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ABSTRACT

Using the cognitive fit paradigm as a theoretical framework, this study compared the problem-solving performance of users of a hypertext-based learning aid to the performance of users of a computer-based linear text learning aid. Subjects were 103 undergraduate MIS (Management Information Systems) majors enrolled in an information systems analysis course. Learners' performance was compared on three levels of task complexity: analysis, synthesis, and evaluation. Results indicated that users of the hypertext-based learning aid were more effective and efficient at the highest level of complexity tested. This suggests that hypertext-based learning aids would be more appropriate to more complex learning tasks than to less complex ones. One table presents analysis of variance results for learning time and method. (Contains 44 references.) (Author/MES)

HYPERMEDIA AIDS FOR ADVANCED LEARNING IN COMPLEX AND ILL-STRUCTURED KNOWLEDGE DOMAINS

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Using the cognitive fit paradigm as a theoretical framework, this study compared the problem-solving performance of users of a hypertext-based learning aid to the performance of users of a computer-based linear text learning aid. Learners' performance was compared on three levels of task complexity: Analysis, Synthesis and Evaluation. Results indicate that users of the hypertext-based learning aid were more effective and efficient at the highest level of complexity tested. This suggests that hypertext-based learning aids would be more appropriate to more complex learning tasks than to less complex ones.

INTRODUCTION

Along with the evolution of information technology (IT), computer-based learning has evolved from programmed instruction to some more complex content-focussed learning environments. With faster, more powerful and cheaper systems, the applications have multiplied. Today, learning environments come in all sizes and shapes. They engage learners in authentic context-sensitive learning tasks, support collaborative learning activities and socially-negotiated interpretations of domain knowledge, among other issues. Examples of these environments include anchored instruction, computer-supported intentional learning environments, and cognitive flexible hypertexts (Jonassen, 93).

Obviously, computer-based training and learning systems are not the solution to every problem in training and education. In the computer-based training and learning literature we can find encouraging results and discouraging ones. On one hand we found studies indicating that computer-based training (CBT) can improve learning, attitudes, and job performance (Adams, 93; Eberts, 88; Eberts and Brock, 84; Francis, 92; Kearsley, 85; Nelson and Palumbo, 92; Price, 91; Radlinski and McKendree, 92), on the other hand some studies did not clearly indicate the benefits of using CBT (Hiltz and Johnson, 90; Horowitz, 88; Leidner and Jarvenpaa, 93).

This resembles the graph *versus* tables controversy which went on during the 80s and early 90s. Vessey (91) offered an interesting explanation for the inconsistency of the results obtained by researchers. Using the cognitive fit paradigm, she proposed that the issue of fit between the task supported and the tool used had to be taken into account in order to adequately assess subject performance.

Following this line of thought, the research described here compared learning performance of subjects using two different computer learning aids, linear and hypertext. Performance was assessed for three levels of task complexity: analysis, synthesis, and evaluation.

The remainder of this paper describes the research and its results. In the following section we discuss IT and learning. The Cognitive Fit Paradigm is presented in Section 3. The research model and the hypotheses are outlined in Section 4. The research method is contained in Section 5. In Section 6 the results are presented along with a discussion of our findings and of the limitations of the study.

IT AND LEARNING

The potential for information technology to revolutionize education does exist. Part of the reason that information technology has yet to revolutionize daily classroom activities is its rapid evolution. It is very difficult to keep current in a field that is only a support for the primary activity, which is teaching. With so many options, it is hard to find the right fit between the available technology and the goals of learning.

Since the early versions of hypertext authoring tools, it has been argued that hypertext will have an impact on learning. In a way, by merely linking documents some assume that there will be major educational effects, that hypertext systems will solve most, if not all, educational problems, and that once students have access to hypertext they will dramatically improve in some almost magical way. This has prompted a strong reaction known as the "hype" of hypertext, or "hyper-expectations" These expectations have also prompted a reaction that considers hypertext just another *buzz word* and suggesting that those *promises* cannot be fulfilled.

In a theoretical review of the use of information technology (IT) to enhance management school education, Leidner and Jarvenpaa (95) looked at the pedagogical assumptions underlying the design of IT for educational purposes. In an effort to stimulate innovative applications and rigorous examinations of the effectiveness of these applications, they discussed five models of learning in the context of management education: objectivism, constructivism, collaborationism, cognitive information processing, and socioculturalism.

The objectivist model of learning is based on Skinner's (53, 69, 71) stimulus-response theory. The goals of learning here are to understand reality and modify our behaviour accordingly. Reality is seen as an objective entity waiting to be understood. Educators who agree with this model believe that expertise is an accumulation of knowledge and we need to be able to transfer this knowledge to novices. Here, knowledge is also an objective entity that can be stored and transmitted. So the main concern of educators in this model is to find an efficient way to do so. They believe that instructors are the source of knowledge and they should be in control of the learning process.

The main difference between constructivism and objectivism is that reality is understood differently by either theory. Constructivism sees reality as a subjective experience. Knowledge is not transmitted, but created in a series of interactions by each learner. This model calls for a learner-centred approach. Instructors are facilitators of knowledge, but learners should be in control of the process. Individuals learn better when they are forced to discover things themselves rather than by being told or instructed.

For the educators that adhere to the collaborationist model of learning, learning emerges through shared understanding of more than one learner. In other words, learning does not exist in isolation. So, in order to generate knowledge, socialization is promoted, as well as group skills, communication, listening, and participation. Involvement is seen as critical for learning. In this context, instruction is communication-oriented, and the instructor is seen as a questioner and a discussion leader.

The Cognitive Information Processing model looks at learning as the creation and transfer of new knowledge into long-term memory. Its goal is to improve the cognitive processing abilities of learners, by improving recall and retention. Here, prior knowledge affects the level of instructional support needed, and educators believe that learners have limited selective attention. So they are concerned about instructional aspects of stimuli that can affect attention. They need some kind of feedback on student's learning in order to adapt to their needs.

Finally, those who adhere to socioculturalism see learning as subjective and individualistic, and as a means to empowerment, and emancipation. They believe that action-oriented, socially conscious learners will change society rather than merely accept or understand it. Then, instruction is always culturally value-laden, and embedded in a person's every day cultural or social context.

It is easily understood that educators having different views of the education process will have different assumptions about how IT can help them achieve their goals. In order to classify these assumptions, Leidner and Jarvenpaa's (95) analysed different ways educators view information technology: As a means to automate, informate up, informate down, and transform. These "visions" are based on Schein's (92) organizational research in IT.

The vision to automate. When educators see IT as a way of replacing expensive, unreliable human labour with sophisticated systems and other information technologies, they have a vision to automate. They see in these technologies a way to save money, to improve quality, and to make schools more effective. They acknowledge that teaching and learning cannot be automated, but they believe there are some aspects that can be better served using computers, particularly the delivery of information. Within this vision, Leidner and Jarvenpaa (95) grouped the following technologies, since they are seen as prone to provide tools for manipulating and representing instructional material in a classroom: Instructors consoles with or without standalone student computers, Computer-Assisted Learning, and Distance Learning technologies.

The vision to informate up. For some educators, IT can become the ultimate educational control tool. They assume that by installing the right kind of information system they can monitor the educational process, pinpoint problems rapidly and prescribe remedial measures. Technologies that fit this purpose, identified by Leidner and Jarvenpaa (95) include key response pads and any kind of E-mail system that allows communication between instructors and students.

The vision to informate down. In an educational context, this means that instructors share the responsibilities of the learning process with learners, mainly by providing students greater access to information. Students now can critically analyse information and discuss issues between themselves and with the instructor. The technologies identified within this vision include Hypermedia, the Internet, Simulations, Virtual Reality, and Classrooms with synchronous communication devices either with or without group support (Leidner and Jarvenpaa, 95).

The vision to transform. In education this view will translate into a new understanding of the classroom, by making its physical boundaries obsolete; of teamwork, by having more effective interactions; of the learning process, by allowing it to become a continuous, time-independent process; and of the creation of knowledge, by enabling it to be a multilevel, multi-speed process. Leidner and Jarvenpaa (95), identified virtual learning spaces known as Asynchronous Communication Across Distances (ACADs) technology either with or without group support.

In order to assess the impact of IT on learning, Leidner and Jarvenpaa (95) evaluated each one of these visions against the five theories of learning regarding control of the pace and content of learning, and the purpose of instruction. They suggest that IS researchers, interested in this area, can benefit by using well-established variables from educational research rather than creating new ones. By examining well-defined learning outcome variables as dependent measures in studies of the impact of IT on learning, their findings will be more comparable and easier to interpret.

Hypermedia in general, and hypertext in particular places much of the control of the content and pace of learning in the hands of students. The purpose of study moves away from knowledge dissemination to knowledge creation. Much of the knowledge has already been created, i.e., is explicit, but the instructor is no longer the primary creator of it. Then its structure becomes very important and students become part of the knowledge creation process, while the instructor becomes a mediator rather than an adviser of the learning process.

We can conclude, that hypermedia is more properly used in constructivist or cognitive information processing environments, with an emphasis on conceptual learning and higher-order thinking. That was also noted previously by Jonassen (93), Duffy and Jonassen (92), and Spiro and Jehng (90).

Cognitive flexible hypertexts are intended to engage learners in more meaningful, transfer-oriented, advanced knowledge acquisition. Cognitive Flexible Hypertexts are supported by the Cognitive Flexibility Theory (Spiro et al., 88). This theory is a conceptual model for instruction based upon cognitive learning theory and attempts to avoid oversimplifying instruction, provides multiple representations of content, emphasizes case-based instruction, focuses on context-dependent knowledge, and supports the natural complexity of the content domain in order to foster the development of advanced knowledge, particularly in ill-structured knowledge domains.

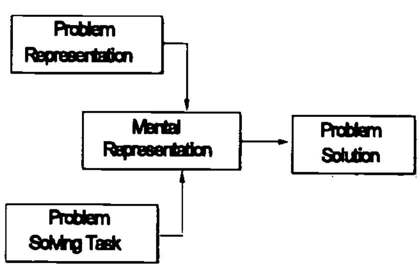
THE COGNITIVE FIT PARADIGM

In the MIS literature, the graphs *versus* tables controversy which went on during the 80s and early 90s was similar to the controversy about the effectiveness of computer-based learning aids. The inconsistency of the results had captured the attention of several researchers since some results proposed that subjects using graphs performed better than subjects using tables, other studies proposed exactly the opposite, while other studies reported no differences. Vessey (91) gathered the results of all those studies and used them as her source of data. Using the cognitive fit paradigm, she proposed that the issue of "fit" has to be taken in consideration in order to make an assessment of subjects' performance.

Vessey (91) developed the notion that complexity in the task environment will be effectively reduced when the problem-solving aids support the task strategies required to perform that task. She termed that notion: *Cognitive Fit.* Her model was based on a general model of problem-solving depicted in Figure 1. The model views problem-solving as an outcome of the relationship between problem representation and the problem-solving task. Processes in her model are represented by the flows and arrows linking pairs of elements in the model. Also, in this model, she uses the mental representation as a problem representation in human working memory.

The Cognitive Fit Paradigm provides a theoretical background to research on information processing theory (Vessey and Galletta, 91). Newell and Simon (72) stated within their Information Processing Theory that human problem-solvers will strive to reduce their efforts while solving a problem, since they are limited information processors. In order to facilitate the problem-solving process that human problem-solvers use in completing the task, the processing effort must be reduced. If the tool is matched to the task, the processing efforts will be reduced. This is precisely the paradigm of Cognitive Fit. Using this paradigm, she proposed that *"problem-solving with cognitive fit results in increased speed and accuracy of performance."*

Figure 1 General Problem-Solving Model (Vessey, 91).



Cognitive Fit is a cost-benefit characteristic that suggests that *"for most effective and efficient problem-solving to occur, the problem representation and any tools or aids employed should all support the strategies (methods or processes) required to perform the task"* (Vessey, 91). This means that the problem representation a problem-solver uses must be considered in the context of the task to be solved. Also, designers should concentrate on determining the characteristics of the tasks that the problem-solvers must address. Once these characteristics have been determined, they should be supported with the appropriate tools. In other words, despite individual preferences, some tasks demand specific tools; If those tools are available, the task's goals will certainly be attained. This does not mean that there is only one way to obtain the task's goals. What it implies is that when cognitive fit exists, it confers advantages in performance.

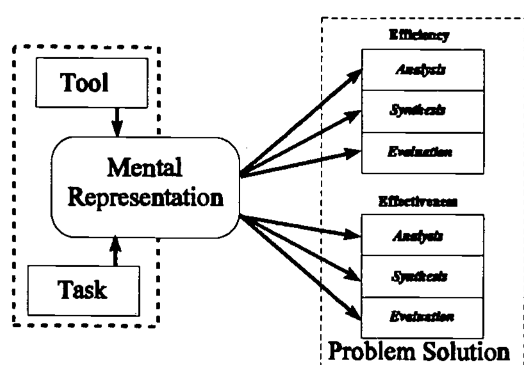
One immediate implication for systems design within the Cognitive Fit Paradigm is that designers can examine the nature of the task to be performed and consequently support the task by providing the problem solver with the problem representation that matches the task (Vessey, 91). The management literature has long investigated the notion of fit (Joyce, Slocum and Von Glinov, 82; Venkatraman and Camillus, 84; Drazin and Van de Ven, 85; Alexander and Randolph, 85; Van de Ven and Drazin, 85; Venkatraman, 89). This investigation is useful since the notion of fit has been broadened. In this ample context, the notion of Cognitive Fit also benefits.

Cognitive Fit, then, can be used as a construct to measure the match of several task-tools pairs in different domains and/or contexts. It will provide enough confidence to researchers, designers, or practitioners to assign a particular tool in order to perform a given task. Unfortunately the literature on Cognitive Fit is limited. This research is offered as a continuation of that work.

THE RESEARCH MODEL

The research model shown in Figure 2 depicts the effects of accessing and using information from linear and nonlinear systems on problem-solving for specific types of problem tasks. This model consists of four components: the user's mental representation, the tool, i.e., information access and display (linear versus nonlinear), the task, and problem-solving performance (efficiency and effectiveness).

Figure 2 Research Model.



In our model, mental representation is the way the problem is represented in human working memory, i.e., the way it is understood. This representation is the output of the characteristics of both the tool used to learn the model and the task. According to Vessey (91), Cognitive Fit Theory views problem-solving as an outcome of the relationship between problem representation and problem-solving task.

The independent variable Tool, captured by means of the treatments, is a special case of the Problem Representation variable used in the cognitive fit paradigm.

A number of studies have been conducted comparing the effectiveness of hypertext and linear text. Some studies involved both the electronic and print media. Others, such as the current study, involve only one of the two media. In some of the studies the goal was to evaluate the effectiveness of hypertext as a search tool, i.e., a tool for locating specific information within a document. Typically in these studies subjects would receive a set of questions, to be answered. There are only a few studies dealing specifically with the question of the educational effectiveness of hypertext as compared to linear text.

A few studies have been conducted in order to compare hypertext-based educational systems to linear text-based ones. After the first ACM (87) conference on Hypertext, held at The University of North Carolina - Chapel Hill, there was an explosion of interest about hypertext in general, and specifically on its educational implications. At Brown University, a group of researchers developed the Hypertext Editing Support System (HESS), the File Retrieval and Editing Support System (FRESS), and Intermedia, three hypermedia systems. These systems were used in a series of empirical studies (Catano, 89; Van Dam, 88; Yankelovich et al., 88).

One of these studies, conducted with FRESS, involved a course on poetry. Results showed that subjects in the experimental group wrote three times as much for both analysis and informational discourse as did subjects in the control group (Catano, 89; Van Dam, 88), even though results were unreliable due to a very small experimental group.

Gordon, et al. (88) conducted a study in order to evaluate the use of hypertext as an intra document text format. Subjects were asked to read two articles, one in linear text, the other in hypertext. Findings indicated that linear text subjects were more successful remembering basic ideas for both types of articles, and showed a better assimilation of the macro-structure contained in the articles labelled as general interest. Subjects indicated a preference for linear text indicating that hypertext required more effort, while reading the material.

In a study to compare the performance of subjects exposed to hypertext material (Khalifa and Ramírez, 92) exposed subjects to hypermedia material in four non consecutive lectures. Results were only conclusive in the between subjects analysis, after the third lecture. Also, each group obtained a higher average mark on the lectures where they used the hypertext material.

Results regarding the benefits of hypertext-based systems have not been conclusive. One reason we can mention is that the learning material was quite simple and the lack of complexity made it equally suitable for linear and hypertext applications. We believe that by including the level of complexity as part of an experimental design, it can be demonstrated that hypertext systems will offer some clear advantages for learning.

An ill-structured domain is determined by its conceptual complexity and its across-case irregularities. In other words, each case or example of knowledge application typically involves multiple conceptual structures (multiple schemas, perspectives, organizational principles, etc.), each of which is individually complex (including both concept and case complexity). The pattern of interaction varies substantially across cases of the same type (each case looks like a 'new' one).

Examples of ill-structured domains include medicine, history, art appreciation, literary interpretation, system's modelling, and systems design. Furthermore, Spiro et al. (92) argue that *all domains which involve the application of knowledge to unconstrained, naturally occurring situations are substantially ill-structured.* They give as an example, the case of engineering, which employs basic principles of Physics (most of them well-structured in the abstract) to "messy" real-world cases. The nature of each case in engineering is so complex and differs so much from other cases that it is difficult to categorize them under any single principle.

Therefore, learning to carry out a procedure, use a concept, understand a system, in this context becomes onerous. Simple examples, memorization and simplification are no longer useful. Knowledge here is intertwined and dependent, has significant context-dependent variations, and requires the ability to respond with flexibility to complex situations.

Problem-solving performance refers to the type of assignment used to elicit different levels of performance. These assignments deal with different levels of the taxonomy of educational objectives (Bloom, 56). Once learning has happened, the understanding of the material may be elicited from the learners at different levels. It may be elicited as verbal information or some other form, depending on the capabilities targeted: intellectual skills, cognitive strategies, verbal information, attitudes, or motor skills.

A group of educational researchers developed what is known as Bloom's Taxonomy of Educational Objectives (Bloom, 56). A taxonomy that (1) provides classification of the goals of our educational system, (2) facilitates the exchange of information about curricula developments and evaluation devices, (3) specifies objectives to facilitate learning experiences and prepare evaluation devices. It consists of explanations of six levels of thinking in the cognitive domain (i.e., Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation). In the forty years of its existence, Bloom's educational learning taxonomy has been widely used in developing instructional and testing material.

The taxonomy consists of three parts: the cognitive, the affective and the psychomotor domains. The cognitive domain, which is the concern of this research, includes those objectives that deal with the recall or recognition of knowledge and the development of intellectual abilities and skills. It is the domain in which most of the research in curriculum development and evaluation has taken place.

Probably the most common educational objective is the acquisition of knowledge or information. In other words, it is desired that as a result of completing an educational unit, students will be changed with respect to the amount and kind of knowledge they possess. Frequently, knowledge is the primary, sometimes almost the only, educational objective in a curriculum. By knowledge, we mean that students can give evidence that they remember, either by recalling or by recognizing, some idea or phenomenon with which they have had experience in the educational process.

Bloom's taxonomy regards knowledge as basic to all other elements it encompasses. Problem-solving and thinking are not carried out in a vacuum. They are based on some kind of knowledge. Knowledge becomes the material of the problem or the yardstick to verify the accuracy and adequacy of the solution.

With respect to the dependent variable in the research framework of cognitive fit, problem-solving performance has been made operational as effectiveness and efficiency of the problem solution for each one of the levels of complexity used to design the tasks (Analysis, Synthesis, and Evaluation). Effectiveness is captured as a percentage of the maximum score for each level of complexity.

Following Vessey's (91) argument that in order to fully account for time and accuracy tradeoffs, both have to be assessed jointly, Efficiency is captured as a ratio of the obtained score, divided by the time spent solving the problems for each level of complexity. In the literature, efficiency is measured as speed, but captured by the time spent solving the task, (Vessey, 91, Vessey and Galleta, 91), which we find inappropriate in this learning situation, mostly because we expect to be able to qualify the use of time while learning and solving problems with the obtained score.

Bloom's taxonomy includes six levels from knowledge to evaluation. We are interested exclusively in the three higher levels of the taxonomy since this research deals with complex and ill-structured material, suited for advanced learning. Since the first three levels deal mainly with the knowledge of the "language" of the domain in question, then knowledge, in Bloom's terms involves remembering either by recall or recognition the ideas, material or phenomena of the domain under study. Advanced learning takes these issues as given. Since subjects have had a previous introduction to the theme, they are familiar with these ideas, material or phenomena. Therefore the knowledge of these ideas is independent of the learning method used by subjects in our research.

A similar argument can be made for comprehension, the next level in Bloom's taxonomy, since comprehension represents the lowest level of understanding, with an emphasis on a grasp of meaning or whether learners know what has been expressed and are able to use the material or idea without further explanations. Again, advanced learners are familiar with the terminology of the domain in question to a point that they are able to follow a discussion in the domain without difficulty.

The next level, application, deals with abstractions of elements in the learning domain, mainly to see whether learners are able to identify them in a concrete situation. At this level, subjects are not asked to do more than identify elements in a particular situation. Advanced learners are expected to do that without major problems.

Since analysis involves the breakdown of ideas into its constituent elements, this is the first level of interest in our model. Here, advanced learners need more than an understanding of the material, they are asked to analyze each element and see whether they can indicate how the material is organized, and detect the relationship of its parts. The learning material will definitely have an impact on how these issues are conveyed to the learner. So starting with analysis, and continuing with synthesis and evaluation, these are the levels of complexity of interest in the present research.

Research Hypotheses

This section presents the hypotheses derived from the research model, in light of the Theory of Cognitive Fit. These hypotheses are organized according to the level of complexity and separated by the variable under study.

H_{1A}: Users learning from the hypertext version of the learning material will perform more effectively on a case study than users learning from the linear version of the same material, when the emphasis of knowledge is on quantitative and qualitative judgments (i.e., level of complexity is Evaluation).

At this level, subjects using the hypertext version are expected to have a deeper understanding of the model and based on that model, make more sound judgments. This means that they will be more accurate in their judgments according to a previously validated instrument.

H_{1B}: Users learning from the hypertext version of the learning material will perform more efficiently on a problem-solving test than users learning from the linear version of the same material, when the emphasis of knowledge is on quantitative and qualitative judgments (i.e., level of complexity is Evaluation).

This hypothesis is similar to H_{1A}. The only difference is the variable of interest. H_{1B} deals with efficiency in the same way that H_{1A} deals with effectiveness. The main difference is that subjects are not only expected to be more accurate, they are also expected to do it faster.

H_{2A}: Users learning from the hypertext version of the learning material will perform more effectively on a case study than users learning from the linear version of the same material, when the emphasis is on inferences made about the learning material (i.e., level of complexity is Synthesis).

Subjects are expected to make inferences about the model in a specific case situation. Since the understanding of the material will be different from those in the control group from those in the experimental, we expect to observe this difference on the way they make inferences in a case study.

H_{2B}: Users learning from the hypertext version of the learning material will perform more efficiently on a problem-solving test than users learning from the linear version of the same material, when the emphasis is on inferences made about the learning material (i.e., level of complexity is Synthesis).

We can present a similar argument between H_{2A} and H_{2B} regarding efficiency versus effectiveness. At this level subjects are also expected to perform faster and more accurately.

H_{3A}: Users learning from the hypertext version of the learning material will perform as effectively on a multiple choice test as users learning from the linear version of the same material, when the emphasis is on breaking the model into its constituent parts (i.e., level of complexity is Analysis).

At this level, advanced learners will be able to grasp this knowledge from both versions of the material, so they are expected to perform equally well. This hypothesis is presented as a way to validate our approach that all the previous levels of the taxonomy are not really meaningful at the advanced level. In other words, the learning material being implemented in hypertext will not make a difference unless subjects using it are requested to have a deeper understanding of the material, and also to use the information for more complex tasks.

H_{3B}: Users learning from the hypertext version of the learning material will perform as efficiently on a problem-solving test as users learning from the linear version of the same material, when the emphasis is on breaking the model into its constituent parts (i.e., level of complexity is Analysis).

Finally, the same argument is made between H_{3A} and H_{3B} where subjects in both modules are expected to perform equally in accuracy and in about the same amount of time.

Basically what these hypotheses say is that the effectiveness and efficiency characterising performance of subjects in the experimental group working on problem-solving increases as the level of complexity does, compared to the control group. These hypotheses are based directly on the Cognitive Fit Theory discussed previously. What it is new here, is that by incorporating the level of complexity in this model, we are looking to settle the differences in the results of the use of hypertext for learning literature, regarding the benefits of using hypertext as a tool for learning.

These hypotheses argue for a reduction of the ambiguity associated with stating instructional objectives and a translation of these objectives into relevant test items. In particular, this research deals with the three highest levels of the cognitive domain: analysis, synthesis and evaluation (Bloom, 56). After forty years of usage, this taxonomy provides a reliable way for designing test material.

RESEARCH METHOD

A full randomized design was used that includes two factors: Hypertext and Linear text. This arrangement gives six possible outcomes, coded **HA**, Hypertext version-Analysis, **HS**, Hypertext version-Synthesis, **HE**, Hypertext version-Evaluation, **LA**, Linear version-Analysis, **LS**, Linear version-Synthesis, and **LE**, Linear version-Evaluation.

A complex and well-supported implementation model was used, the one developed by Lucas, Ginzberg and Schultz (90). It is a rigorous and integrative model of the process of implementation. It combines the two major streams on the research of implementation: process and factor research. The model consists of two stages: the adoption of the system by the manager, and its usage by his or her subordinates. Since each of these two stages is complex in itself, we decided to work exclusively with the manager sub-model (referred to here as the Manager Model).

Lucas, Ginzberg and Schultz (90) developed this structural model of implementation incorporating many of the results of past implementation research studies. It is based on the research traditions of causal modelling, attitude modelling, and innovation process modelling. They used this approach to explain the phenomena of systems implementation with a conceptual model rich in theoretical implications but complex. Its complexity has often discouraged its inclusion in the Information Systems (IS) Curriculum.

The variables included in the model are based on the research findings of previous implementation studies. The logic of the model is that implementation begins with management initiation and acceptance of a given IS and ends with user satisfaction with the system. Factors leading to manager acceptance are *personal* (MANAGER DECISION STYLE, MANAGER DEMOGRAPHICS), *task-related* (MANAGER JOB CHARACTERISTICS), and *system-specific* (MANAGER KNOWLEDGE OF SYSTEM, MANAGER ASSESSMENT OF SYSTEM AND SUPPORT). TOP MANAGEMENT SUPPORT is seen to influence both MANAGER'S BELIEF IN THE SYSTEMS CONCEPT and MANAGER'S INVOLVEMENT with systems development. Beliefs and involvement do not directly lead to ACCEPTANCE; rather stronger belief leads to more involvement. Also, both stronger belief and more involvement lead to more knowledge of the system. All this to say, that some factors depend on other factors which increases the complexity of the model.

The Hypertext Module

The Hypertext module consists of nine screens and ten windows. The first screen is an introduction to the model and the learning objectives are stated as goals. Subjects go through the remaining screens and windows at their leisure. Every time they move from one screen to another (or to a window), a tracer captures the time they access that location and writes this information into a tracing file. Links are filtered through programs that highlight the relevant information concerning the selected factor or influencing dimension. It really does not matter the way they traverse all the information, the tracer captures this "personalized" trip and keeps the information for future analysis.

The Linear text Module

The linear text module is a copy of the hypertext module without hyper-links. The only links are linear links that allow users to move from one screen to the next, either forwards or backwards. This way we are sure that the information presented to both groups is the same. What is different is the way to access the information.

The Test and the Cases

The testing material consists of three parts: A multiple choice test dealing with analysis of the information presented on the learning module. A short case-study, in which the subjects are expected to make some inferences based on the learning material. A longer case-study dealing with the implementation of an information system, subjects are expected to make judgments regarding the success (failure) of its implementation, based on the learning material. These testing materials were validated through a pilot study (Ramirez, 1997).

Subjects were one hundred and three undergraduate students (49.51% females, 50.49% males) majoring in MIS in their last year of a Bachelor of Commerce program, enrolled in an Information Systems Analysis course. At this level, the learning material is more relevant and motivated participation. Participation was voluntary. A couple of incentives were offered. Five extra points, participation points, in the course mark were offered to increase participation, and cash prizes to top performers in each group were offered to motivate performance.

Experimental Procedures

There was an information session for all the students in the targeted population. In this session, subjects were invited to participate in and informed about the study.

Subjects had a hands-on training session. Even though it was almost certain that subjects have had a previous exposure to similar tools: mice, icons, windows, links, etc., their knowledge was not taken for granted.

The first module, training, consists of six screens and nine windows. The purpose of this module is to allow subjects to move successfully around four locations (HomePage, Point A, Point B, and Point C) while reviewing information.

When subjects were familiar with the system's features, they were exposed to the learning material. Students were allowed to spend as much time as needed learning its content. The learning module, contains the information of Lucas, Ginzberg and Schultz' (90) Implementation Model. There were two versions of this material, a hypertext-based, and a linear version.

When subjects finished working with their version (hypertext, linear text) of the learning material, they were advised that they had finished with it. They had two options in the form of labelled links (buttons: REVIEW MODULE, and WRITE THE TEST). When they chose to write the test, they left the learning module and moved on to the test and the cases.

RESULTS

Table 1 presents the results of the tests of Between-Subjects Effects for the dependent variables Effectiveness and Efficiency in Evaluation, Synthesis and Analysis. In order to compensate for the deficiencies of running simultaneous tests, the univariate analyses were adjusted using the Holm Simultaneous Testing Procedure (Holm, 79). This procedure (Holm, 79) is a refinement of the Bonferroni adjustment for conducting a family of tests. It is applicable when the simultaneous tests is a particular set of pair-wise comparisons, contrasts, or linear combinations that is specified by researchers in advance of the data analysis.

The Holm procedure carries out the simultaneous testing by obtaining the P-value for each test but then modifies the level against which the P-value is compared in order to improve the power of the test (Holm, 79). Consequently, the Holm procedure may find significant effects when the Bonferroni procedure does not, for the same significance level. This procedure, slightly more complex computationally, allows adjustments for one side tests, since a P-value must be found for each test.

The results on effectiveness and efficiency in evaluation by method indicated significant effects ($F=5.984$; $p=0.008$ and $F=5.477$, $p=0.010$). These findings support our claim that the hypertext resulted in superior problem-solving than the linear system. Results in synthesis and analysis do not indicate significant effects.

Learning time shows significant effects with effectiveness in evaluation ($F=7.178$, $p=0.009$) and analysis ($F=17.818$, p 0.0009) as well as with efficiency in analysis ($F=12.482$, $p=0.001$).

These results suggest that subjects' performance is more effective and efficient when using a hypertext-based learning aid at a higher level of complexity than at lower levels. This can be interpreted as, hypertext-based learning aids significantly improve problem-solving performance of subjects at higher levels of task complexity, i.e., there exists cognitive fit between the level of complexity and hypertext-based learning aids.

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TABLE 1
ANALYSIS OF VARIANCE RESULTS FOR LEARNING TIME AND METHOD

Level	Variable	Learning Time	Method
Evaluation	Effectiveness	F(1, 100)=7.178, p=0.009	F(1, 100)=5.984, p=0.008
	Efficiency	F(1, 100)=3.754, p=0.056	F(1, 100)=5.477, p=0.010
Synthesis	Effectiveness	F(1, 100)=0.014, p=0.907	F(1, 100)=0.339, p=0.281
	Efficiency	F(1, 100)=0.136, p=0.713	F(1, 100)=0.293, p=0.295
Analysis	Effectiveness	F(1, 100)=17.818, p=0.000	F(1, 100)=0.940, p=0.335
	Efficiency	F(1, 100)=12.482, p=0.001	F(1, 100)=1.066, p=0.304

This implies that educators or trainers can benefit from hypertext by using this kind of learning aid to address complex and ill-structured learning materials. To insure that resources are better allocated and not wasted, educators and trainers could insist that learning material that is complex and ill-structured may be implemented in hypertext. Also, they may insist that only that kind of material be implemented in hypertext, since there is a direct improvement on performance.

A major contribution of this research is the methodology used to assess the cognitive fit of more complex pairs of tools-tasks than those reported previously in the literature. The research design and the experimental materials were based on the "match" between the technology and the task, under the cognitive fit paradigm. It is within this theoretical framework that the effects of hypertext and level of complexity were analysed and hypothesised.

The material was designed within the philosophy of constructivism. One of the assumptions that works well in this model is that meaning varies with how the individual creates it from his or her experiences. Since no subjects in the hypertext module chose to traverse the information sequentially, each one of them had a different learning experience. Each of them created her or his own construction of the model. This did not mean that some were right and others wrong; the model learned is the same, their understanding of it was different.

An important feature of the hypertext learning material used is that it allowed learners to selectively visit each dimension and the factors/dimensions that have a direct/indirect influence on them. This option provided a way to understand the patterns of association (by means of the highlighted information) which revealed the conceptual information of the model. We can say that just by exploring, in a constructivist manner, subjects in the hypertext module were actually learning.

CONCLUSION

The major purpose of this study was to make an assessment regarding the contribution of hypertext-based learning aids in the acquisition of advanced knowledge. A hypertext-based learning aid and a linear text learning aid were developed and tested in order to conduct this research. Subjects were randomly assigned to the treatments, i.e., hypertext and linear text. Subjects in the hypertext group were designated as the experimental group and those in the linear text group were designated as the control group.

Three sets of two hypotheses were formulated and tested. The first set is concerned with effectiveness and efficiency of performance at the level of Analysis in learning. The second is concerned with effectiveness and efficiency of performance at the level of Synthesis in learning.

Finally, the third is concerned with effectiveness and efficiency of performance at the level of Evaluation in learning. In all these cases, the hypotheses were tested at the =0.05 level of significance and adjusted for multiple comparisons using Holm's Multiple Comparison Procedure (Holm, 79). We found that at the highest level of complexity tested, Evaluation, the tool had a significant effect on effectiveness and efficiency of subjects' performance.

Limitations

One of the major limitations of this research is the method chosen for this study. We used a laboratory experiment, emphasising internal validity, but weak external validity. Despite considerable efforts to minimize the limitation, external validity suffers from the artificiality of a laboratory setting and data collection procedures. Thus, findings are less likely to be generalised across settings (Cook and Campbell, 79).

On one hand, we had an artificial setting, on the other, we used a complex and well-supported implementation model. The setting was artificial mainly because subjects worked in a different environment than they regularly use, i.e., a classroom. Otherwise, we can claim that the learning environment is similar to any other computer-based learning material. The content, though, is an actual implementation model. This model was implemented directly from the book it was reported without any simplification.

Subjects were undergraduate students, majoring in MIS, enrolled in a System Analysis Course. For them, the learning material is similar to the one included in their syllabus for the course, even though this particular model is not included. Therefore, it may still be appropriate to generalise the findings to similar populations, i.e., MIS majoring undergraduate students.

Differences in performance were measured by having subjects work on the same problem-solving tasks. The experiment took place in a two-week period. It is possible that subjects commented among themselves the kind of problem-solving tasks used. But, since they were unaware of exactly what options were correct, it would not help them much to know in advance the kind of tasks they would be evaluated.

One important limitation is the fact that complex models are difficult to implement. The information necessary to show differences that exist, mainly in perception, can rapidly escalate. Sometimes it may not be feasible to attempt its implementation; Other times, it may be irrelevant to do so. One of the most important learning experiences, derived from this research, is the acknowledgement that finding a workable balance between feasibility and relevancy should be the main goal when designing instructional material for hypertext.

Directions for Future Research

Hypertext is not the solution for every problem in learning. There are many aspects of learning where hypertext does not have a meaningful contribution. That was clearly shown in this research. Still, we need some criteria to determine which aspects of the learning process are better served with hypertext. It seems that those areas where information is not linear, or where by imposing linearity the information is not oversimplified, are excellent choices.

The design of the new generation of hypertext learning aids should foster learning by discovery in a constructivist way, bring some kind of structure to ill-structured material, and allow material to be revisited at different times, in different contexts. In cases where the amount of information is overwhelming, that information should be broken into modules and meaningful links should allow the traversal of each of them from different parts of the system. When necessary, the system should provide "guided tours" to the information. One aspect to investigate on these guided tours, is whether they promote motivation to learn.

This study can be extended in at least two ways. First, it may be worth investigating the application of hypertext-based learning aids to other tasks dealing with knowledge acquisition. Second, a similar assessment of Cognitive Fit can be performed using other tools (multimedia, World Wide Web, Internet, Intranet, etc.) for similar tasks (learning). We can use Leidner and Jarvenpaa's (95) theoretical information technology fit with other theories of learning, to match the task-tool pairs.

With the advance in IT applications, we expect to find more applications of these technologies in schools, universities, and organizations. If that is the case, it will be possible to used those tools instead of having to create them specially for research studies, increasing the external validity of research findings.

In conclusion, this research is the beginning of what is anticipated to be a rich stream of research based upon measuring the effects of emerging technologies on training and learning. It seems that this kind of research in not only needed, it is also urgent. Emerging technologies are having more and more an impact on the way we educate and train in particular, and do businesses in general.

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