm expressed by the participants. The enthusiasm displayed by the students and the surprisingly deep nature of the discussion that followed the experiment convinced me that the visual computer simulation was worth the effort and has considerable future potential.

Reflecting on the research has raised a number of questions for me that will be discussed in the following section on implications for future research.

Implications for Future Research

Based on the results of the study and the reflection on the research, some implications for future research are suggested here:

- that the visual simulation be tested by other apparel design instructors to validate its usefulness in presenting the subject material, ease of use, effectiveness and to provide recommendations for enhancing the software program;
- 2. that a similar experiment be carried out with a larger sample size and randomization of subjects into control and experimental groups to increase the statistical power of the study;
- that any further research using a visual computer simulation take place over a minimum of one semester and that ways to measure transferability of the knowledge and skills gained, be addressed.
- 4. that further research be carried out to investigate how students' individual thinking and learning styles can best be addressed using a visual computer simulation.
- 5. that a framework be developed to evaluate the qualitative aspects of the use of the medium that emphasizes both cognitive and behavioral aspects of instruction using a variety of assessment techniques; and
- 6. that further research be carried out that looks more deeply into the nature of objectbased simulations. The following are a few of the questions that could be considered:

- 6.1 What does the learner learn from using the visual simulation used in this study; concepts related to production costing and planning, how to do mathematical calculations, or both?
- 6.2 Can using a visual computer simulation change the definition of learning for the learner, and if so, how?
- 6.3 Can a person become a better thinker as a result of using a visual simulation?
- 6.4 Does interaction with a visual computer simulation alter the users' perspective on the world around themselves?

Implications for Instruction

Based on the results of the study and the reflection on the research, some implications for instruction are also suggested here.

The extent of this study was to provide a prototypical solution for instructors who need resources to teach apparel production management. Future considerations for the design of the software include: allowing the teachers and the students to alter the parameters; provisions for the effects on a production system due to breakdowns, bottlenecks and absenteeism; opportunities for the users to experiment with a variety of production systems; and an environment in which students can research and create their own models of a factory floor. Interactive video should be incorporated in the development of future software.

An object-oriented computer language should be used to develop a framework for teachers and students to access and manipulate so that they are actively involved in the decision making in the development of their own models without the distraction of actually having to learn the programming language.

Instructors in clothing design programs should consider how the curriculum can be organized to maximize the use of microcomputer technology as an integral part of the curriculum. The challenge will also require consideration for the incorporation of a variety of teaching/learning strategies, such as collaborative learning, and the changing role of the instructor from that of a lecturer to a facilitator. The effort will be well worth it. Since, as Alan Kay (1984) said, "As in all the arts a romance with the material must be well under way." (p. 9)

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Appendices

Appendix A

Senior Matriculation Courses Completed by Students Enrolling in the Fashion Design Program at Kwantlen College

Grade 12 Courses Completed

Subject	Art/Art Related	Mathematics	Home Economics
1	x	x	
2	х	х	X
3	х		х
4			
5	x		х
6		x	Х
7			Х
8			Х
9	Х	х	
10			
11	Х		
12			
13	х		X
14		х	
15	Х		х
16			
17	Х		х
18	X		х
19	х		х
20	х		X
21	x	X	X
22	х		X
23	X		X
24	X	X	
25	х		
26			
27		X	
28		Х	X
29	X		X
30	X	Х	X
31	X		
32	X		X
33	X		Х
34			
35			х
36			х

37	х		х
38	X		х
39	х		х
40			x
41	х		х
42			х
43	х	х	х
44			
45	х	Х	х
46	х		х
47	x		х

Note: x = course completed

Totals:301232Results:64% completed grade 12 Art26% completed grade 12 Mathematics26% completed grade 12 Mathematics68% completed grade 12 Home Economics81% completed grade 12 Art or Home Economics

From the results of this small sample, it would appear that students enrolling in the Fashion Design Program at Kwantlen College are more inclined toward the artistic than the mathematical.

Appendix B

Scanned Photographs of the Visual Computer Simulation Screen (Note: screen printouts were not available)

Scanned photographs of the visual computer simulation screen can be found on the next four pages. The following is a brief description of each.

Figure 3 is the opening screen of the visual computer simulation. See Appendix D for a description of the objects on the screen and for a more detailed explanation of how the simulation is used.

Briefly, students use the simulation by selecting "Style" options from the spreadsheet. When the "Basic Skirt" has been selected (See Figure 4), workcentres which represent each of the steps in the production of the garment are displayed on the screen and the production times for each step are displayed on the spreadsheet.

Students are then required to connect each of the workcentres (See Figure 5) to establish the path that the bundles of garment pieces will follow as the garments are being constructed when the simulation is running.

Figure 6 is an example of the style "w/Pock/Vent" (with pockets and vent) in full production. The production times for each style and answers to the first two questions for each style are also displayed. At this stage, students can use the simulation to make decisions to determine which style is within the marketable price range for a hypothetical apparel manufacturing company, by comparing production costs for the various styles.

			n gin tun na kalon a gang ga	Sn	
Char Spreadtheat		STEPS			WEACH Mart
Start Production	and the set of the set	Serge Edges			
Stop Production		Darts			
Reset		Pockets			
		Vert			
	́.	Zp/Seems			•
		Wastband			
		Finiting			
Jamens Hourly Production Chart		t. Lineture		·	
1 (1997) - 1997		2 costunt			
3:25		3 #unts/m/W			
NG		t Aurishr.			
		6 cost/serge			
		7 Eworkcent			
		Production	Times & Costs	Rece Ci Pay -	SECON

Figure 3: Opening screen for the Visual Computer Simulation

Cear Spreadsheet		STEPS	Basic Skirt	W/Pockets	w/Pock/Vent
Ster Procedon	anti, adopte, and	Sarge Edges	287		
Stop Production	tin a waki keci ili ili ili ili ili ili ili ili ili i	Darts	4.20		
Reset		Pockets			
	Derb	Vert			
		Zip/Seams	4.21		
	227/30-6775	Waistband	4.01		
		Finishing	508		
Houry Production Chart		t. time/unt			
124	Weissand	2 cost/unit			
	n an	a punts/m/W			
		A Arristr.			
		S Arthyday			
		6 cost/sarge			
		2 Anothere			
			n Times & Costs	Rate of Pay =	- 98.0977

Figure 4: Screen display following the selection of "Basic Skirt"

78

			S	
Oper Spreadcheet	STEPS	Basic Skirt N	STYLES	2 WERENAME
Start Production	Serge Edges	2.81		
Stop Production	Darts	3.86		
Reset	Pockets			
Dada.	Vert			
	Zp/Seams	3.88		
	Wastband	3.75		
	Finishing	519		
Gunnars Housy Production Chart	t. time/unit			
	2 costrunt			
106	3. #untsfretW			
	4 Aurtester.			
	5 Junits/day			
	6. cost/serce			
	7. #workcart			an an an 1917 - Angles Angles an Angles a 1917 - Angles Angles an Angles a
	Protes	en Times & Costs	RibodPers	SILLIN

Figure 5: Screen display following the connection of the workcentres

Clear Spreadsheat		STEPS	Basic Skirt	W/Pockets	wiPccstiert
Start Production		Serge Edges	281	2.82	286
Stop Production		Darts	3.86	4.05	381
Reset		Pockas		571	561
		Vert			4.23
		Zustaans	306		375
		Wasthand	3.75	421	404
		Friding	5.19	5 05 (*****	588
Annual TRANSPITCOLLEGAT CTURE		. Unstant	194	278	2639
			260.	3/3	292
				and the second	an triant
		t Artshi	hangen a Maža		
•	Promotion	S Austrician	at an a star	in [™] g [°] is is n	eres care
44 1		e continuiga			
15		Considerate			
		Press and	ilensil Cooke		

Figure 6: Screen display of style "w/Pock/Vent in full production

Appendix C

Cover Letter and Consent Form

Fashion Design Students FAS 110: Development of the Apparel Industry course Kwantlen College Richmond Campus

October, 1991

Dear Fashion Student:

As part of my Master's thesis research, I have developed computer programs to teach apparel production design and costing. The title of my research is *Effectiveness of a Visual Computer Simulation in Instruction of Apparel Production*. My advisor at the University of British Columbia is Dr. D. Bateson (822-5203). I would like your assistance in field testing these computer programs.

The purpose of this research study is to provide students of fashion design with a realistic learning experience relevant to production in the apparel industry. A visually interactive computer simulation will be compared to a computerized spreadsheet simulation, to teach production management to college students who tend to be more artistic than mathematical.

The study is in the context of the material normally covered in unit four: Mass Apparel Production. The study consists of three parts. The first part is an exercise to assist in identifying your learning style. It is not a test, for there are no right or wrong answers. The second component is an exercise to assess your ability to solve problems related to determining production costs. Your score on this exercise will not affect your grade for this course. The results will be used as a basis for comparison with the third component of the study, an inclass exercise on the material covered in the simulations. The inclass exercise will count ten percent toward your final mark.

As participants are being recruited from intact classes, one group will be assigned the visual computer simulation and the other group the spreadsheet computer simulation. The entire study will take place within the normal course of events during the last three weeks of this course. An opportunity will be provided for you to try the simulation you did not use in the study, after the experiment is completed, should you desire to do so.

All of the data collected will be confidential. You will be assigned numbers; your name will remain anonymous. Original results for each component of the study will be returned to you. Photocopies of the originals will be retained by me until the entire study is completed. The photocopies will then be destroyed.

If you choose not to participate in the study you will still be required to do the computer simulation assigned to you as well as the inclass exercise in order to complete the requirements for the course. Your final grade for this course will not be affected if you choose not to participate in the study. Any participant can withdraw from the experiment at any time. Your name will remain anonymous. Again, should you withdraw from the study your final grade for this course will not be affected.

If you agree to participate in this study, your contribution will be greatly appreciated. Should you have any questions concerning the purpose or procedures related to this study, please do not hesitate to ask. Thank you.

Sincerely,

Mary Boni Instructor FAS 110 Office #420N Phone 599-2551

Please complete and return the following Consent Form before you leave class today.

CONSENT FORM

To: FAS 110 students

From: Mary Boni

Re: study titled Effectiveness of a Visual Computer Simulation in Instruction of Apparel Production

I have received a copy of the cover letter and consent form that explains the purposes and procedures of the study.

Please check YES or NO

Do you agree to participate in this study? YES _____ NO ____

If you said YES to the first question, do you want a copy of the study results? YES _____ NO _____

(signature of student)

Appendix D

Student Lesson: Visual Computer Simulation (Experimental Treatment)

Apparel Production Management

A) Introduction

The purpose of this tutorial is to provide an opportunity for you to experience how apparel factory layout designs and apparel production costs are arrived at.

What you see on the screen is:

- a series of *buttons* on the left side of the screen that are to be used to run the simulation;
- a sewing machine *workcentre* with carts on either side to display the number of incoming bundles of garment pieces to be sewn on the left, and the outgoing bundles on the right;
- a *spreadsheet* that displays three skirt 'Styles' and the 'Steps' needed to produce each style using the progressive bundling piece work system. The average time to complete each step has been previously arrived at and built into the simulation using a probability distribution so that each time the simulation is run, different data will be supplied. When you have finished running the simulation use the bottom section of the spreadsheet to answer the seven questions related to production time and cost.
- a *line graph* that will chart the number of garments completed per hour;
- a *clock* that will show how much time has passed as the simulation is running.

B) Setup and Running the Simulation

Your instructor will demonstrate how the simulation works. Follow along using this handout. Detailed instructions are provided here so that you can work independently later.

Do the following:

Select the cell that reads 'Basic Skirt' by placing the mouse cursor on the cell and clicking on the left mouse button. Wait. Observe what is now displayed on the computer screen.

Now you see 5 workcentres. Each represents a step needed to construct this garment style. The production time for each of the 'Steps' now appears on the spreadsheet in the column below 'Basic Skirt'. In a simple factory setting, one sewing machine operator (worker) is assigned to each step.

Before you can 'Start Production' you must connect each of the workcentres to show the path that the bundles of garment pieces will follow as the garments are being constructed. Do it now using the following directions.

With the left mouse button, click on the workcentre labeled *Serge Edges*. A small icon in the shape of a pencil will appear on the screen. Drag the mouse straight down until the pencil and the pencil line you have drawn is in the centre of the next workcentre. Without moving the pencil, click on the left mouse button twice. The whole screen will redisplay leaving a line with an arrow displayed to show that the two workcentres are now connected. In the centre of the second workcentre, click with the left mouse. When the pencil appears, connect *Darts* to *Zip/Seams*. Then connect the rest of the workcentres.

Now you may select the button 'Start Production'. Watch the production line in operation for 3 or 4 simulation-time hours. Note how the bundles move from workcentre to workcentre. As a bundle moves through *Finishing* it is recorded on the line graph. Note how many garments were completed per hour. When you feel that you have seen enough, select 'Stop Production' with the left mouse.

C) Determining Production Times and Costs

Record the data given on the computer screen onto your copy of the spreadsheet (see page 3). Note that the average 'Rate of Pay', in this example, for each operator, given at the bottom of the spreadsheet, is \$8.00 per hour. All of this data is to be used to answer the questions on the following page. Write your answers to the questions on your copy of the spreadsheet.

Do the questions in order, as many answers rely on the answer from the previous question(s).

To check your answer, or for help if you are not sure how to arrive at an answer, place the mouse cursor on the appropriate cell of the computer spreadsheet. Click the left button of the mouse. You will now see a small menu that says 'help' and 'answer'. If you again use the left mouse button to click on help, a rectangular shaped box, that provides information on how to go about answering the question, will pop up on the screen.

Try it. Place the mouse cursor on the blank cell in the column labeled 'Basic Skirt' and the row that refers to question 1 - '1. time/unit'. Click on the cell with the left mouse button. Now click on 'help'. Experiment with the 'More Help' and 'Exit Help' buttons that you now see on the screen. When you are finished with 'help' be sure to use 'Exit Help' to keep the screen clear.

Click on the same cell again, next to question 1, but this time select 'answer' by clicking on the left mouse button.

Work through the questions for the 'Basic Skirt' using the 'help' option as needed. Try to answer each question on your own before you check the answer. Check your answers as you go.

Questions - the computer reference is in brackets following each question:

- 1. What is the total time required to complete the construction of one unit (garment)? See (1. time/unit) in the left hand column of the spreadsheet.
- 2. How much does it cost to construct one unit? (2. cost/unit)
- How many units per hour can each worker complete? (3. #units/hr/W)
- 4. How many units can this production setup complete in one hour? (4. #units/hr.) Compare your answer to the line graph.
- How many units can this production setup complete in an 8 hour day? (5. #units/day)
- 6. How much does it cost to serge the edges of each unit? (6. cost/serge)
- If a factory needs to produce 200 units per day to meet its sales quota, how many workcentres will be needed? (7. #workcent)

STYLES						
STEPS	Basic Skirt	w/Pockets	w/Pock/Vent			
Serge Edges						
Darts						
Pockets						
Vent						
Zip/Seams						
Waistband						
Finishing						
1. time/unit						
2. cost/unit						
3. #units/ hr/W						
4. #units/hr.						
5. #units/day						
6. cost/serge						
7. #workcent						

Figure 7: Production Times & Costs

Now select the w/Pockets (with pockets) style, set up and run production as you did for the Basic Skirt style, and work through each of the questions.

Then try the w/Pock/Vent style and work through the questions without using the help option.

Appendix E

Student Lesson: Spreadsheet Computer Simulation (Control Treatment)

Apparel Production Management

A) Introduction

The purpose of this tutorial is to provide an opportunity for you to experience how apparel factory layout designs and apparel production costs are arrived at.

The spreadsheet you see on the computer screen displays examples of garment production layouts using the progressive bundling piece work system for three skirt styles. The 'Styles' are listed across the top of the spreadsheet. Each of the sewing 'Steps' needed to construct each of the styles is listed in the left hand column, from 'Serge Edges' to 'Finishing'. The average time to complete each step has been previously arrived at and built into the simulation using a probability distribution so that each time the simulation is run, different data will be supplied.

B) Instructions

If you have not already selected the cell that reads 'Basic Skirt', do so now by placing the mouse cursor on the cell and clicking on the left mouse button.

The numbers that now appear in the column below 'Basic Skirt' are the production times for the 'steps' needed to construct this garment style. In a simple factory setting, one sewing machine operator (worker) is assigned to each step.

Record the data given on the computer screen onto your copy of the spreadsheet that is provided for you on the following page. Note that the 'Rate of Pay' for each operator, given at the bottom of the spreadsheet, is \$8.00 per hour. All of this data is to be used to answer the questions on the following page.

The answers to the questions are to be written on your copy of the spreadsheet.

Do the questions in order, as many answers rely on the answer from the previous question(s).

To check your answer, or for help if you are not sure how to arrive at an answer, place the mouse cursor on the appropriate cell of the computer spreadsheet. Click the left button of the mouse. You will now see a small menu that says 'help' and 'answer'. If you again use the left mouse button to click on help, a rectangular shaped box, that provides information on how to go about answering the question, will pop up on the screen.

Try it. Place the mouse cursor on the blank cell in the column labeled 'Basic Skirt' and the row that refers to question 1 - '1. time/unit'. Click on the cell with the left mouse button.

Now click on 'help'. Experiment with the 'More Help' and 'Exit Help' buttons that you now see on the screen. When you are finished with 'help' be sure to use 'Exit Help' to keep the screen clear.

Click on the same cell again, next to question 1, but this time select 'answer' by clicking on the left mouse button.

Work through the questions for the 'Basic Skirt' using the 'help' option as needed. Try to answer each question on your own before you check the answer. Check your answers as you go.

C) Questions - the computer reference is in brackets following each question:

- 1. What is the total time required to complete the construction of one unit (garment)? See (1. time/unit) in the left hand column of the spreadsheet.
- How much does it cost to construct one unit?
 (2. cost/unit)
- How many units per hour can each worker complete?
 (3. #units/hr/W)
- 4. How many units can this production setup complete in one hour? (4. #units/hr.)
- How many units can this production setup complete in an 8 hour day? (5. #units/day)
- 6. How much does it cost to serge the edges of each unit?(6. cost/serge)
- If a factory needs to produce 200 units per day to meet its sales quota, how many workcentres will be needed? (7. #workcent)

STYLES						
STEPS	Basic Skirt	w/Pockets	w/Pock/Vent			
Serge Edges						
Darts						
Pockets						
Vent						
Zip/Seams						
Waistband						
Finishing						
1. time/unit						
2. cost/unit						
3. #units/ hr/W						
4. #units/hr.						
5. #units/day						
6. cost/serge						
7. #workcent						

Figure 7: Production Times & Costs

Now select each of the other two styles and work through each of the questions for them as you did for the Basic Skirt.

Appendix F

Scanned Photographs of the Spreadsheet Computer Simulation Screen (Note: screen printouts were not available)

Scanned photographs of the spreadsheet computer simulation screen can be found on the next two pages. The following is a brief description of each.

Figure 8 is the opening screen of the spreadsheet computer simulation. See Appendix E for a description of the objects on the screen and for a more detailed explanation of how the simulation is used.

Briefly, students use the simulation by selecting "Style" options from the spreadsheet. When the "Basic Skirt" has been selected (See Figure 9), production times for each of the steps in the construction of the garment are displayed on the spreadsheet. The "help" option to answer question 1 is also displayed in Figure 9.
Start the	Clear	Stape	wPerfors .	wPock/Vert
Simulation	Spreedsheet	Serge Eigen		
		Caris		
		Pockets		
		Vert		
		Zip/Seams		
		Waistband		
		Finishing		
		i imerunit		
		2 cost/unt		
		3. #units/ht/W		
		4 Junestr.		
		5 Auntstoay		
		d. cost/serge	an a	
	н	7. Sworkcart		

Figure 8: Opening screen for the Spreadsheet Computer Simulation

. 1

the Cont	Steps	Basic Stat		W/Pock/
spreadshoet,	Sarge Edges	290		
	Derts	3.94		
To Ind the total production	Pockats			
time per unit for a "Basic Skitt":	Vert	++ 		£
add the times given for each		397		
step" under the beading Resic Skirt"	Waistoand	376		
	Finisterg	5.05		
	1. timeturit			
Nore Ext	2 cost/int			
Help	3 #unts/n/W			
	4. #unitshr.			
	5 Junts/day			
	6 cost/serge		- 17 2 * 7	
	7. #workcart			

Figure 9: Screen display using "help" to answer question 1

Appendix G

Pretest

(one mark per question, except #10 - 3 marks - Total 15 marks) No name please - just the last 4 digits of your telephone no.

1. Divide:

a. .12 by .036 b. 60 by 19.31

2. Convert these fractions to a decimal:

a. 1/8 b. 3.08/19.31

3. Multiply:

a. 0.02 X 2300 b. 14.3 X 8

4. Circle the largest number:

2/3 4/5 3/4 5/8

5. If 4 metres of fabric cost \$96.00, how much will 10 metres cost?

- 6. A stack of 40 sheets of construction paper is 2.5 cm thick. What is the thickness of one sheet of paper?
- 7. Each of the models in the fashion show ate 2/3 of a pizza after the show. If they ate 12 pizzas in total, how many models were in the show?

8. A machine sews on 225 buttons in 3 hours. There are 1000 buttons to sew on. How many will be left unsewn after an 8-hour shift?

9. If it takes 20.68 minutes to sew one garment, how many garments can be produced in 4 hours?

10. Draw and label a simple illustration to show how a factory floor layout of sewing machines, to be used to mass produce a basic skirt, would look. (3 marks)

Appendix H

Item Analysis: Pretest

Item Analysis Worksheet

Test	# of Correct # of Correct		Difference
Item	Responses in	Responses in	Between High
#	High-Scoring	Low-Scoring	& Low Scoring
	Group: 27% N=14	Group: 27% N=14	Groups
1a	14	4	10
1b	14	10	4
2a	14	6	8
2b	13	4	9
3a	13	14	-1
3b	14	12	2
4	13	2	11
5	14	12	2
6	14	9	5
7	11	2	9
8	13	7	6
9	10	4	6
10	8	1	7

Total: 13 items

Results: a negative difference between the two groups of scores occurred in one instance

a positive difference between the two groups of scores occurred for the remaining 12 items

- there was a difference of 1 to 4 between the two groups for 3 of the items

- there was a difference of 5 or more between the groups for the remaining 9 (69%) items

Appendix I

Posttest

Costing Exercise

The last 4 digits of your phone no.

Put your name on the back of the last page.

Total marks - 15 - counts 10%

Underline or circle your final answer for each question.

- 1. Why does the designer have to cost a garment before a sample is made? (1 mark)
- 2. a) If it takes an average time of 38.47 minutes to produce a dress and the rate of pay is \$7.50 per hour, what is the average cost to produce a dress? (1 mark)

b) How is the average time to produce one garment arrived at? (1 mark)

3. T-shirt style #402 takes an average time of 8.75 minutes to produce. The company's production goal is 1000 T-shirts of that style per 8 hour day. How many machine operators are needed to meet the projected volume? (2 marks)

4. Use the following information to answer 4. a) to e).

A pair of shorts takes an average of 25.13 minutes to produce and the rate of pay is \$9.00 per hour:

- a) What is the average cost to produce one pair of shorts? (1 mark)
- b) If it takes an average of 5.6 minutes to sew the pockets for one unit, what is the average cost of the production of the pockets for each pair of shorts? (1 mark)

c) If it takes 2.86 minutes to serge the edges of all of the pieces for one pair of shorts, what is the average serging cost per unit? (1 mark)

d) If there are 6 operators producing the shorts, how many units can the group complete in an 8 hour day? (1 mark)

e) If the rate of pay is \$8.00 per hour, what is the average cost to produce one pair of shorts? (1 mark)

5. a) If the average number of garments produced per hour per operator is 2.57 and a factory needs to produce an average of 210 units in an 8 hour day to meet its sales quota, how many operators will be needed? (2 marks)

b) Illustrate the production flow for a skirt with pockets using the number of operators you determined (use your answer from 5.a) will be needed to produce 210 units per day. (3 marks)

Appendix J

Item Analysis: Posttest

Item Analysis Worksheet

Test	# of Correct	# of Correct	Difference
Item	Responses in	Responses in	Between High
#	High-Scoring	Low-Scoring	& Low Scoring
	Group: 27% N=14	Group: 27% N=14	Groups
1	14	13	1
2a	14	6	8
2b	12	9	3
3	13	4	9
4a	14	9	5
4b	14	3	11
4c	13	5	8
4d	13	5	8
4e	14	7	7
5a	14	7	7
5b	9	3	6

Total: 11 items

- Results: a positive difference between the two groups of scores occurred in every instance
 - there was a difference of 1 to 4 between the two groups for 2 of the items
 - there was a difference of 5 or more between the groups for the remaining 9 (82%) items

Appendix K

Summary of Data Experimental Group - Visual Simulation

Subject	Pretest	Lea	rnin	g Sty	Thinking Style		
	Max.	Max. Score	C	ateg	ories		Max. Score
	Score 15	15	a	b	c	d	9
1	4.0	5.0	0	2	-1	-2	5.7
2	10.0	10.0	1	-2	-1	1	5.5
3	11.5	15.0	0	-2	1	1	4.6
4	13.5	11.0	1	0	2	1	6.0
5	7.0	5.0	0	1	2	0	6.7
6	7.0	7.0	1	-4	1	1	6.2
7	7.5	13.0	0	2	-4	-4	4.3
8	6.0	7.0	0	-1	0	2	
9	8.0	15.0	1	-4	-1	2	5.0
10	7.0	11.5	1	-4	0	2	
11	8.0	8.0	0	0	-2	3	5.0
12	10.0	10.0	0	1	-1	1	5.9
13	11.0	11.0	1	4	-4	-4	5.8
14	9.0	12.0	1	4	-4	-4	6.1
15	9.0	10.0	1	-4	4	-3	4.9
16	14.0	9.0	1	2	-1	-1	6.4
17	11.0	10.0	0	4	-4	-4	5.1
18	6.0	11.5	1	0	-2	0	5.5
19	5.0	13.0	1	0	-3	1	5.5
20	6.0	8.5	0	4	-2	-1	5.0
21	12.0	13.0	1	3	-4	-1	5.8
22	11.0	11.0	1	-2	0	0	7.8
23	12.0	10.0	1	4	-4	-4	7.8
24	11.0	14.0	Ō	-1	-3	3	6.1
25	15.0	8.0	Õ	-4	Õ	3	5.4
26	40	5.0	Ő	-2	ž	1	5.8
20	10.0	5.0 7 0	Ő.	3	õ	0	5.6
2,	A	verages	Ū	5	Inte	erpre	tations & Averages

9.09	10.02	a: visualization	.52	5.74
		b: written word	.15	on a scale from
60.6%	66.8%	c: listening	-1.1	1-9, over 5
		d: activity	-0.2	indicates right
		•		brain thinker

 \pm .5 is significant

Appendix L

Subject	Pretest	Posttest	Lea	rning S	tyle	Thinking Style
	Max.	Max. Score	C	alegone	:S 	Max. Scole
	Score 15	15	a	D C	a	9
1	13.0	13.0	0	3 -1	0	4.9
2	12.0	13.0	1	-3 0	1	4.1
3	14.0	13.5	1	2 -4	0	6.2
4	13.0	8.0	1	0 0	0	5.3
5	10.0	9.0	0	4 -1	-1	
6	12.0	13.0	1	-1 () ()	5.5
7	11.5	14.0	-1	3 1	0	5.2
8	11.0	7.0	1	-4 () 1	6.5
9	11.0	12.0				5.0
10	8.0	11.0	3	-2 -4	4 0	6.0
11	13.0	12.0	1	0 -1	0	5.9
12	13.0	13.5	1	-4 -]	3	6.2
13	14.0	11.5	1	-2 -3	3 3	5.3
14	7.0	6.0	1	0 -4	2	4.5
15	12.0	13.0	0	4 -1	-1	6.1
16	10.0	12.0	1	0 (0 (5.4
17	12.0	12.0	-1	0 -1	3	5.9
18	12.0	7.5	1	3 -	2 -1	4.4
19	11.0	14.0	1	-2	01	4.7
20	13.0	11.5	1	-4 -4	43	6.5
21	12.0	6.0	-1	0 0	2	5.7
22	11.0	9.0	1	0 -	1 1	6.2
23	12.0	5.0	1	1 -4	4 1	
24	8.0	12.0	0	0 () 2	5.2
25	8.0	10.0	0	-3	40	4.6
	А	verages		Inte	erpretat	ions & Averages
	11.34	10.74	a: visual	ization	.52	5.74

Summary of Data Control Group - Spreadsheet Simulation

11.3410.74a: visualization.525.74b: written word.15on a scale from75.0%69.6%c: listening-1.11-9, over 5d: activity-0.2indicates rightbrain thinker

 \pm .5 is significant