LEARNING PRINCIPLES ESSENTIAL FOR EFFECTIVE COMPUTER ASSISTED INSTRUCTION (CAI)

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Abstract (1)

Guidelines and recommendations for effective computer assisted instruction are presented based on a review of the current theories and research relating to cognitive conceptions of learning and instructional design which are documented by metanalytic techniques. The main focus is on how metacognitive processes are conceptualized and integrated for the most effective development of any interactive technology for learrning. These concepts are then integrated into sequencing and synthesizing instructional strategies, with an emphasis on micro strategies of learning. Emphasis is placed on learner characteristics important for learning, so that any instructional program can be developed which will be most effective for specific students, learning with specific conditions, and for specific learning tasks. The most effecacious use of any interactive technology for learning will come about when the learners' knowledge, cognitive skills, conations, understanding, expectations, and motivations are taken into consideration.

(١) يرجى ملاحظة ملخص هذه الدراسة في اللغة العربية بعد نهاية هذا البحث للاستفادة منها .

* INTRODUCTION :

Throughout history, information technologies such as the printing press, photography, radio, television, and satelite communication, have had an important effect on society and education. Within the past few years, the most important development in information technology has been the computer, which Nobel Laureate herbert Simon referred to as a " once in several centuries invention. " The potential of the computer is virtually unlimited, and as stated by Carver Mead, one of the main developers of silicon chip technology, " the microelectronic revolution has already enhanced productivity in information – based technology by a factor of more than a million – and the end isn't in sight " (33). It is expeted that there will be a significant increase within the next decade.

The computer's ability to employ a range of different symbol systems, to process information that it receives, stores, retrieves, and presents, and its ability to transform translate, sort, integrate, calculate, and do many other functions, gives it an unlimited potential for instructional purposes. As pointed out by a number of educators (13, 60, 61, 63, 64, 79), of all the information technologies developed to date, only the computer has the one – to – one socratic ability to engage the learner actively in the learning process. This one feature, interaction, is the most important feature of computer assisted instruction (CAI).

Although the computer has a tremendous potential for enhancing learning the results of using computers in learning have been disappointing (7, 8, 10, 12, 55). CAI has been found to be significantly better than traditional instruction only in slightly less than half of the studies conducted to the present time (1). What we have learned so far indicates that there is no one – to – one correspondence between what a teaching method or activity can produce and how it is perceived and/or if it is effective. As stated by Salomon and Gardner (72), not only do individual differences and prior knowledge play an important role in determining how learners process and react to an instructional activity, much depends on how individuals tend to or choose to process the information or react to the activity that they are engaged in. They conclude that computers do not effect learners in any uniform way, that the effectiveness of the learning experience depends on many factors including the traits and goals that students bring to the learning situation, the way that they apprehend the technology and the situation, and the particular volitional choices that they make.

Although many reasons have been given for the lack of conclusive results of the effectiveness of computers to enhance learning, recent criticism has suggested that there has been too much emphasis placed on the computer and not enough on instruction (24). According to some CAI researchers (2, 65, 66, 74), lack of consistent results is due to the failure of CAI designers to successfully integrate learning theory concepts with the unique capabilities of computer technology. As pointed out by recent CAI authors (62, 80), the capabilities of computer hardware and software design make it possible to develop learning environments that can integrate a range of instructional strategies currently known to improve learning as well as making it possible to add strategies, Park and Seidel (62) advocate using a systems approach that allows CAI authors to incorporate various instructional principles and research findings in the design and development of instructional software. However, the incorporation of these concepts into CAI software is limited to the extent of the developer's knowledge of learning and instruction principles, and thus requires developers to become more knowledgeable about learning theory and pedagogy (67).

The first question is when educators dealing with CAI, they are facing tow essential questions, " How can we effectively use the total potential of the computer for learning, ". The Second question is " What learning theories and pedagogy are most appropriate for CAI ? " As pointed out by Walker and Hess (85), the successful use of computers in education depends on both the cognitive and motivational processes in learning and the social structure of the educational setting. The purpose of this paper is to present guidelines and recommendations for effective CAI sequencing and synthesizing instruction which have been conceptualized during the past decade.

*** THE ESSENTIAL EVENTS OF LEARNING :**

During the past 20 years, there has been an emphasis within psychology to describe learning in cognitive terms and to identify the structures and processes of learning. Cognitive concepts of learning focus on the acquisition of knowledge and knowledge structures, that is, on the learning process rather than on the behavior of the learner. A number of psychologists have come to agreement as to the cognitive events that are essential for learning (28, 34, 37, 43, 48, 51, 88, 89). Gagne (30) provided a useful summary of these events, which he contends must occur for learning to be successful even though these events do not have to be performed by the learner. Directly related to these cognitive events, pscychologists have developed nine events of instruction that have a direct correspondence to these cognitive events (9, 24, 31, 32, 84). The two lists are as follows :

Cognitive Events	Instructional Events
– Attention / Alertness	– Gaining Attention
– Expectancy	– Informing the learner of the objective
– Retrieval to working memory	– Stimulating recall of prerequisite learnings
– Selective perception	– Presenting stimulus material
– Semantic encoding	– Providing learning guidance
– Retrieval and responding	– Eliciting the performance
– Reinforcement	– Providing informative feedback
– Cueing retrieval	– Assessing performance
– Generalizing	– Enhancing retention and learning transfer

The list of instructional events is commonly associated with programmed self – instructional materials and can also provide the basis for CAI software (32). Gagne and Briggs (31) refer to this list as short – circuting methods in the learning sequence, and indicate that these methods are very effective with low ability students or with students who have little prior knowledge in the particular subject being learned. How these cognitive and instructional events are utilized by learners have been described by psychologists as intellectual skills and cognitive strategies. Intellectual skills, or procedural knowledge, are the concepts, rules, and procedures needed by a person to apply verbal knowledge in learning situations through the generalization of principles. Merrill (53) defines these skills as the application of some abstraction to a specific case, using knowledge, and as the derivation or invention of new abstractions of finding new knowledge. Anderson (3) describes these skills as the conditions necessary for specific learning actions, These skills are similar to what psychologists call fluid ability, which deals with abstract and sometimes nonverbal reasoning, and represents the ability to generate solutions to novel and complex problems (15, 19, 76). As described in the literature by several psychologists (30, 77, 88), the eight intellectual skills or processes are :

- Translation, the conversion of symbols to " parallel " symbols.
- Transformation, conversions across symbol systems.
- Mathematical operations, or applying mathematical rules to the manipulation of numbers.
- Classification, grouping of symbols according to predetermined rules.
- Organizing, ordering of symbols according to some rule such as alphabetical, chronological, numerical, etc.
- Integration / synthesis / Combination, combining of different information.
- Inference, identifying connections between two concepts previously thought to be unrelated.
- Mapping, identifying higher order relations among lower order relations.

How these intellectual skills are utilized by the learner forms what pscyhologists call cognitive strategies. These are the " executive control processes " that enable a learner to exercise control over the cognitive events of attending, perceiving, encoding, remembering, and thinking (30). Flavell (29) refers to these strategies as macroprocessing. These strategies are usually grouped into three general processes : planning, includes metacognitions such as setting goals for studying, skimming material, generating questions before reading the text, doing a task analysis of the problem, prediction of one's ability to retrieve the necessary prerequisite information, anticipation of difficulties and the resources needed to resolve them, and a strategy of coordination of lower –order processes of thinking. All of these activities help the learner plan the use of strategies and the processing of information as well as to activate relevant aspects of prior knowledge. Research indicates that good learners engage in more planning and more metacognitive activities than poor learners (68).

Monitoring activities are the essential strategies of meta – cognition which enable the learner to gather and interpret information about his performance and the effects of that performance. These include tracking of attention as one reads or studies, self – testing while reading a text to insure comprehension of the material, checking the direction and level of attention, progress, and performance or comprehension, and the identification of situational factors that are operating to either facilitate or hinder learning. Monitoring activities assist the learner in understanding the material and integrating it with prior knowledge. On the basis of these monitoring activities, the learner can mak adjustments in his or her learning behaviors, which lead to the third process of self – regulation.

The self regulation a continuous adjustment and fine – tuning of cognitive processes, and incldes such behavior as changes in allocation of attention, self – talk, reviewing of material, self – reinforcement, seeking help from additional resources, and using test – taking strategies. All of these activities are assumed to improve performance by assisting learners in checking and correcting their behavior as they proceed in a learning task.

Sternberg (77) includes these three groups of processes in his componential concept of learning, and goes on to include two other aspects : contextual and experiential. The experiential aspect involves the learner's ability to create and to synthesize previous experiences in new and insightful ways, and then to automatize the cognitive processes that are required for specific learning tasks. The contextual aspect relates to the learner's ability to adapt to and manipulate the environment, that is, to be able to select and shape the learning situation to fit his or her needs. These concepts form the basis of a person –environment or person – situation interaction psychology (19), and most these concepts deal with the interaction of motivation and personality.

Motivational aptitudes deal with the learner's initial engagement in the learning process and the subsequent persistence in attempting to learn. Possibly the expectancy – value moder of motivation is most applicable to learning situations (5). Recent developments have focused on the role of the learner's perceptions of cognitions as the central focus for achievement dynamics (26, 27, 56, 86, 87). These researchers have pointed out that it is not actual task difficulty that determines the learner's expectancy for success in learning, but the learner's perceived probability of success based on their perception of the difficulty of the learning task and their perceived ability, which are the two most important components of motivation. There is much research documenting the importance of expectancies for academic performance, task persistence and task choice (26, 40). Some of the factors that are important determinants of expectancy are self – concept and perceived self – concept (6, 50, 75), perceptions of task difficulty (40, 86, 87), perceptions about the stability of their achievement and perceived competence (26, 86, 87), beliefs about the controllability of the learning situation (40, 50), and perception of self – efficacy (6, 75). The learner's beliefs about the internal or external (extrinsic) locus of motivation are also important (41, 49). Generally learners who believe in internal sources of control perform better than those under external sources. Harter (40) has indicated that there are five student – centered dimensions of intrinsic motivation to want to learn : challenge, curiosity, mastery, independent judgment, and internal evaluative criteria.

Other important factors to consider are those dealing with individual differences and contextual factors, which have been identified in studies focused on aptitude – treatment interaction or attribute – treatment interaction, usually referred to as ATI studies, As summarized by cronbach and Snow (21), there are so many learner differences such as ability, motivation, anxiety, ethnicity, socioeconomic status, education background, and past experience that could interact with each other and with instructional procedures, that one should focus on differences that make a difference or which are unique to a specific learning situation. Thus, much of the research in this area is focused on which learning procedure works best in a given context.

Closely related to these factors are the unique characteristics of the learning tasks in determining a learner's reaction to a learning situation and cognition. Results of research (11, 25, 54) in this area indicates that five aspects of the person and the environment have to be considered in understanding learner cognition : student characteristics, the nature of the materials (verbal, visual, complexity, sequencing), the learning activities (attention, rehearsal, elaboration), the criterial task (assignment, type of examination), and the context in which the students and tasks are embedded, There are three general components of the task in Doyle's (25) model : the task that the student is required to learn, the cognitive operations involved in performing the task, and the resources available for students to use in completing the task. Sternberg (77) listed seven metacomponents that are relevant for performance in many if not all task situations : decision as to just what the probledm is that needs to be solved (understanding the nature of the problem) : selection of lower – order components or processes to solve the problem : selection of one or more representaitons or organizations for information : selection of a strategy for combining lower – order components to facilitate performance ; decision regarding allocation of attentional resources; solution monitoring; and sensitivity of external feedback.

There is much evidence that learning is much more domain specific than what earlier learning theorists believed (35). An instructional method may be effective in one subject area but not in others, or for introductory level material but not for advanced material. For example, research has shown that novices and experts in a given area solve problems in fundamentalyy different ways (16). As with motivational factors, it is the learner's perception of the task and difficulty that is usually most influential on learning (27, 56, 86) Much of this research has been summarized by Doyle (25).

*** DEVELOPING INSTRUCTIONAL DESIGNS :**

The information that we know as to what is essential for learning to take place can be used to design effective learning systems. Current theories of cognitive learning have identified various functions that must be performed if learning is to occur. For example, Sternberg (78) indicates that nearly all cognitive theories of learning incorporated three functions that must be performed if learning is to occur : the collection of new information, or selective encoding (sifting out relevant information for further processing), selective combination of disparate pieces of new information, and selective comparison in relating new information with old information previously obtained.

Several overall designs have been suggested for instruction that incorporate these known concepts of conceptual learning such as that of Glaser (36) who identified four components of a learning system : (1) analysis of the nature of the task – what knowledge or information structures are needed and what cognitive strategies and procedures are applied to this information, (2) the need to specify the learner's initial knowledge and skills both with regared to general skills and those specific to a given learning task, (3) specify the transformation processes required to get from initial state to desired state and to specify the conditions that facilitate this transformation, and (4) monitoring the learning process and assessement of progress, Thus the designer must develop an instructional procedure for a particular group of learners, for a specific learning task, and for a specific situation.

The importance of organization and structure for learning based on the concept of hierarchies in the conceptual structure of subject matter has been documented by research (42, 58). Comprehension, understanding, and recall are facilitated by presenting organization in the instructional material. Requiring students to actively organize material trains them to pay close attention to the relationships among concepts and facilitates comprehension, especially for less skiliful learners. Direct instruction in strategies is very important to learners, some psychologists consider this as a requirement (52, 68), and there is much evidence that these strategies must be taught : knowledge about cognition and application of cognition (17, 20, 88). Activating learners' cognitive processes and linking the instructional material to learners' relevant knowledge structure by building advanced organizers into the learning sequence facilitates learning. Using analogies, models, metaphors, and examples are ways to bridge the gap between what the learner already knows and what he needs to know before he can successfully learn what is to be learned. Participant modeling is one concept that can be effectively used to enhance learning (73).

As stated by Reigeluth and Stein (70), the result of an instructional design should be a prescription of what instructional methods should be used for a given objective for a given group of students at a given time in their learning sequence. Two important aspects of instructional design are how the instructional events should be sequenced and how the interrelationships among concepts and ideas should be taught to students. Two types of instructional strategies have been developed to provide sequence and synthesis (71) : macro strategies are those used to organize a set of related skills and knowledge into lessons, and micro strategies are used to structure the reaching of individual ideas, facts, principles and procedures.

The empirical research on sequencing indicates that micro sequences have a much greater impact on learning than macro sequences (83). This may be due to the fact that the two basic questions of what should be sequence and how it is sequenced have been answered for micro sequences but not for macro sequences. Merrill's Component Display theory has been shown to be an effective way to sequence learning (53). His theoretical paradigm identifies five specific prescriptions regarding micro sequencing : (1) present the generality before the examples for use – a – generality outcomes : (2) present the examples before the generality for find – a – generality outcome : (3) arrange instances of examples and practice in a divergent sequence : (4) arrange instances in an easy – to – difficult sequence : and (5) provide non – examples matched with examples. Specific events have been identified for each of these prescriptions. For example, to attain use – a – generality, three major events have to occur : the presentation of a generality (definition or rule), the presentation of examples, and the availability of practice with feedback. Research has suggested three principles for the selection and sequencing of learning : match examples and nonexampales when teaching concepts, successive examples should be as divergent as possible, and the examples should represent a range of difficulty and be presented in an easy – to – difficult order (44). Although macro sequencing research has not identified an effective useful model of sequencing, Van patten et. al. (83) reviwed some of the current strategies such as Bruner's hierarchial sequencing, Merrill's shortest path sequencing, and Reigeluth and Stein's elaboration sequencing.

As summarized by Van Patten (83), research on the suggested synthesizing strategies is inconclusive with regard to their effect on learning. The strategies that appear to be useful are Quillian's networking as a structure for teaching (23, 69), Hanf's mapping which focuses on the use of concept mapping as a way of describing the relationship among ideas (4, 39, 59), and the synthesizer to relate and integrate the individual ideas for a single type of content (70).

*** CONCLUDING COMMENTS :**

Designing an effective instructional system is not easy. As pointed out by Tickton (81), instructional technology is a systematic way of designing, carrying out, and evaluating the total process of learning and teaching in terms of specific objectives, based on research in human learning, and employing a combination of human and nonhuman resources to bring about more effective instruction. The purpose of this paper was to present some basic ideas and concepts essential for learning that have the potential for increasing the effectiveness of learning systems, and currently being considered in recent developments (24, 38, 62, 80). For example, Walker and Hess (85) have incorporated the nine events of instruction in their examples of CAI to teach various. Butler (14) has developed a comprehensive model of learning based on these concepts considered essential for learning. As emphasized in much of the literature on learning (22, 45, 57), learners are active involved processors of information, the goals of learning must be clear and must be made explicit to the student, emphasis should be on small lesson units or small steps, immediate feedback and evaluation must be provided, and the enormous individual differences in the rate of learning, both between individuals and for an individual learning different types of material must be provided for. As suggested by the concepts and principles presented in this paper, the learner should be the focus of any instructional technology. As concluded by clark (18), the greatest gains in the meta – analyses of technology learning (46, 47) resulted from applications which emphasized the basic principles of learning.

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◻ ملخــص الدراســـة ◻

مبـادئ التعـلم الاساسـية وتطبيقـاتها في التدريـس بمسـاعدة الحاسـوب

يعيش الانسان الآن في عصر اتفق على تسميته بعصر ثورة المعلومات ، ولقد ساعـدت المخترعـات الحديثة في مجال الالكترونات على سرعة وسهولة نقل وتبادل المعلومات بحيث أصبح كوكبنـا الـذي نعيش فيه قرية صغيرة اقتربت فيها المسافات المكانية والزمانية .. وأمس مجـال الالكترونـات مجـالاً لا يمكن التنبؤ بما قـد يطرأ عليـه من تغييرات نوعيـة من المتوقـع أن تنقـل البشريـة إلى مجـالات أرحب . ولقد شملت هذه التطورات مخترعات عديـدة كان من بين أهمهـا الحـاسوب . ذلـك الجهـاز الذي تأثرت به مجالات الحياة المختلفة تأثراً بالغاً كنتيجـة للنقلات النوعيـة التي طرأت عليـه بحيث أصبح بما يتمتع به من امكانيات متنوعة جهازاً لا يمكن الاستغناء عنه .

ولقد استفادت عمليتا التعليم والتعلم من الحاسوب وامكانياته اللا متناهية والمتمثلة في المقدرة على معالجة المعلومات وتخزينها واستعادتهـا ونقلهـا وترجمتهـا وفرزهـا ودمجهـا وإجراء الحسـابـات عليهـا وغير ذلـك من الامكانيـات . وأصبحت عمليـة التعليم أو التـدريس بـاستخـدام الحـاسوب تقوم على أساس التفاعل الفردي من قبل المتعلم وهذا ما كان يقوم به سقراط منذ أمد بعيد .

وعلى الرغم من امكانيات الحـاسوب اللا متنـاهيـة فـان نتـائج البحوث المتعلقـة بـاستخـدامـات الحاسوب في عملية التعـليم لم تتفق مع التوقعات وكان مؤدي النتائج التي تم التوصل اليهـا أنـه ليس هناك تأثير موحد للتدريس باستخدام الحـاسوب على كل المتعلمين بل أن هنـاك عوامل تتـدخل في الموقف وتـؤثر فيـه ، من قبيـل سمات وأهـداف المتعلم وطريقتـه في فهم واستيعـاب التقنيـة ومـدى حرية الاختيار لديه .

وقـد رأى البعض أن التوصل إلى هـذه النتـائـج يمكن ارجـاعهـا إلى أن التركيز في الاتجـاهـات السابقة كان منصباً على الحاسوب كجهـاز وليس على عمليتي التعليم والتعلم ، ولم يكن هنـاك تكامل بين نظريات التعلم وما تشتمل عليه من مفاهيم وبين امكانيات الحاسوب ، وفي حالة ايجاد مثل هذا التكامل يصبح بـالامكان خلق بيئـة تعليميـة منـاسبـة تستخـدم استراتيجيـات تعتمـد على استخـدام

الحاسوب وتستفيد من امكانياته . ونقطة البداية في تحقيق هذا التكامل هو أن يعرف مستخدمو الحاسوب في التدريس كيفية الاستفادة من امكانيات الحاسوب بالاضافة إلى معرفة نظريات التعلم ومدى ملاءمتها والاستفادة منها في عملية التدريس ، أن نجاح عملية التدريس على وجه العموم وباستخدام الحاسوب على وجه الخصوص ينبغي أن تدخل في حساباتها العمليات المعرفية ودافعية المتعلم والبيئة التي تتم فيها هذه العملية التدريسية .

وتعالج الدراسة الحالية الخطوط العريضة وتعرض لأهم التوصيات الخاصة باستخدام الحاسوب في عملية التدريس استخداماً فعالاً . وعرضت للنظريات والبحوث التعلقة بالمفاهيم المعرفية وتصميم نماذج التدريس وركزت على فهم العمليات المعرفية وكيفية تكاملها وتطبيقها في مجال التدريس بمساعدة الحاسوب . كما عرضت الدراسة لهذه المفاهيم في صورة استراتيجيات تدريس مركبة ومسلسلة مع التركيز على استراتيجيات التعلم المصغر .

وركزت الدراسة أيضاً على السمات الهامة والمطلوب توفرها لدى المتعلم الأمر الذي يساعد على تصميم البرامج التدريسية الفعالة والمناسبة لحاجات الطلاب ولظروف عملية التعلم ولمختلف المهام التعليمية ، واقترحت الدراسة الحالية في النهاية إلى أن الاستخدام الأمثل لأية تقنيات في عملية التعليم ينبغي أن يأخذ بعين الاعتبار رصيد المتعلم من المعلومات ومستوى مهاراته المعرفية ومدى فهمه وتوقعاته ودافعيته .