Uses of information technology in creativity, innovation and problem solving.

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Abstract

This project was meant to examine current uses of information management technology in areas of creativity, innovation and problem solving. The study was conducted by reviewing existing scholarly literature, and by evaluating select softwares relative to creativity and creative problem solving. The reported findings were meant to serve as a basis for further inquiry and development into applications of electronic information processing technology in the creativity domain.

State University of New York
College at Buffalo
Center for Studies in Creativity

Uses of information technology in creativity, innovation and problem solving.

A Project in
Creative Studies

by

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Dr. Scott G. Isaksen, Director
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Dedication/Acknowledgements

This work is dedicated to two great women.

First, Dr. Ruth Noller, the project advisor's mentor, a pioneer in both Creativity and Computer Science, whose gentle wisdom helped to draw this author toward the field of creativity like a moth to the flame.

Second, the author's grandmother, Mrs. Evelyn Sharpe, whose limitless and unconditional love, confidence and support brings into form and substance the truth of what creativity is all about.

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Finally, loving thanks is due to the author's wife, Linda, for taking that Creative Studies class where we first met; and for collaborating with the author and with God to create our children Gillen and Caitlin (one of whom spilled a glass of milk on Dad's Master's Project).

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Section 1:

_Selecting_and_Defining_a_Topic_

Introduction

The arrival of the computer, particularly the personal computer (PC), promises to have historical impact rivaling that of the printing press, telegraph, telephone, radio and TV. The abundance of testimonial to this makes any effort to substantiate it seem trite. Academics, economists, futurists and prognosticators from every discipline hail the current avalanche of PC's as the presage of an "information age" which will transform forever the way humans regard their world, each other, and their approach toward living (Pagels, 1988).

A study of creativity and problem-solving processes, when linked with a basic understanding of information systems, reveals interesting parallels between the two domains.

Since the machine performs many of the more routine information processing functions, such as tabulation and sorting, the user is given greater freedom and latitude to play, explore and create. As the user becomes more adept with the machine, confidence grows in the accessibility of data stored therein. The focus of the exercise changes from content to process.

This is precisely what happens in the development of problem-solving skills. A guideline for the creative problem solving facilitator is to focus on process and not to try to influence content.

One method of problem solving in particular, Creative Analysis, is concerned with definitions and classifications of objects, with operations and rules governing relationships between and among objects and classes of objects, and with the organization and systemization of "things" and what they do. There are clear similarities between this kind of approach to problem solving and artificial intelligence functioning (Michie, 1979).

These parallels, and other observable associations, prompted the writer to conduct a pilot study during the Fall of 1989 to determine if, and to what degree, information processing technology was being researched and developed for use in areas of creativity, problem solving and innovation.

Rationale

The pilot study described above showed that work of some significance has been accomplished using information technology in a number of domains having close association to the the field of creativity. These include education, cognitive science, psychology, business administration and management. It was also apparent that there is an increasing need for creativity in developing and working with computer applications. (Couger, 1990)

Computer applications exist which help to individualize learning, thereby avoiding some of the more rigid aspects of a mass education system which can inhibit creative development. Similarly, programs are available which aid in problem solving and promote creative approaches to problem resolution. Studies are being conducted on the effects of computerized group idea generation systems on the creative process. Cognitive engineers are developing electronic, working models of learning processes and cognitive functioning. Expert systems exist which bring huge reservoirs of knowledge and experience to bear in solving problems.

The advent of information processing technology has created something of a paradox with regard to learning and problem solving. Due, in large measure, to the rapidly increasing capabilities information systems provide for accessing and processing data, the "half-life" of new knowledge is shrinking rapidly. Estimates indicate that half of the data absorbed by a student ten years ago was outdated or obsolete five years ago. (Toffler, 1980). There is a steady influx of new information accompanied by a divestiture of old, disproven or irrelevant data. This results in a routine process, of increasing frequency, of redefining reality.

The ability to manage and process information, i.e., skill in problem solving, is becoming increasingly more valuable and practical than the simple ability to retain information, much of which will soon be obsolete (DeGreene, 1991; Sellwood, 1989; Ackoff & Vergara, 1981; Kurland, 1968).

While the computer can be seen as a major contributor toward the creation of conditions which place increasingly higher premiums on awareness of process, as opposed to content; it is also becoming a valuable tool in the problem solving process itself (Elam & Mead 1990; Tisone & Wismar, 1985). Problem solving is directly concerned with the gathering and manipulation of information. Computers, as information management machines, can list, sort, add, subtract, combine, rearrange, modify, minify, reverse, tally and cross-tabulate more pieces of information faster and in far more and different ways than the conscious human mind.

The field of information management systems is also changing rapidly. New technology is typically obsolete in a year or two. This is yet another reason for developing skill in problem solving (Parayil, 1991). It also indicates a need for caution against making assumptions about what one can or cannot do with the technology, since a task that is tedious or cumbersome for a computer today might be easily accomplished tomorrow.

It is important, when investigating uses of information technology in creativity, to understand what it is that can be regarded as relatively stable and dependable, and what is subject to frequent and sometimes drastic change. Basic knowledge of the breadth and depth of existing literature and research related to the uses of computers and information technology in areas of creativity, problem solving and innovation is necessary in order for scholarly inquiry to yield information of lasting value. It was the purpose and intent of this study to make a significant contribution to this knowledge base.

Contribution to and Coordination with Existing Effort

The Center for Studies in Creativity (CSC) was already engaged in the development of a Creativity Based Information Resource (CBIR), a computerized system in which literature relating to various aspects of creativity, problem solving and innovation is collected, annotated and made available to scholars, researchers and interested professionals. The identification of a need for a central source of information on computers in creativity presented an opportunity to make a valuable contribution to an existing project, which would, in turn, provide a fitting vehicle for redistribution of project findings.

Consistent with the mission of the Center for Studies in Creativity, and its current research and scholarship initiatives and priorities for expanding and enhancing knowledge of creativity, it was determined to identify areas in which research has been, and is being, conducted with relation to the use of information technology in creativity, innovation and problem solving, and to assess the amount of effort expended in each area. Studies most frequently cited in existing literature had to be cross referenced, thereby identifying those which were regarded as significant by scholars in the field.

In order to provide the solid foundation upon which further study may be conducted, a very broad, divergent search of literature and resource materials was first conducted. This was followed by an analysis of findings, and subsequent identification of criteria for selection of a much smaller but strongly representative body of material relative to uses of information technology in creativity, innovation and problem solving, which was supported or at least acknowledged by current research. To ensure adequate representation of literature on various identified areas, and to provide a solid foundation for further study, a goal of 100 such citations was set. Ninety-seven relevant literature citations were finally annotated, indexed and entered into the CBIR database.

In addition, an effort was made to identify and, where possible, acquire copies of computer applications which could be used in areas of creativity, innovation and problem solving. Eleven such products were acquired. These were also reviewed and annotated for inclusion in the CBIR listing, bringing the total to 108 new annotations.

Outcome

The most immediate and obvious result of this undertaking was the creation of a single information resource on the use of computers in creativity. This literature has been analyzed, indexed and annotated; and findings have been reported in a variety of contexts and formats in addition to CBIR. Such interested persons as human resource professionals, trainers and personnel managers may contact the Center for a quick reference on computer software available for their particular needs. Scholars, researchers and software developers may query this resource for existing studies related to their area of interest.

The foundation was also laid for more focused inquiry into uses of computer technology in creativity, innovation and problem solving.

Computers have been instrumental in bringing to the fore widespread recognition of the value of problem solving skills and awareness of the process of solving problems. It is important for problem solving practitioners to understand why and how this has come about. Information processing machines impact the creative process in environmental, operational and logistical ways. An awareness of the different ways computer systems may affect creativity and creative skill development is prerequisite to further exploration of the properties brought to creativity by information management technology.

Section 2:

_Collecting_and_Organizing_Information_

Introduction

A review of literature dealing with uses of information management technology in areas of creativity, problem solving, creative behavior and creativity skill development was conducted by this writer during the Fall of 1989. This information was seen as valuable in planning more focused inquiry into uses of information technology in the creativity domain. Data will be presented here according to categories reflected in findings.

Data Selection and Classification

Creativity is a transdisciplinary and multifaceted phenomenon. Creativity, problem solving and innovation have bearing and applicability in every field of endeavor. For purposes of this study then, it was necessary to broaden the criteria for selection of literature to include categories contained within the controlled vocabulary used for selecting literature in the CBIR system (See appendix G). This would more explicitly reflect the different areas in which research is currently being conducted and give some indication of the extent to which development is occurring in each.

Ultimately, the literature was categorized according to the CBIR search terms assigned.

The literature review indicated that significant research has been conducted in such areas as:

A) the impact of computer systems on business, industry and organizational climate and functioning;

B) the effects of and potential for computers in education; and

C) artificial intelligence concepts and constructs and relationships with human cognition;

Findings will be assembled according to these classifications.

There was very little material which specifically addressed information systems and creative processes. In a study undertaken by John Couger (1990), at the University of Colorado, on creative approaches taken in information systems design, it was noted that, while over 4000 articles have been published on the subject of creativity (Rickards, 1987) only five of these relate to information systems. These focused on the business and organizational domain.

A) BUSINESS, INDUSTRY AND ORGANIZATIONS

Information systems perform a great many functions in the business world. Applications range from financial and accounting systems to engineering, graphic arts and communications. Current literature points toward a need for creative approaches to be used in developing computer systems. These systems must, in turn, support and enhance, rather than inhibit, creativity among a diversity of users and in a variety of organizational contexts.

Creativity in Design

Couger's review identified five articles having direct relevance to creativity and information systems. Of the five, Telem (1988) shared Cougers' concern with the poverty of creativity in information system design. He (Telem) advocated a group idea generation and decision making procedure called Brainstorming and Collective Decision-making Technique (BCDT), and Theory Z, a collective decision-making approach popular among Japanese managers, as effective and efficient means for identifying information requirements in the development of information systems.

In a treatise using a human factors and ergonomics approach in advocating a fundamental paradigm shift in information systems development and utilization, DeGreene (1991) gave examples of recent large, technology-based system failures to illustrate shortcomings of the traditional western orientation toward rationality, analysis and reduction. Emergent technologies are presented as potentially restrictive and inflexible unless a more realistic, evolutionary-oriented approach to design and implementation is adopted.

One of the reasons more creative approaches to development have not been utilized to date is that the development of computer software is an expensive and time-consuming process. Managers and decision makers often view practices associated with creativity and creative problem solving to be irrelevant, time consuming and wasteful.

To aid in the resolution of this problem, creativity researchers will have to continue developing ways of minimizing wasted time and resources in these efforts. In a paper with just such a purpose in mind, Coyne (1989) suggests ways of preparing for, and remaining receptive to, ideas for software development and offers strategies and techniques for determining viability of these ideas.

It seems clear that a merger of information systems developers and creativity scientists will have to occur in order to meet the challenges and opportunities presented by information technology. Of concern will be the effects of information systems on the ability of those using such systems to function creatively in their work.

Effects on User Creativity

Three of the articles identified by Couger advocated system designs which accommodated and fostered creativity in it's utilization by individuals and groups.

Elam & Mead (1987) presented a review and discussion of factors influencing creativity, largely from a socio-psychological perspective. They offered five related guidelines for consideration in the design of decision support systems (DSS) which would be less rigid and restrictive and more accommodating of human creative processes. Eliot (1987) discussed analogical thinking and the fostering of creative thinking in organizations.

Nunamaker, Applegate and Konsynski (1987) reported on a study of the effects of an electronic group decision support system used for group idea generation. Results indicated that, while certain negative effects were noted, the electronic system enhanced productivity, quality and user satisfaction in idea generation. This paper was one of a number of articles included in this study which related to a noteworthy project involving electronically supported group idea generation. More will be said about that project in section four of this report.

Is was clear that a diverse and growing body of researchers and developers exists who share the viewpoint that creative approaches are needed to meet the demands of information systems developers in the years ahead.

Diversity of Applications

Neither creativity nor information systems are subjects which fall under a single discipline. Ackoff and Vergara (1981) cite a globally accelerating rate of change as indicative of a need to explore and adopt creativity techniques in solving research and development problems, particularly by decision scientists and information systems developers.

Toward this end, Sage (1981) offered an extensive analysis of existing theory and research on elements of information systems design. Behavioral considerations include cognitive styles, information processing, problem solving, judgment and decision making. These human factors were reviewed in an organizational context. Processes were flowcharted and discussed in relation to a comprehensive cross-section of literature from a variety of research domains.

For example, in the field of chemical engineering, Geschka, et al, offered an assortment of idea-generation techniques for use in a logical, structured format such as might be easily applicable to practical, results-oriented engineering applications (Geschka, Schaudde & Schlicksupp, 1973). In drawing parallels between changing technology and the process of problem solving, Parayil (1991) pointed toward changes in agricultural technology employed in grain production in third world countries. He stressed that this observation is of major importance in strategizing for technological change.

Implementation in Organizations

A number of studies have analyzed the effects of computer systems on the work environment with regard to creativity and innovation, productivity, communications and organizational climate. There are commonalties in both the design and findings of some of these which deserve serious attention.

For example, in a study of variables influencing implementation of technological and administrative innovations in hospital organizations, Kimberly and Evanisko (1981) examined the effects of individual, organizational and contextual factors on the adoption of technological and administrative innovations in a hospital setting. Individual variables considered were tenure, cosmopolitanism, educational level and substance, involvement in committees, and medical and administrative activities. Organizational variables were centralization, specialization, size, functional differentiation and external integration. Contextual variables were competition, size of city and age.

It was found that the variables considered were much better predictors of technological innovation than administrative; that different types of innovation were influenced by different types of variables; and that organizational variables, particularly the size of the organization, were the best predictors of both types of innovation.

In a similar vein, Ein-Dor and Segev (1978) attempted to establish a conceptual context within which elements of the organizational framework having impact on the implementation of management information systems (MIS) might be examined and discussed. Elements were:

1) organizational size; 2) organizational structure; 3) organizational time-frame; 4) extra-organizational situation; 5) organizational resources; 6) organizational maturity; 7) psychological climate; 8) responsible executive and 9) steering committee. These elements were categorized as uncontrollable, partially controllable and fully controllable.

In seeking to define characteristics of organizations which tend to employ computer technology, Yap (1990) considered size, sector, performance (of tasks), task, people, structural and environmental factors. He found that computers were used more often in organizations having high percentages of information workers and whose structure is more formalized.

Olson and Lucas (1982) reviewed a number of dimensions wherein various applications of information technology impact organizational functioning. These dimensions included: 1) nature of the work itself; 2) human factors; 3) communications; 4) management; 5) interpersonal relations; 6) interdepartmental relations; and 7) organizational structure and processes.
They concluded with suggestions for research and development.

All of these studies, and others which were identified, examine factors related to the use of information systems within the organizational climate which affect creativity and creative behavior.

Communications

Information systems have significant impact on organizational communications which, in turn, effect creative functioning within and among organizations.

In a report on the various benefits of computers in organizational communications, Bennett, Durand and Betty (1990) compared the effects of keyboard-generated business communications to traditional pen and paper methods in areas of: 1) abstraction, 2) appropriateness for business communication, 3) clarity, 4) coherence, 5) conclusions (explicit), 6) conciseness, 7) confidence in decision, 8) focus and relevance, 9) expertise and analytical skill of writer, 10) interesting writing style, and 11) objectivity. Findings indicated that communication persuasiveness and effectiveness was enhanced by use of information technology.

Using two trinity models, Borovits, Ellis and Yeshekel (1990) examined organizational interactions from a social-psychological perspective with regard to group work and communication patterns, task performance, conflict resolution, and interpersonal attractions.

Collaborative group work and multi-directional communication were seen as more conducive to productivity than individual work and circular communications in developing information systems.

Interorganizational communications and use of information technology was explored by Kydd and Jones (1989), who describe organizational information processing and how shared information technology (SIT) may be accepted or rejected; helped or hindered by organizational culture. They make suggestions regarding when, how and between/among what types of organizations SIT may be beneficial.

The concept of shared information technology appears to run contrary to the competitive nature of business. However, due to the rapidity of changes in technology, the competitive edge they can provide, the large expense involved with acquiring and maintaining state-of-the-art information systems and the fact that these continuing improvements show no signs of slowing down, technology sharing may become a fiscal necessity for organizations. This, in turn, is likely to contribute to changes which are occurring in both inter- and intra- organizational functioning.

Changes in Organizational Functioning

An interesting perspective shared by some computer scientists is that the existing concept of management information systems (MIS) no longer includes all factors pertinent to effective and efficient design and utilization. A suggested alternative is called an organization information system (OIS). Van Gigch and Le Moigne (1990) contended that a) new research and understanding into the structure and functioning of organizations combined with b) the utilization of electronic information technology in organizations in ways other than exclusively managerial and strategic render the concept of management information systems (MIS) inaccurate. An organization information system (OIS) view was proposed which was said to more accurately reflect current systems utilization and purpose.

The foregoing examines information system utilization from the perspective of the administrator and decision maker. The educator has also benefitted greatly, and promises to continue to benefit, from the influx of information technology.

B. EDUCATION

Computer systems do not only present new challenges and opportunities in the workplace. They create new demands, and offer new avenues for meeting those demands, in the classroom.

As early as 1968, Kurland (1968) suggested that education should be preparing students for a world of change. He posited that technology had vastly broadened the scope of education, and that learning would be increasingly merged with, rather than removed from, world events as they occur. He described how technology can truly "individualize education in a mass education system." With the information explosion increasing in momentum, such admonitions appear to be gaining recognition and acceptance.

Impact on Curriculum

Sellwood (1989) suggests that problem solving skills and technological literacy are primary factors in the development of a workforce capable of competing in a global marketplace. He presents problem solving as a continuing process rather than an activity to be intermittently engaged in, and challenges educators to find ways to engender problem solving skills in students at a younger age and to encourage the development of thinking skills rather than rote learning, placing more responsibility for learning on the student.

Computers have invaded the schools both as learning aids and, increasingly, as part of required curriculum. Educators recognize the present value and nearly unlimited potential for computers to provide individually-paced instructional programming which can bring vast reserves of information into the learning experience.

In a review of resources and capabilities offered by personal computers for accessing information via telecommunications technology, McCade (1988) suggested that educators could make almost boundless information resources available to students by including telecommunications instruction in their curriculum; and would increase computer literacy in doing so.

Taking a futuristic look at potentials and possibilities for computer applications in education, Green (1984) speculated on changes likely to come about in the classroom environment and how those could affect learning. He portrayed a scenario in which teachers spent more time educating and less time acting as disciplinarians.

Adams and Hamm (1989) described the computer as the possible bridge between a perceived need for renewed emphasis on "the basics" in education, and the need to nurture children's imagination. They suggested a variety of ways such a bridge might be developed across a broad spectrum of educational domains.

Effects on Educators

Another scenario demonstrated how, due to constantly changing technology, educators are given a frequent opportunity to re-orient themselves with the learning experience. As a result, they may be better equipped to teach. Rossman (1984) argued that teachers have an opportunity to experience the learning process by having to familiarize themselves with the continually changing and updating computer technology being implemented in the classroom. This was presented as a chance to get in touch with processes continually undergone by students.

Effects on Creativity and Problem Solving Skills

Where creativity and problem-solving skill development is concerned, computers may be bringing unexpected benefits into the equation. Some studies show that problem-solving abilities may be enhanced through training in computer programming. Of particular interest to creativity researchers are effects of using the LOGO artificial intelligence language on problem-solving skills

In an abstract from a presentation at the LOGO '84 conference, Leron (1984) described learning as occurring first at the syntactical level, progressing to the semantic level, then to the expert level, at which point many stall. He advocated what he called "Quasi-Piagetian Learning," wherein psychological difficulties inhibiting learning need to be understood and addressed in bridging the gap between subject-matter-centered and child-centered learning .

Lehrer, Guckenberg and Lee (1988) reported on a study in which 45 third grade children were randomly assigned to groups given instruction using a general-knowledge based LOGO program; a LOGO program emphasizing knowledge of geometry; or to a control group. The results showed that LOGO-based instruction had a positive influence on efficiency in planning and dynamic quality of geometric conception. LOGO-based instruction in geometry also increased metacognitive skills.

Others studies, however, declare such findings inconclusive. In studying the effects of learning either BASIC or LOGO computer programming languages on problem solving skills; and the comparative value of training in either language on problem solving ability; Shaw (1986) reported that there was no indication such training had a significant positive effect on problem solving skills; nor that either had significant value over the other.

Another 1986 study examined the impact of training in computer programming on mathematical and reasoning skills, cognitive skills most predictive of computer programming ability and level of knowledge on programming following two years of high school study (Kurland, Pea, Clement and Mawby, 1986). The results did not indicate significant understanding of programming, and parallel learning did not appear to occur. The authors suggested that more research in computer programming education might provide indicators of where transfer learning might occur.

In a discussion of the effects of the advent of microelectronic technology in the classroom and on learning, Mandinach and Linn (1986) contend that experimentation and research have just begun. While the possibility that enhanced problem-solving ability seems to result from instruction in computer programming is indicated, they suggested that computerized learning environments have far to go to reach maximum potential. The reason for these disappointing results, as much as anything, is that the potential is so great.

One such avenue of research promising great benefit to educators, among a great many others, is that of the artificial intelligence researcher and cognitive scientist.

C. ARTIFICIAL INTELLIGENCE AND COGNITION

One of the intriguing characteristics of information systems is that they emulate human thinking processes which we associate with intelligence. Such human-like technologies as natural language processing, speech recognition, computer vision, robotics, automatic programming, expert systems and decision support systems have emerged.

Dreyfus and Dreyfus (1988) described the development of artificial intelligence theory from historical and theoretical perspectives. They examined various arguments between and among scholars and researchers regarding practicalities and possibilities with mechanized symbol manipulation, modeling mental functioning, problem solving, learning, logic and statistical relevance

The Artificial Intelligence Debate

Since the days of the earliest computer systems, much debate has occurred around the question of whether or not machines can actually think. One of the pioneers of computer science, Alan Turing (1964), considered the question "Can machines think?," by first defining the terms "machine" and "think"; then by discussing a variety of dissenting viewpoints from diverse disciplinary perspectives. From a philosophical perspective, he described a concept for a learning machine.

In countering Turings' and others' contentions, Niesser (1976) discussed intelligence in the cultural context. He suggested that the ability to solve problems contained in intelligence tests might be termed "academic intelligence" and that artificial intelligence is generally thought of in terms conforming to norms dictated by academic intelligence. He argued that cognitive development and self-modification are examples of true intelligence which cannot occur in machines.

Searle (1980) constructed an argument in which the distinguishing factor between human mental processes and computer programs is intentionality. He stated that programs designed to produce intentionality must have causal powers equal to that of the brain. The article was accompanied by commentary from 27 colleagues in the fields of philosophy, psychology, physiology and the behavioral, cognitive and computer sciences; and concluded with a response to each from the author. In a subsequent article, Searle (1990) further argued that, whereas computer programs are formal, or syntactic, human minds have mental contents, or semantics, and that syntax by itself is neither constitutive of nor sufficient for semantics. He contends that computer programs are neither constitutive of nor sufficient for semantics, and that formal, mechanized processes are incapable of the causative powers of the human brain.

In examining arguments for and against the idea that machines might think, Churchland and Churchland (1990) contrast expectations of Turings' test for conscious intelligence with Searles' argument that conscious intelligence must possess real semantic content. They agree with Searle that "syntax by itself is neither constitutive nor sufficient for semantics", i.e., conscious intelligence. "Classical" artificial intelligence is compared to neural networks, which mimic nervous system functioning.

Computers and Creativity

In this debate, a pivotal question is whether or not computers can be creative. In a thought-provoking discussion of various current philosophical contentions regarding the potential for computer technology to be creative, Carl Hausman (1985) described expectations for outcome of the creative act. While skeptical in tone, he remained receptive to further discussion and consideration of future perspectives.

Wolfe (1983) examined the degree to which computers can be programed to create original, aesthetic musical compositions. He presented examples of computer generated melodies which illustrate that computers cannot produce music which calls for aesthetic discrimination and intuitive decision making.

Decision Making

Whether or not computers can create, it is clear that they can aid in the study of decision making processes. Green and Hughes (1986) examined the effects of training in the use of decision support systems (DSS) and cognitive style on four decision process attributes. These were 1) time taken to reach a decision; 2) number of alternatives generated; 3) amount of data considered in making a decision; and 4) number of features of DSS used. Results suggested that specific DSS training approaches would be beneficial for managers with differing cognitive styles .

Jacob, Moore and Whinston (1989) explored the rationale for an integrated human-computer information processor and considered information processing capabilities within a formal model of decision-making.

Much effort has been, and continues to be expended at the international level on studying the use of information technology in the replication, modeling and study of subjective probability, utility and decision making (Brehmer, Jungermann, Lourens & Sevon, 1986).

The concept of decision-making, or "thinking" machines may initially seem to be outlandish or far-fetched. However, in a procedural description of the performance of such tasks as extrapolation of sequential patterns, algebra word problems, the "tower of Hanoi" puzzle, perception in chess, understanding instructions to perform a new task and spelling in English, Herbert Simon (1876) clarifies the process of mechanizing the accomplishment of such tasks. He identified basic capabilities required to include a means of identifying and categorizing stimuli, short-term and long-term memory, all of which are standard components of a computer system.

Simons' is one of several praiseworthy efforts to identify elements of human cognition and define interactions between and among those elements in a programmable way.

Cognitive Engineering

An exciting new sub-discipline called cognitive engineering is beginning to emerge from such efforts. "Thinking machines" are being used to model human cognition. Young (1979) described computer-based systems which are employed to model human cognitive processes as consisting 1) a of long term, large volume data storage component; 2) a short-term data storage, or memory component; 3) a recognize-act capability and a 4) conflict resolution or problem solving component. He described a number of psychological models under study through such production systems.

Woods and Roth (1988) described cognitive engineering as the process of assembling effective supports for problem solvers. This process is said to manage the increasing complexity of the world through perspectives which are ecological and semantic, and are both performance and systems oriented.

Problem Solving

Information systems are being developed which replicate problem-solving processes. A noteworthy example of this was found in a computer program developed by Allen Newell of Carnegie Mellon Institute, in collaboration with John E. Laird of the University of Michigan and Paul S. Rosenbloom of the University of Southern California, called SOAR (State, Operator And

Result) (Waldrop, 1988). SOAR exemplifies Newell's unified theory of cognition, which holds that all cognition involves some form of problem-solving. When SOAR reaches an impasse in seeking to solve a problem, it sets up a subgoal to resolve the impasse. When the subgoal is met, it is stored as a new "chunk" of knowledge for future reference whenever a similar impasse should occur. The program has been used successfully in a variety of complex situations, and has received critical acclaim in both the academic and corporate worlds.

It is clear that the capabilities provided by information technology relating to information processing, intelligence, problem solving and cognition provide researchers with vast new worlds to explore and increasingly powerful tools and resources with which to conduct that exploration.

Summary

The literature was classified as applying to the general domains of business, industry and organizations; education; and artificial intelligence and cognitive science. Applications of computer technology in these areas of creativity hold the promise of exciting and revolutionary things to come.

Section 3:

_Project_Planning_

Introduction

The pilot study conducted in the Fall of 1989, and described previously in this report, laid the groundwork for developing a plan of action in meeting the goal of this project, i.e., to contribute significantly to the knowledge base on uses of information management technology in creativity.

At that time, a database was developed to aid in indexing and categorizing literature and software. The database also listed agencies and organizations, thought to have related interests, which were contacted in the course of collecting information. Data elements contained therein, where available or applicable, were:

Author

Title of publication

Journal or publication name

Edition

Place of publication

Date

Volume

Issue

Document type

Location in publication / page(s)

Abstract or annotation

Index terms / search terms

This database was of great value in determining the course and direction this inquiry would take.

Criteria were selected for the initial, divergent phase of information gathering in order to assure inclusion from all relevant areas. Materials regarded as pertinent had to relate to:

A) information technology, computers or computer applications; and

B) creativity, innovation or problem solving

The latter terms included applicability in such areas as education, cognition, administration and management, conflict resolution and decision making.

The pilot project identified a total of 95 literature references, not listed in CBIR, which clearly met the above criteria. It also identified 35 relevant, or peripherally relevant, software products (See appendix D); and 69 academic and professional organizations with related interests (See appendix C). This material served as a starting point for a more thorough investigation of information sources.

Software developers and other organizations having interest in creativity were contacted for purposes of collecting information on, and, where possible, acquiring copies of, computer software for inclusion in this report. It was also hoped that any efforts similar to this one which might be underway could be identified.

These agencies were classed as either developers marketing a product or public agencies or organizations offering a service or affiliation. In general, developers were identified through various marketing media such as product listings, software catalogs, promotional mailings and bulletin board services. Agencies and organizations were identified through such organizational references as the Encyclopedia_of_ Associations and the Instant_Information organizational reference.

A query letter (See appendix I) was sent to each of the 69 agencies and organizations as well as to 22 of the 35 software developers. This letter explained the focus and intent of the project and requested promotional materials on products and/or services, and, where available, demonstrator or sample copies of related software products.

Respondents were flagged as such in the database listing (Appendices C and D), and are described in section 4 of this report.

Literature

A process of divergence followed by convergence was employed in identifying literature for review and annotation. A database search focusing on computer applications, computer-aided creativity and artificial intelligence was conducted on the CBIR system. This produced 50 citations.

Literature searches were also conducted on the ERIC, PsychLit, Social Science and MedLine database listings. Duplications were noted and removed, producing a total of 509 citations. All of these were added to the database containing the 95 references identified in the pilot study.

Since titles listed in CBIR had already been screened for relevance, eighteen of the citations listed there were selected as having explicit applicability to investigating uses of information technology in areas of creativity, innovation and/or problem solving. Copies of these were obtained, and the bibliographies from these articles were entered into the master database.

Of the remaining 604 citations not already listed in CBIR, titles of articles and, where available, accompanying abstracts were reviewed in order to identify material which clearly evinced applicability to the purposes of this study. Twenty-four were selected. Copies were also obtained of these articles, and the bibliographies were entered. The result was a total of 1402 literature citations. Data contained in this master listing was instrumental to the generation of criteria for selecting articles to be included in this study.

The 18 articles listed in CBIR and the 24 selected from the master listing were each given an identification number. Once the list of references cited in each article was entered into the master database, this number facilitated an accounting of duplicate referencing. Any article cited in more than one publication was included in the final listing. There were four of these.

The process of identifying which of the remaining citations to include required some understanding of the breakdown of pertinent subject areas. Any identifiable sub-categories needed to be given appropriate representation in the final listing.

In order to accomplish this, the index / search terms accompanying each article were downloaded into a single data file. This was subsequently indexed using a word-processing utility which identified the frequency of occurrence of each term. This keyword index was reviewed for particular relevance to the creativity and innovation domain. From it, a list of key words and search terms were identified which were either a) equivalant to, or closely paralleled, existing CBIR search terms; or b) was deemed relevant to the purposes of this study, but for which no CBIR search terms currently existed.

Articles which fit the latter criterion, and which were ultimately included in this study, formed the basis for recommendations which were made for the addition of search terms to the CBIR controlled vocabulary. These terms are reported in section four of this report.

In this literature selection process, it was also deemed of value to try to determine if particular scholars and researchers could be regarded as eminent in the area of creativity and computers; or if the same could be said of any particular college, university or research institute. Names of authors and of universities, institutions and organizations with which authors were associated were separated and indexed using the word processing indexing utility described above. This helped to determine volume of work being published by each author, and where significant work was being accomplished. Dates of publication were also considered in order to determine if a particular article or study had "stood the test of time."

With the above data in hand, the master database was reviewed for literature which: a) was cited in works by other scholars or researchers; b) related specifically to the purposes of the study as identified by search term assignment; c) was written by an individual whose name appeared frequently in the author index; d) originated at a college, university or institution which appeared frequently in the agency index; or e) was dated prior to 1970. A total of 142 publications were identified through this screening process.

In the process of locating and obtaining copies of these articles for review, it was determined that 38 would require undue effort to obtain, considering that a) the focus of each of the 38 was represented in publications which were obtainable; b) none was regarded as a "must have" for the purposes of this study and; c) a total of 100 citations was the goal for this project.

Twelve which were obtained were determined, upon review, to meet selection criteria in only a peripheral way. Another six articles were identified through the course of acquiring and reviewing selected literature, as valuable additions to the knowledge base under assembly, bringing the final total to 97 pieces of literature. Copies of all 97 references were obtained, and each was reviewed and annotated for inclusion in CBIR.

Software

The acquisition, review and annotation of relevant computer software was also a goal in this study. It was confirmed by the CBIR System Administrator that CBIR would accommodate annotations of computer software. In order to standardize a procedure for this, it was necessary to devise a format for entry of annotations of computer software which would result from this study. This consisted of a single document itemizing the data elements for annotating computer programs, following the existing annotation format used for entering literature citations (See appendix J).

At the time the pilot study for this project was conducted, the sources of information on computer software related to creativity were the DataPro and Software_Reviews_on_File computer software indices, various software catalogs, promotional materials received at the Center for Studies in Creativity, and word-of-mouth through associations with like-minded individuals.

As noted previously, lack of funding was a limitation. Only those products which were obtained free of charge could be given critical review. Fortunately, a good number of those few software developers whose products most specifically fit the purpose and intent of this study provided samples of their product.

Software was therefore classified into products which were reviewed, annotated and included in CBIR; and products which were identified through alternative means but not reviewed.

Those products reviewed were further categorized as having direct relevance to creative problem solving and having peripheral relevance to creativity. Products reviewed having direct relevance to creativity were evaluated from a more critical percpective toward applicability in some aspect of problem solving.

It was necessary to devise a format for performing these evaluations. Toward this end, a set of review criteria entitled "Checklist_for_Evaluating_Published Thinking_Skills_Instructional_Programs" developed by Treffinger, et.al (1993) were modified for use in reviewing computer programs.

To this modified criteria set was added information necessary for contacting the developers or distributors of the software, a checkoff grid for evaluating technical aspects of the program, and an ALU (Advantages, Limitations and Unique Connections) form (See Appendix H).

In sum, there were three different types of software reviews carried out in the course of this project. These were:

1) The Creativity Software Listing, a listing of 18 pertinent computer products categorized as applying to a) Creative Problem Solving; b) Understanding the Problem; c) Idea Generation; or d) Planning for Action. The list includes name, address and phone number of the developer, cost of the product and brief description of the program (See appendix E). This listing includes all products identified, whether they were examined first-hand or not;

2) CBIR Annotations, an objective review and APA-style annotated reporting on 11 computer programs pertinent to creativity (See appendix B). This listing includes all products which were examined first-hand, and;

3) a Creativity Software Review, a critical review of computer programs having direct applicability to Creative Problem Solving (See appendix F). This listing

includes products which were determined to directly relate to creative problem solving and which were examined first-hand.

Upon completion of the review, analysis and reporting phases of this study, donated software products were also reviewed by staff at Butler Library, State University of New York, College at Buffalo. Of these, the Mindlink, and Idegen++ programs were already carried by the library. The Idegen++ program which was contributed to this study was granted on a time-limited basis, and was rendered non-functional after 1991. The donated copy of the Mindlink program will be maintained by the Information Services staff at the Center for Studies in Creativity.

Other products deemed appropriate for inclusion at the Butler Library were the Choices,_Choices and Chronos programs, both from Tom Snyder Productions. The remainder are archived at the Center for Studies in Creativity.

Summary

Literature and computer software was assembled from a variety of sources for this study. Criteria used for selection was derived by overlaying identifiers assigned to existing listings with the CBIR controlled vocabulary; and through analyzing a large body of existing literature from a variety of perspectives. Findings were reported from both objective and subjective standpoints.

Section 4:

_Presenting_and_Documenting_Project_Activity_

Introduction

This study focused on uses of information technology in creativity in the literature, and in terms of available computer software. This report will be divided into those categories.

A goal was set for 100 annotations to be contributed to CBIR as a result of this project. The final number of citations contributed was 108. This included 11 computer programs (See Figure 1).

Figure 1.

Significant areas of research being conducted relating to computers and creativity were in:

A) business, industry and organizations;

B) education; and

C) artificial intelligence and cognition;

These classifications appear to hold under the headings given for information sources, i.e., literature and software. Findings in the literature will be reported according to those sub-headings.

The Controlled_Vocabulary_for_CBIR (See appendix G) was valuable in further organizing and classifying project findings. These terms are used for identifying citations contained within the CBIR database as they relate to user-specified combinations of subject areas.

In the course of reviewing and annotating the literature, it became apparent that certain areas were receiving enough attention or had reached a stage of maturity sufficient to warrant the addition of terms to the controlled vocabulary.

The following search terms were added to the CBIR index as a result of this study:

under the Main Term - "Humanities"

the Sub term - "Language"

under the Main Term - "Computer Applications"

the Sub terms - "Decision support systems"

"Expert systems"

"Simulation"

under the Main Term - "Management"

the Sub term - "Human Resource Management"

The recommendation for addition of these search terms to the CBIR controlled vocabulary was made after it became clear that significant attention was being given these subject areas in the literature. CBIR search term utilization for this project is represented in Figure 2.

Administration.................14
 Administrators.............8
 Managers....................5
Arts...........................1
 Performing.................1
Assessment......................1
Behavior........................2
Blocks..........................2
 Barriers...................2
 Blocks to creativity........1
Business......................21
 Business administration.....2
 Corporate culture...........3
 Industry....................5
 Leadership..................1
 Managers....................5
 Performance.................1
Climate.........................1
 Environment................1
Cognitive......................17
 Ability.....................6
 Cognition..................10
 Functioning.................1
 Level.......................7
 Metacognition.............11
 Style.......................4
Communications................17
 Communication..............1
 Communication tools.........4

Fig. 2.

Each literature citation was assigned search terms from a variety of different areas and domains relative to the study of creativity. Thus, within the body of information presented here there is a great deal of ambiguity and overlap. The complete listing of literature and software annotations can be found in Appendices A and B.

I. LITERATURE

Of the 97 literature citations selected for this study, 84 related to computerizing some aspect of the study or application of creativity, problem solving and innovation. The remainder related in some way to the heuristics of, and structured, systemized approaches to, problem solving.

Sub-categories for the 84 citations on computerized applications can be seen in Figure 3.

Figure 3.

While it was the intent of this project to examine uses of information technology in creativity, it is apparent that a need for the reverse, i.e., creativity in information systems design, is gaining in urgency. Ackoff and Vergara (1981) call for decision scientists and information systems developers to adopt creativity techniques in solving research and development problems. Sage (1981) offered a particularly thorough and insightful analysis of theory and research on elements of information systems design. Such human factors as cognitive styles, information processing, problem solving, judgment and decision making were reviewed within an organizational context.

While the literature points toward a need for creative approaches in developing computer systems, it is equally clear that these systems must support and enhance, rather than inhibit, creativity among a diversity of users and in a variety of contexts.

Group Decision Support Systems (GDSS)

An Electronic Meeting Support (EMS) system was created for such a purpose in 1985 at the University of Arizona (Valacich, Dennis and Nunamaker, 1991). It is important to discuss this EMS, or "GroupSystems" concept early in this section, since it, and systems like it exemplify many of the key ways in which information management systems impact group, and individual, creativity.

These systems, also referred to as Group Decision Support Systems (GDSS) have been assembled in several locations nationwide, and are available commercially from information systems developers. They consist of a network of computer workstations arranged in semicircular fashion, contain a control console and at least one large video-screen display. Various peripheral options include white boards, overhead projectors, printers and copiers. Newer systems may include multi-media attachments and other enhancements for idea-generation stimulus. The workstations are set into enclosures which provide privacy for individual participants in a group process.

The systems were designed to aid in such group activities as:

- communication
- planning
- idea generation
- problem solving
- issue discussion
- negotiation
- conflict resolution
- systems analysis and design

Group members each sit at a workstation and interact with one another through the network and through the main public display. The group process is orchestrated by a facilitator trained in use of the software. Verbal communication as well as electronic communication can occur, and various processes and interactive techniques can be followed depending on situational requirements. The overall goal is to help "reduce or eliminate the dysfunctions of the group interaction (i.e. process losses), so that a group reaches or exceeds (i.e. process gains) task potential" in accordance with the concept of (group) process losses and gains (Steiner, 1966, 1972; Hill, 1982) on which the system was built.

Dysfunctions in the group process which contribute to "production blocking" and which are said to be effectively reduced or eliminated through use of the electronic meeting system are described as:

a) attenuation blocking, wherein group members who are prevented from verbalizing their ideas subsequently forget or suppress them because they seem less relevant or original at a later time;

b) concentration blocking, which occurs when members focus on trying to remember an idea rather than on generating new ideas;

c) attention blocking, or listening to other group members speak rather than generating new ideas;

d) unequal air time, the unequal division of verbal communication time among members of a group, (time availability shrinks in proportion to the size of the group);

e) evaluation apprehension, which results from the fear of negative evaluation of ideas shared with the group;

f) free-riding, is the tendency of some group members to refrain from contributing to the completion of the group task;

g) cognitive inertia, refers to the tendency to remain focused on a topic of discussion without deviation;

h) socializing, the excessive tendency to engage in non-task related behavior;

i) failure to remember or to listen to comments of others;

j) incomplete analysis, or the failure of group members to use available information or to challenge others' assumptions.

In addition to their usefulness in commercial applications, GDSS systems have been used to study the effects of an electronic meeting environment on idea generation (Connolly, Jessup & Valacich, 1990; Valacich, Dennis & Connolly, 1991), group creativity (Nunamaker, Applegate & Konsynski, 1987), and impact on large groups (Nunamaker, Vogel & Konsynski, 1989; Dennis, Heminger & Nunamaker, 1990), all with positive results. While certain negative effects were noted, the electronic system clearly enhanced productivity, quality and user satisfaction in idea generation.

Creativity in Systems Design

Information systems developers and creativity scientists will have to pool resources in order to meet the challenges and opportunities presented by information technology in the years ahead.

As noted previously in this report, Couger (1990) examined uses of creativity techniques in information systems design. He reviewed a number of different definitions of creativity, and suggested a model for infusing a variety of creativity techniques into the informations systems development process at the end of each of the four traditional stages of: 1) requirements definition, 2) logical design, 3) physical design, and 4) program design. This was offered as a way to help systems developers remain competitive in a global marketplace. The cost-effectiveness of such techniques could only be justified hypothetically. Since no organizations were found which actually used creativity techniques in information systems design, no relevant data was available.

Of concern will be the effects of information systems on the ability of system users to function creatively in their work. Notwithstanding some of the more sophisticated possibilities offered by artificial intelligence, computers are generally programmed to operate according to very rigid and inflexible rules of operation. Such rigidity is generally an impediment to creative functioning. Systems developers will have to stike a balance between providing the structure and expediency for which computers are valued; and providing an environment conducive to creativity and innovation on the part of the user.

This problem applies to the ways information systems impact organizational climate as well as to the individual user. Studies of the effects of computer systems on such workplace concerns as productivity, communications and organizational climate, deserve serious attention.

Organizational Information Systems

One emerging theory holds that the traditional Management Information System (MIS) paradigm is becoming increasingly outdated by the depth, breadth and rapidity of technological advances over the past two decades. (LeMoigne & Sibley, 1986; van Gigch & LeMoigne, 1990).

Drawing on Simon's "Information Processing Paradigm" (1977, 1979, 1981a, 1982), this theory argues that the cybernetic-based MIS model takes too narrow a view of the role of information systems in organizations. A new systemic model called an Organization Information System (OIS) is suggested as an intermediate step toward an Intelligent Information System.

In addition to such decision support and control-related functions as collecting, sorting, retrieval and and data processing; this OIS model is designed to perform such symbol-manipulating functions of complex organizations as memorization, communications, self-regulation, maintenance and self-testing.

The idea is significant to this study in that it gives greater attention to process concerns as opposed to content. The implementation of such systems will ultimately increase understanding of the structure and functioning of organizations and social systems. In so doing, they will create new demands, and offer new avenues for meeting those demands, in the classroom.

Society, Education and Beyond

There are very convincing arguments which contend that computers will change the entire structure of society as we know it (Toffler, 1980). Visible examples of this are present in all areas of daily existence, from the way checkouts are accomplished in the supermarkets, to the way monthly bills are paid, to the way studies such as this are conducted, prepared and presented. Work which could once only be accomplished at the office can now be just as easily done at home. This capability, in turn, significantly impacts a primary social element, the family unit.

These facts will have an increasingly significant effect on the demands society will place on its educational institutions; and on the way those institutions will go about educating students.

As stated repeatedly in this report, the mass quantities of information available are helping to precipitate a focal shift from content to process in the educational domain. Information retention abilities are coming to be regarded as secondary to information processing and problem solving skills (Green, 1984; Sellwood, 1989). This will impact curriculum accordingly. Educators will need to familiarize themselves with creativity and problem solving skill development.

Computer systems are also having significant influence on existing theory of intelligence, learning and cognition. Increased understanding of how the mind functions and how learning and problem-solving occurs has resulted from research which regards both the computer program and the human problem-solver as information processing systems. This research is beginning to benefit educators in developing better ways to individualize education (Bruer, 1993).

As artificial intelligence capabilities develop, knowledge-based, or expert, systems continue to aid decision-making processes in a wide variety of disciplines. These systems are also bringing researchers to new understandings about the mental processes and psychodynamics of the human mind. While it is unclear, at present, how this may affect education; it is clear is that changes will continue to occur as a result of information processing systems.

Artificial Intelligence and Cognition

Such technologies as natural language processing, speech recognition, computer vision, robotics, expert systems and automatic programming combine to create an intriguing view of information systems as they emulate processes associated with human intelligence.

Arguments in favor of the notion that machines might be programmed to think point toward the systemization of thinking processes as the means whereby this will be accomplished. It is contended that the various models of cognition and cognitive functioning can be integrated into a programmable "Unified Theory of Cognition" in which all learning involves some form of problem solving (Waldrop, 1988). Since it is arguable that problem solving can be equated to, or at least closely parallels, creativity; this theory would seem to bridge the gap between learning, or retaining knowledge, and thinking, or manipulating that information in ways which are both unique and of value within a given context.

An opposing viewpoint holds that, in order to think, computers must have the same causative powers as humans. Searle (1980, 1990) contends that computers are syntactic in their functioning. They can only manipulate symbols as they have been programmed to, have no intentionality, and therefore no causative powers. Human thinking, on the other hand, is said to have mental content, which attaches semantic meaning to symbols. Included within these meanings can be cognitive variables and imaginative and motivational factors far too complex for mechanization.

Whether or not computers can think and create, it is clear that they can provide researchers with powerful new tools, in the form of software which relates to intelligence, problem solving and cognition, with which to explore vast new worlds.

II. SOFTWARE

In order to identify and classify computer software products having applicability to creativity, innovation and problem solving, a number of products were acquired and reviewed (See appendix B). It was not possible to obtain and examine all of the products found to be applicable. Some of the products which were acquired and examined first-hand did not directly apply to problem-solving, but were reviewed and annotated due to their peripheral relevance to creativity. Information regarding relevant computer products which could not be acquired and examined first-hand was derived from other sources, such as promotional materials, software catalogs and listings, and software clearinghouse reviews (See appendix E).

In the previous section of this report, categorizations used to present computer software identified in this study were described. These were:

a) Creativity Software Review, which consisted of programs which had direct relevance to creative problem solving and which were examined first-hand;

b) CBIR Annotations, which contained programs examined first-hand and had either direct, or peripheral relavance to creativity; and

c) Creativity Software Listing, which included all software products identified which had direct relevance to creativity, and a sampling of products which could be said to have peripheral relevance to creativity or creative problem-solving.

Information on software identified in this study will be reported according to those categories.

Creativity Software Review

Where this software category was concerned, the Creative Problem Solving model developed at the Center for Studies in Creativity, was used as a basis for evaluating and reporting on software. This model incorporates three components into creative problem solving. These are:

Understanding the Problem,
Generating Ideas
Planning for Action
(Isaksen & Dorval, 1993)

Computer software was reviewed with regard to the applicability of each to the above components.

These products were also evaluated for technical merit in the following areas:

Ease of installation - or how much technical expertise is required to get the program loaded and running on the personal computer system.

Clarity of manuals - is the user documentation easy to read and understand? Is it sufficient?

"Intuitive Use" - does the program lend itself to easy, "intuitive" operation? Does the use of the program come naturally?

Screen Aesthetics - is the layout and appearance pleasing to the eye? Are key elements on the screen easy to identify?

Help Functions - is technical assistance a keystroke away? Is the "help" key easy to identify? Is the assistance provided effective and easy to understand?

Relevance of Output - does the product yielded at the end of the computer session apply in a meaningful to way to solving a real problem?

Value of output - to what degree can the product yielded at the end of the computer session help in solving a real problem?

Mobility of Output - can the product yielded at the end of the computer session, or data assembled in the process of working on the problem, be transferred to another program, system or context? Can the output be exported to an application which might be better suited to manipulate or report data in a certain way?

The following programs, listed under "Software Reviews" were reviewed and evaluated by the writer.

Idegen++ (1990) was originally developed by Finnish creativity researcher Vilkko Virkkala. It was a modular style program including functions of idea generation, idea evaluation, and sorting. The program aids in refining ideas and developing problem solutions.

MindLink (1992) was developed after the well-recognized Synectics (TM) model for creative problem solving. It guides the user through problem solving, assists in idea generation and contains a "gym" for developing creative thinking skills.

Lightyear (1984) was a relatively inexpensive decision modeling system. This product allows users to define criteria and assign value to each in examining alternatives to a problem situation. It is one of a number of "weighted decision factor" type systems which are available.

Inspiration (1992) was a computerized flowcharting system which aided in idea generation and development by providing for graphic representations of ideas and their interrelationships.

Thunder Thought (1992) was an idea generation and creative writing program which used computerized word manipulation techniques drawing from a library of terms.

These programs were evaluated for applicability to the components of CPS and in the above listed technical areas. Results are represented in Figure 4.

Insert Figure 4.

Where creativity value is concerned, the programs overall seemed to lend the most value to idea generation. This is something of a surprise, since there are good mainstream computer programs available which apply quite specifically to action planning which might have been incorporated. Also, there appears to be a need for improvement in developing software which will help users who are unfamiliar with problem solving methodologies to clearly understand and define a problem area.

Technical aspects of these programs were generally good. In this review, while there appeared to be a significant problem in the area of user documentation, this was largely due to the fact that two of the products were demonstrator versions of the software, and did not come with complete documentation. The complete reviews are contained in appendix F of this report.

Creativity Software Listing and CBIR Annotations

The remaining two categorizations of software contained more mainstream products. An exception to this general statement would be decision support systems and expert systems, which are usually custom designed and often highly specialized in application. While decision support software is available "off the shelf" it requires user input regarding the nature of the decision making process and criteria used. Computer software relating to creativity was classified as follows:

Computer Aided Instruction

Decision Support Systems

Expert Systems

Problem Solving

Project Planning

In the computer aided instruction, decision support systems and project planning categories there are a good number of quality products available, some of which were offered as part of "integrated systems" packages, or modules which were developed by for use either as "stand alone" programs or as part of a system containg database management, project planning and graphics and presentation software, for example.

Two very good computer aided instruction (CAI) packages reviewed were the Decisions, Decisions (1991) and Chronos (1992) packages. These were both marketed by Tom Snyder Productions. The former aided students, obviously, in learning about the process of making decisions, both individually and as part of a group. The Chronos program used historical events to aid learning about timelines in project planning.

In the decision support category, was the Expert Choice (1983) program, which assists decision makers in structuring problems, and aids in collecting, analyzing and communicating data relative to long and short term goals.

The Confidence Factor (1984) was a decision support tool which consisted of several decision-making aids. It allows assignment of probability factors to variables in a possible problem solution in order to render a "most likely," "best case" and "worst case" prediction.

Some decision support products were developed for use with other popular software products. One such was the Arborist Decision Tree Analysis Package (1985), which accepts data from the a popular spreadsheet system. It allows graphic structuring and evaluation of alternatives and risks associated with complex decision making.

Expert systems aid in decision making in highly esoteric and context-specific situations. They are regarded as an entity of their own under classifications of computer products, they are not regarded as "consumerable" computer products. They were reviewed from the perspective of the literature only. None were reviewed in the course of this study.

Some software products were developed specifically to aid in solving problems. There were a few computer programs offering an integrated approach to problem solving which were not reviewed first-hand. These ranged widely in cost and function.

A very basic and simple such program was the CPSE (1991) program, developed by the Creative Education Foundation in Buffalo, NY. This was a no-frills program based on the Osborn-Parnes model of creative problem-solving.

The Idea Generator Plus (1985) was a system which closely follows the componential model of problem solving described previously in this section. It aids problem solving by describing a situation, generating ideas, then evaluating them.

The Idea Fisher (1977) program employs a cross-referenced database of words and phrases in leading the user through problem solving stages described as orientation-clarification, modification and evaluation.

Two more sophisticated, or "high end" systems were C.R.E.A.T.I.R. (1992), a complete system including hardware and software employing CD-ROM, audio, visual and olfactory stimuli; and The Innovator (1989) a modular group creative problem solving system which focused on organizational culture and climate as well as on human resource and team development concerns.

A good example of the many good project management computer products available was the Macproject Pro (1992) program from Claris Corporation. This was a project planning and development system which allowed major tasks and subtasks to be defined and scheduled for completion. Most such such products provide for such aspects of project management as definition of milestones and timelines, resource allocation, cost factoring and progress monitoring.

No project planning software was found, however, which employed affirmative judgement or solution development techniques such as are employed in creative problem solving methodologies.

Synopsis

It was clear that significant work is being accomplished in the area of computerized applications toward creativity. It is hoped that these, and others, will continue to be developed and enhanced. The uses of information systems by managers, the impact of these on systems on organizations, and their effects on decision making and problem-solving processes as well as on learning are all concerns which apply directly to the study of creativity. Developing technology combined with knowledge based and expert systems are providing a forum for exciting research into the mechanization of cognitive processes.

Summary

The review of literature produced data of much greater breadth and depth than the software review. The literature applied to the general domains of business, industry and organizations; education; and artificial intelligence and cognitive science. Exciting and revolutionary things promise to come from applications of computer technology in creativity.

Much computer software has been developed which applies peripherally to creativity, innovation and problem solving. A few programs exist which were designed specifically for creativity applications; and of these, fewer still which meet the criteria of quality, reliability and affordability.

It appears that any identifiable body of researchers or developers concerned with applications of information technology in creativity is very much in a state of flux.

Section 5:

_Assessment_and_Evaluation_of_Outcome_

Introduction

This study investigated current applications of information management technology in areas of creativity, problem-solving, creative behavior and creativity skill development. A search of existing software and literature was conducted and a number of agencies, institutions and research organizations were contacted in efforts to accomplish this.

Key Findings

In general, it became evident that research and development which may be said to fall under the dual domains of creativity and information systems can be classified as relating to 1) business and organizations, 2) education, and 3) artificial intelligence and cognition.

While the review of literature proved quite fruitful (See appendix A), the same could not be said of the requests made for assistance from other professional agencies and resources. The apparent conclusion drawn from this might be that "much is being said about using computers in creativity, but little is being actually done about it."

Such a statement might be premature, however, in view of the large numbers of organizations in existence claiming interest in matters related to creativity and technology (See appendix C). It would be safer to say that most of the agencies contacted chose not to respond, for whatever reason, and investigate the issue further.

The software review revealed that, while a few problem solving applications which are affordable and of good quality are available, there are only a few (See appendix E). While virtually all computer programs involve data collection in some form, few have been developed in a format intended to be conducive to creative problem solving. There are at least two very sophisticated and expensive systems in operation which are making use of emerging technologies in efforts to facilitate electronically supported group problem solving, e.g., the C.R.E.A.T.I.R. System, developed by IdeaPlex, Inc. in Blacksburg, VA, and noted previously in this report; and the Team Focus (1992) system developed for IBM at the University of Arizona. A large number of less expensive programs have been written which relate to various components of CPS, and the creative problem solving practitioner would be well advised to become familiar with these.

Cognitive Engineering

Another finding was that, while skepticism is plentiful and limitations appear certain, any serious attempts to replicate thinking processes in machines, referred to as cognitive engineering, are being carried out in the arena of artificial intelligence (AI). The continuing development and enhancement of technology is making available to the lay person the processing speed and the increased memory and data storage capacities necessary to fully exploit and develop AI.

Systems Design

There is a clear need for creativity in the development of computer applications and in information systems design. The majority of the applications which have been developed are those which easily lend themselves to computerization. The difficult ones lie ahead. This assertion comes from a number of different quarters, all citing an apparently myopic approach to systems design and development on the part of the information systems industry. The rapid increase in use of the personal computer is expected to add impetus and urgency to this concern. In fact, as the information explosion reaches more and more segments of the general population, more creative approaches to applications development can be expected to appear from users themselves.

It is equally clear that information systems will need to be designed in ways which will accommodate and support the users' creativity. Computers are machines which have traditionally been programed to function in very rigid, inflexible and therefore predictible ways. Such a work environment can be stifling to the users' creativity and probably accounts for the absence of creative approaches to systems design cited above.

CBIR-based Study

This study was the first undertaken at the Center for Studies in Creativity which contributed a large number of citations related to a specific domain to the CBIR system. It is recommended that students undertaking similar projects in the future maintain close communication between the student and the CBIR systems administrator. While it is possible and, in this case, has been acceptable to conduct such a study independent of the guidelines and protocols which regulate and control CBIR data entry and retrieval; it is preferable, and in some areas necessary, for data elements contained within the study to conform exactly to those protocols.

This is particularly true if new search terms are added to the CBIR controlled vocabulary as a result of the study. The student and CBIR administrator should be clear on which terms will be added to this vocabulary, so that, when the new annotations are submitted, these are included where necessary and applicable throughout the course of the project and in the subsequent report. The search terms can serve as valuable indicators of what exists in different subject areas of the literature. But if it is a goal for a project report to reflect this information in a way which is consistent with additions which were made to CBIR, it should be made clear which terms were accepted and under which main-headings they were placed before a great deal of time and effort is expended in data analysis and reporting.

It may also become advisable for protocols and procedures to be developed to facilitate advantages and opportunities provided by information technology in conducting a study such as this. Database listings which are now available provide much larger quantities of data to the student. This data can be electronically manipulated in a variety of ways to provide information which would previously have required many hours of exhaustive review. This creates possibilities for either focused study or cross-referencing which deserve consideration.

Additionally, as was the case with this study, data was submitted to the CBIR systems administrator on electronic media rather than in typed or written form. This can be a time-saving method for submitting annotations, provided data is formatted properly. Protocols and procedures should be developed to facilitate this.

Recommendations for Future Study and Development

It is abundantly clear that a need exists for the integration of efforts between creativity scientists and information systems developers. This is true across all of the three major domains of inquiry of:

Business and Organizations

Education

Artificial Intelligence and Cognition

The following is a listing of additional areas of need for future study and development which were identified as a result of this project:

- Continue to identify and evaluate computer applications related to creativity.

- Continue to add citations related to informations systems and creativity to CBIR

- Establish and maintain dialogue with agencies responding to the query made in this study.

- More focused literature search(es) into such areas as:
    a) Computer aided instruction applications related to creativity.
    b) Computerized convergence technology.
    c) Computerized action planning technology.
    d) Computerized idea generation technology
    e) Artificial intelligence applications.
    f) Other ongoing research

- Study the effects of computer systems on the creative climate of organizations. Consider the effects of:
    - Accessibility of information
    - Potential for processing and manipulating information
    - Inter and intra-agency communication capabilities / shared information technology

- Investigate thoroughly, findings of the Electronic

Meeting Support (GDSS) system developed at the University of Arizona. Document current involvements.

- Study the areas and degrees of effect of computer systems on fluency, flexibility, originality and elaboration skills. Include an anaylsis of cognitive style of the user(s).

- Investigate uses and impact of information systems in education with particular attention given to:
  - uses in the classroom
  - impact of computer literacy and programming skills on learning abilities and problem solving skills

- Computerize the grading process. Integrate level-oriented grading practices, with measures of style.

- Development of user-interactive programming for use in creative/critical thinking skill building.

- Development of computerized creativity assessment instrumentation.

- Development of computerized multivariate profiling system.

- An investigation of developments in cognitive engineering relative to creativity.

- Inquire into the origins or artificial intelligence and how the various programming languages were developed. Of particular interest would be parallels between General Semantics, Creative Analysis and ProLog.

- Investigation of data collection, storage and retrieval technology as may apply to the computerization of the CPS framework.

Future Possibilities

One area in which computers might have significant impact is in process flow. Some people can type faster than they can write, therefore divergent information gathering can occur at a faster rate. Data quantity, therefore quality, would be increased. Progress in voice recognition technology may soon eliminate the need for a CPS facilitator to write on a flipchart, thereby allowing full attention to be focused on group dynamics.

Advances in integrated media designs will create opportunities for the development of all kinds of stimuli for divergent thinking. A wide array of convergence technology awaits the trained CPS practitioner willing to "fine tune" applicability toward the componential model of creative problem solving. If problem solving on an individual basis, the computer could be used as a readily available "process buddy."

Creativity level and style issues can also be given uniquely individual treatment via computer technology. If fluency is not a particular strength in problem solving, a host of idea generation stimuli could be made available at the touch of a finger.

Studies exist which demonstrate that people tend to be more divergently productive alone than when in groups. The computer can allow privacy for problem solving, where problem sensitivity creates such a concern. It also allows the user to start and stop at personal convenience.

Computers are unfeeling, objective, non-judgmental machines which can be programmed to interact in very human-like ways. A study of the ability of people to defer judgement with a mechanical facilitator as opposed to a human might yield very interesting observations, if only the machine existed which could fuction in a way that could closely parallel a trained CPS facilitator.

Contrariwise, if convergence is difficult, the computer may help make CPS deliberate. The problem solver may be forced to focus on only one question at a time. The computer allows the user to work on the same problem again and again, allowing for long term revisitation. This could aid CPS on an individual basis.

George Land (1973) describes the tools humans invent as extensions of themselves. If this is true, then information management systems represent a pinnacle of such human extension. A common current debate centers around whether or not computers can be creative. Whichever viewpoint one chooses to argue, it is clear that they can save time and mental energy in thousands of ways.

The more we understand what happens in the creative moment, the better equipped we will be to mechanize that process or set of dynamics, thereby freeing humans to strive for greater creative heights.

By combining CPS with the unique environment created by information processing machines, an entirely new arena for inquiry into the nature and nurture of creativity, innovation and problem solving will be made available at the Center for Studies in Creativity and to the field.

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Thunder Thought. (1992). Mission Hills, CA: West Consulting.

Appendix A - Annotations, Literature

Appendix B - Annotations, Software

Appendix C - Agency Listing

Appendix D - Software Developers Listing

Appendix E - Creativity Software Listing

= Creativity Software Listing =
Applications - Creative Problem Solving

Program Name: Idea Generator Plus
Developer: Experience in Software, Inc.
Address: 2000 Hearst Ave.
City: Berkeley
State: CA   Zip Code: 94709   Phone: (800) 678-7008
Cost: $195.00
Applications: /CREATIVE PROBLEM SOLVING/UNDERSTANDING THE PROBLEM/IDEA GENERATION/PLANNING FOR ACTION/

Experience in Software, Inc. [1985]. Idea Generator Plus [Computer Program]. Berkeley, CA: Experience in Software, Inc. [Aids problem solving through describing a situation, generating ideas and evaluating ideas. Includes book entitles "The Art of Creative Thinking." by Gerard I. Nierenberg]

Program Name: Idea Fisher
Developer: Fisher Idea Systems
Address: 2222 Martin, #110
City: Irvine
State: CA   Zip Code: 92715   Phone: (714) 474-8111
Cost: $595.00
Applications: /CREATIVE PROBLEM SOLVING/IDEA GENERATION/CREATIVE PROBLEM SOLVING/

Fisher, M. [1977]. Idea Fisher [Computer Program]. Irvine, CA: Fisher Idea Systems. [Employs a cross-referenced database of words and phrases in leading users through problem solving stages of orientation-clarification, modification and evaluation.]

Program Name: C.R.E.A.T.I.R.
Developer: IdeaPlex, Inc.
Address: 602 Allegany Street
City: Blasksburg
State: VA   Zip Code: 24060   Phone: (703) 231-7307
Cost: $35,000.00
Applications: /CREATIVE PROBLEM SOLVING/UNDERSTANDING THE PROBLEM/IDEA GENERATION/PLANNING FOR ACTION/

Ideaplex, Inc., C.R.E.A.T.I.R. [Computer Program]. Blacksburg, VA: IdeaPlex, Inc. [Complete creative problem solving system including hardware and software employing CD-ROM, audio, visual and olfactory stimuli.]

= Creativity Software Listing =
Applications - Creative Problem Solving

Program Name: CPSE
Developer: The Creative Education Foundation
Address: 1050 Union Road
City: Buffalo
State: NY   Zip Code: 14224   Phone: (800) 447-2774
Cost: $50.00
Applications: /CREATIVE PROBLEM SOLVING/UNDERSTANDING THE PROBLEM/IDEA GENERATION/PLANNING FOR ACTION/

Maraviglia, F., CPSE [Computer Program]." Buffalo, NY: The Creative Education Foundation. [Based on the Osborn-Parnes model of creative problem solving. A very basic, no-frills program.]

Program Name: MindLink
Developer: MindLink Inc.
Address: P.O. Box 247
City: North Pomfret
State: VT   Zip Code: 05053   Phone: (800) 253-1844
Cost: $299.00
Applications: /CREATIVE PROBLEM SOLVING/UNDERSTANDING THE PROBLEM/IDEA GENERATION/PLANNING FOR ACTION/

Prince, G. [1992]. MindLink [Computer Program]." North Pomfret, VT: MindLink Inc.. [Based on Synectics model for creative problem solving. Guides problem solving, assists in idea generation and contains a "gym" for developing creative thinking skills.]

Program Name: Idegen++
Developer: Finntrade, INC.
Address: 2000 Powell Street, Suite 1200
City: Emeryville
State: CA   Zip Code: 94608   Phone: (510) 547-2281
Cost: $495.00
Applications: /CREATIVE PROBLEM SOLVING/UNDERSTANDING THE PROBLEM/IDEA GENERATION/PLANNING FOR ACTION/

Virkkala, V. [1990]. Idegen++ [Computer Program]." Emeryville, CA: Finntrade, INC.. [Modular style program which employs idea generation, evaluation and sorting in it's process for problem solving. Employs techniques entitles distant models, general principles and a modification check-list.]

= Creativity Software Listing =
Applications - Creative Problem Solving

Program Name: The Innovator
Developer: Wilson Learning
Address: 7500 Flying Cloud Drive
City: Eden Prairie
State: MN   Zip Code: 55344   Phone: (612) 944-2880
Cost: $6,990.00
Applications: /CREATIVE PROBLEM SOLVING/PLANNING FOR ACTION/

Wilson Learning [1989]. The Innovator [Computer Program]." Eden Prairie, MN: Wilson Learning. [Modular group creative problem solving system. Focuses on organizational culture and climate as well as human resource and team development concerns.]

= Creativity Software Listing =
Applications - Understanding the Problem

Program Name: Goal Solutions
Developer: Enfin Software Corporation
Address: 6920 Miramar Road; Suite 106-A
City: San Diego
State: CA   Zip Code: 92121   Phone: (619) 549-6606
Cost: $99.95
Applications: /UNDERSTANDING THE PROBLEM/DECISION SUPPORT/

Enfin Software Corporation [1986]. Goal Solutions [Computer Program]. San Diego, CA: Enfin Software Corporation. [Aids problem definition by calculating multiple equations using multiple variables. Complex but valuable to users sophisticated enough to utilize properly.]

Program Name: Expert Choice
Developer: Expert Choice, Inc.
Address: 4922 Ellsworth Ave.
City: Pittsburgh
State: PA   Zip Code: 15213   Phone: (412) 682-3844
Cost: $495.00
Applications: /UNDERSTANDING THE PROBLEM/DECISION SUPPORT/

Expert Choice, Inc. [1983]. Expert Choice [Computer Program]. Pittsburgh, PA: Expert Choice, Inc.. [Assists decision makers in structuring problems. Aids in collecting, analyzing and communicating data relative to long and short term goals.]

= Creativity Software Listing =
Applications - Idea Generation

Program Name: Inspiration
Developer: Inspiration Software, Inc.
Address: 2920 SW Dolph Court, Suite 3
City: Portland
State: OR   Zip Code: 97219   Phone: (503) 245-9011
Cost: $295.00
Applications: /IDEA GENERATION/

Inspiration Software, Inc. [1992]. Inspiration [Computer Program]. Portland, OR: Inspiration Software, Inc.. [Computerized flowcharting program which aids in idea generation and development. Employs graphic representation of ideas and interrelationships.]

Program Name: Idea Kaledioscope
Developer: Pussy Willow Software
Address: 205 North Green St.
City: Tuckerton
State: NJ   Zip Code: 08087   Phone: (609) 296-3056
Cost: $199.95
Applications: /IDEA GENERATION/

Pussy Willow Software [1988]. Idea Kaledioscope [Computer Program]. Tuckerton, NJ: Pussy Willow Software. [Ideas are generated by combining all possible arrangements of terms used in and associated with problems statements and ideas. Results are graded according to one to six evaluation criteria.]

Program Name: Thunder Thought
Developer: R.K. West Consulting
Address: P.O. Box 8059
City: Mission Hills
State: CA   Zip Code: 91346   Phone: (900) 884-3578
Cost: $34.00
Applications: /IDEA GENERATION/

West, R. K. [1992]. Thunder Thought [Computer Program]. Mission Hills, CA: R.K. West Consulting. [Idea generation a creative writing aid using computerized word manipulation techniques drawing from a library of terms. Word library may be modified or enhanced by the user.]

= Creativity Software Listing =
Applications - Planning for Action

Program Name: Macproject Pro
Developer: Claris Corporation
Address: 5201 Patrick Henry Drive, Box 58168
City: Santa Clara
State: CA   Zip Code: 95052   Phone: (408) 987-7000
Cost: CALL
Applications: /PLANNING FOR ACTION/PROJECT MANAGEMENT/

Claris Corporation [1992]. Macproject Pro [Computer Program]." Santa Clara, CA: Claris Corporation. [Project planning and development system in which major tasks and subtasks are defined and scheduled for completion, resources allocated and interdependencies represented.]

Program Name: The Confidence Factor
Developer: Simple Software, Inc.
Address: 2 Pinewood
City: Irvine
State: CA   Zip Code: 92714   Phone: (714) 857-9179
Cost: $389.00
Applications: /PLANNING FOR ACTION/DECISION SUPPORT/

Simple Software, Inc. [1984]. The Confidence Factor [Computer Program]." Irvine, CA: Simple Software, Inc.. [Decision support tool consisting of several decision-making aids. Allows assignment of probability factors to variables in a scenario in order to render a "most likely," "best case" and "worst case" prediction.]

Program Name: Arborist Decision Tree Analysis Package
Developer: Texas Instruments, Inc.
Address: P.O. Box 1444
City: Austin
State: TX   Zip Code: 77251   Phone: (800) 847-2787
Cost: $595.00
Applications: /PLANNING FOR ACTION/DECISION SUPPORT/

Texas Instruments, Inc. [1985]. Arborist Decision Tree Analysis Package [Computer Program]." Austin, TX: Texas Instruments, Inc.. [Allows graphic structuring and evaluation of numerous alternatives and risks associated with complex decision making. Accepts data from Lotus 1-2-3 spreadsheets.]

Program Name: Defining Goals and Objectives
Developer: Thoughtware, Inc.

Address: 100 Chopin Plaza, P.O. Box 011151
City: Miami
State: FL   Zip Code: 33101   Phone: (305) 854-2318
Cost: $99.00
Applications: /PLANNING FOR ACTION/DECISION SUPPORT/

Thoughtware, Inc. [1984]. Defining Goals and Objectives [Computer Program]." Miami, FL: Thoughtware, Inc.. [Helps distinguish between long-term and short-term goals, assess effectiveness and modify goals and objectives for improved efficiency and effectiveness.]

Program Name: Lightyear
Developer: Thoughtware, Inc.
Address: P.O. Box 011151
City: Miami
State: FL   Zip Code: 33101   Phone: (305) 854-2318
Cost: $99.00
Applications: /PLANNING FOR ACTION/

Thoughtware, Inc. [1984]. Lightyear [Computer Program]." Miami, FL: Thoughtware, Inc.. [Decision modeling system which defines and assigns value to criteria used in examining alternatives to a problem situation.]

Appendix F - Software Reviews

Appendix G - Controlled Vocabulary for CBIR

Appendix H - Checklist for Evaluating Published Thinking Skills Instructional Programs

Appendix I - Sample Query Letter

Appendix J - Software Review Annotation (Sample format)