The Selection of Learning Theories and Representation Techniques in Computer Aided Instruction

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Abstract: By the needs of learners and the help of technological environments, there exist so many kinds of educational methods that can be utilized in our daily life. Especially the portion of online education increases as the development of technologies. The basic framework of CAI is affected by the learning theories like objectivism and constructivism. The former is suitable for fixed, sequential, structured, and passive learning style and the latter is suitable for selectable, unstructured, active, and self-controllable learning style. This research is focused on the relationship between the learning theories and representation methods in various kinds of online education. The guidelines for selecting learning theories and multimedia representation in each case of the educational situations are suggested. These are made out of the properties of media, learners, and learning contents. First of all, consideration of learning theories and analysis of multimedia properties are done, and from these results, guidelines are formed. Then they are applied to each type of online education methods – simulation, tutoring system, hypermedia system, drill and practice, distance learning – of CAI. The results showed that the optimal methods for CAI is related to properties of learners and contents, and these properties consist basic factors for the appropriate representation of multimedia. In the process of learning, simulation, information system, and hypermedia system are appropriate to the group of applicable attributes of the learning goal and active participation of learners, and tutoring system and drill and practice to the group of memorable attributes of the learning goal and passive participation of learners.

***Key words*:** *Multimedia, Constructivism, Objectivism, Computer aided Instruction*

1. Introduction

Computing and communication technology continue to make an ever-increasing impact on all aspects of cognition, education and training. Technologies for education give a new paradigm for teaching and learning in our environments. The development of computer mediated media and the distribution of network environments change the methods, models, and technologies related to education. As the learning environments have been changed, computer aided instruction (CAI) has differentiated its form and function. Many researches related CAI have been done in recent years, and CAI is classified in two types (Lockard, Abrams, and Many, 1994). Type-I of CAI is the one that computers help instructors to prepare teaching materials, to manage learners and so on. This type of CAI does not change the strategies of instruction, but reduces the time and efforts occurring in the process of instruction. On the other hand, in Type-2 of CAI, computers are considered as a main tool of instruction. That is to say, Type-2 of CAI changes instructional strategies and forms of instruction. Today, new technologies related to

education are mainly focus to the Type-2 of CAI, and this type increases its portion in the area of CAI.

Learning is not just a phenomenon or process of monotony, but the complex combination of contents, methods, and philosophies. Various learning theories and principles take effects on the basic frame of learning environments. For the effective utilization of CAI, the selection of appropriate learning theories and representation methods for the users and contents is an important step in designing instruction. In this research, guidelines from objectivism and constructivism for selecting CAI methods are suggested in the fields of properties of media, contents, and learners.

2. Perspectives on Learning Theories

Today, people enumerate the characteristics of our society as postmodernism, decentralization, openness, diversity, intelligent network, and the knowledge based society. These characteristics affect the other side of society, for instance, learning environments. By these characteristics, learning environments change their forms, functions, and attributes and eventually discriminate them from previous ones. One of the solutions for the new environment is the network based instruction, so we call, CAI. In considering CAI, the nature of learning should be discussed previously. The two categories of learning theories that construct the basic frame of CAI are constructivism and objectivism.

Objectivism maintains the facts speak for themselves, and that knowledge is the reflection of ontological reality. The objectivist's goal of understanding is to know the entities, attributes, and relations that already exist. The goal of learning is, therefore, to know the independent existence of information and acquisition of that information (Duffy and Jonassen, 1992). In this model, the content of "what is to be learned" is considered to be a stable entity that can be organized into a structure involving a series of learning steps. The objectivists' viewpoint assumes that the role of the teacher is to transfer or transmit knowledge to a student (Eun-Sook Kwon, 2001). So, learning materials are analyzed as a sum of entities, learning is focused to memorize these entities and to emphasize microscopic aspects of activities. Objectivism cannot consider the properties of learners and specialties of social or cultural aspects, and these characteristics make the learners behave passively in the classroom. For these reason, learning methods based on objectivism are said to be deficient in creative and flexible thinking, problem solving ability, and effective information analysis.

Constructivism is a new perspective on knowledge that is dependent on a person and constructed through interaction with environments that a person belongs to. In other words, constructivism interests in how people construct knowledge, and the way of constructing knowledge is related with the prior experiences, mental structure, personal belief and so on. Constructivism refigures the relationship of an object to knowledge by eliminating resource to the external object from theory. Since knowledge cannot be reduced to a direct apprehending of reality, constructivists focus on the transformation of knowledge and its development within students. The constructivist approach incorporates the notion that learners build knowledge base through personal experience. Constructivists, therefore, emphasize active learning rather than passive, for participating in and interacting with the surrounding environment in order to create a personal view of the world (Eun-Sook Kwon, 2001). The appearance of constructivism is closely related with the change of society as mentioned in the previous part. In agricultural society, education of apprentices was done with the help of family, while in industrial society, education of mass or group was done in schools. But there is an important hypothesis in constructivistic learning process. It is that human beings are considering external things differently from one another by their own

experience or faith. Also, constructivists insist that knowledge or value of our life is not an objective representation of external things of generalized context, but only analysis and construction of a peculiar context (Jong-Moon Kim, 1999).

For many years, objectivism is thought as a desirable theory for instruction and regardless of the properties of learners and contents, all instruction was done in the same way. But in recent years, objectivism is used mainly in the field of learning, where memorization of contents is important. In contrast to the objectivistic learning, constructivism helps learners to construct knowledge of their own through active experiences in their context. According to Dick (1992), one of the objectivistic researchers, constructivistic learning approach is appropriate to the learners with the high level of learning ability rather than lower level. This fact is found not only in objectivistic researchers but also in constructivistic researchers. Constructivistic approach is more suitable to unstructured studies like humane studies or sociology rather than structured studies like math or physics. Also the goal of constructivistic learning is to increase problem solving ability and to activate cognitive strategies in learning by means of conversations or projects based learning (Issacson, 1992).

Table1. Differences between Objectivism and Constructivism

	Objectivism	Constructivism
Knowledge	Static, Structured Math or Physics	Dynamic, Unstructured Humane studies or Sociology
Reality	Predictable, Manageable, Regular	Not predictable, Complex, Chaos
Properties	Truth or knowledge is absolute one that cannot change.	Truth or knowledge is something meaningful and adaptable to anyone.
Keywords	Understanding, Consistency, memorization	Creation, Construction, application

3. Representation of Multimedia

3.1 By Media Properties

There exist various media and methods for representing information, but considering the properties of information, one medium represents information more adequately than the others. That is to say, the most appropriate media could be selected as long as the exact nature of information is understood.

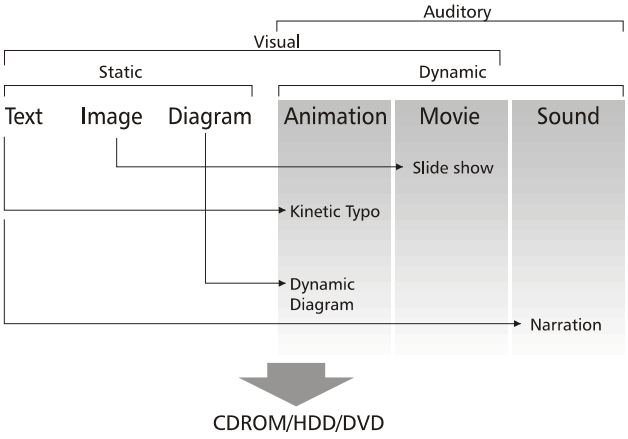

Figure 1. The types of multimedia and the relation of each entities

As shown in Figure 1, multimedia types are classified as text, image, diagram, animation, movie, and sound according to representation methods, and they are restructured by sensory as visual, auditory, haptic, and olfactory or by state as static or dynamic representation. When time variable is added, text as visual and static information

becomes kinetic typo that is similar to animation, or narration that is similar to sound. In different point of view, multimedia types are considered as a physical medium for storing information such as CDROM, HDD, and DVD. But in this research, only soft and conceptual parts of multimedia are considered.

Text has authority reflected in a long tradition of trust and confidence in printed words. The so-called text literacy reflects our experience and tradition to extract information from text. Printed text endures and people perceive it as more stable than screen text. Screen text, on the other hand, can be easily changed and deleted, which also affects the user's trust in its content. Many educators believe that this is an argument against employing CAI. But many factors can contribute to raising the quality of the text in CAI, such as window size, navigation methods, and scrolling to help the reader to orient.

Images can represent complex information at a glance, but the quality of an image can vary greatly according to many factors. In CAI, selecting instructional images that are clear and understandable could optimize their positive effects. The most important functions of images and diagrams in text are shown in Table 2.

Table 2. Roles of images and diagram with text

Categories	Roles	Description
Images	Representation	Graphics of a specific item can explain more effectively than text.
	Perspective induction	An image of a suffering animal for a campaign against animal experiments immediately shows the topic of the text, for example.
Diagrams	Interpretation	To make a difficult text easier to understand.
	Organization	Images can make the structure of the text clearer or explain spatial and structural functions.
	Transformation	Semantic networking tools in CAI consciously use visualization to achieve a cognitive effect to support memorization aspects in a text.

Movie, animation, and simulation have the time varying attribute, which attracts users' attention. This movement makes it possible to demonstrate complex conditions and relationships between actions and events. In virtual reality productions, users can experience a virtual reality by walking through a real-world space, exploring the environment, and zooming in on and examining specific objects.

Audio combines naturally with many visual stimuli, such as video and animation. Sound can make a graphical interface more realistic, giving it an audio texture. In games, audio effect can increase the user's motivation to play by providing alert or feedback for successful actions, and this also can be applied to CAI system.

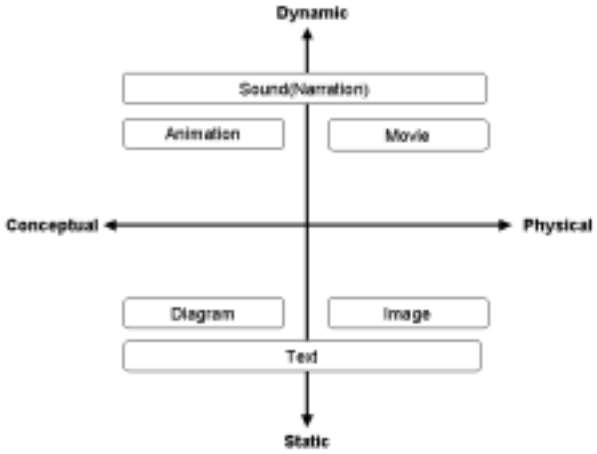

Figure 2. Relation of multimedia types and information properties

The relation of multimedia types and information properties is shown in Figure 2. Static information types are

characterized by state, descriptive attributes, relationships, spatial orientation, or value. Dynamic information types are characterized by procedures, events, causality, and discrete or continuous actions. Text and diagram play important role in conceptual and static information, and in similar way, sound and movie help learners to understand the materials of physical and dynamic information. Diagram and animation are good to explain conceptual information, while image and movie are good to explain physical information, especially facts. The more detailed relation is continued in next part.

3.2 By Contents Properties

The important part of multimedia selection is to analyze the learning tasks for matching presentation forms with learning contents. Merill (1983) suggests four categories of learning contents – facts, concepts, principles, and procedures. Facts are declarative knowledge for memorizing or understanding learning contents, and concepts are description of something already defined by someone else for memorizing or understanding, too. Principles are explanation of rules or relations, and procedures are description of rules of process. Principles and procedures are focused to be applicable to real world on the basis of memorization and understanding. These four types of learning contents are structured with the previous properties of information - conceptual or physical, and static or dynamic. Each of learning contents - facts, concepts, principles, and procedures - can have a static or dynamic form when represented using multimedia. Information types take an important role when selecting appropriate medium in CAI. Most of all, static and dynamic aspects of information is said that the essential factor of media selection. The optimal means of representation must be defined in logical terms for the effective learning in CAI.

As a general heuristic, descriptions of dynamic functionality or a process should be represented dynamically. Similarly, static information contents such as historical facts should be represented with the media of static property. In Table 3, relation of contents properties – conceptual or physical, static or dynamic, fact, concept, principle, and process - and multimedia types – text, image, diagram, movie, animation, and sound - is shown as important(◎) or normal(○).

Table 3. Relation of contents properties and multimedia types (◎:important, ○:normal)

Description	Conceptual / Static				Conceptual / Dynamic				Physical / Static				Physical / Dynamic			
Type	Fact	Con.	Prin.	Proc.	Fact	Con.	Prin.	Proc.	Fact	Con.	Prin.	Proc.	Fact	Con.	Prin.	Proc.
Text	◎	◎	◎	◎					◎	◎	◎	◎				
Image	○								○							
Diagram		○	○	○						○	○	○				
Movie					○	○	○	○					◎	◎	◎	◎
Animation					◎	◎	◎	◎					○	○	○	○
Sound					◎	◎	◎	◎					◎	◎	◎	◎

3.3 By Learner Properties

Young people today are used to computers, and a situation in which they have more control over the speed and order of the teaching sequences can motivate learning. The opposite may apply to older users. Skepticism of new techniques can be a powerful barrier for learning using CAI. While it may be a matter of time until a broader spectrum of the population starts to use and take advantage of computers in daily life, this may only hold for software with simple user interfaces. The trend is toward programs with a large expansion of functionality within a complex structure. For such programs, the problem for older people can be of a cognitive perceptual nature

rather than simply acceptance. In a study that investigate the effect of age for learning systems of varied complexity, groups between 25 to 35 and 50 to 60 years old were better able to capture the system model than 65 to 75 year-age group (M.D. Rama, 1997). The last group also showed no learning effect. Age-related cognitive changes seem to influence the time it takes to learn to use a new system. All users can have a better chance to learn to use domestic product faster if they have an interface style that doesn't rely much on working memory and the capacity to hold spatial information. Another aspect of acceptance is that the pedagogic tradition doesn't adapt to the new possibilities rapidly. We have a long tradition in verbal learning, by representing and retrieving knowledge verbally. People who have a verbal learning style may not be able to take full advantage of multimedia representations. For many people, books have a value that cannot compete with computers. Books are easy to transport, can be personalized, offer comfortable reading compared to a screen, and have texture.

For a long time, users haven't been aware of the quality requirements for software products. This is changing for consumer software and will also change for teachware as it becomes more common. Furthermore, teachware has to match user needs, be attractive and easy to use, and perform effectively to justify expensive development cost.

4. Application on CAI

Integrating multimedia in CAI provides new ways of presenting information that can enhance learning and understanding in various ways. The benefit of CAI is to impart knowledge reliably, fast, and inexpensively. CAI systems offer the learners the possibility of learning at home or in office, thus saving time and effort by not having to travel to another place to learn. In comparison to learning from a book or in classroom setting, CAI can offer the learner a more active role. Active participation is an established precursor to knowledge acquisition, and can be supported with new learning technologies such as BBS, whiteboard, video conferencing and so on. The more tasks related actions that a learning process includes, the higher the retention rate and the greater the ability to transfer the knowledge to new situations. According to the technologies and learning theories which the system based on, CAI systems have different figures, some of them are appropriate for the structured learning contents or others not. The properties and explanations of each CAI system are summarized in Table 4. The more detailed descriptions of each are followed.

Table 4. CAI system and properties of each system

CAI system	Property	Learner	Explanation	Application
Simulation	Constructivism oriented	Expert users	Participatory, Active	Controllable experiment
Tutoring system	Objectivism oriented	Novice users	Passive, Sequential	Basic fact or concept
Hypermedia system	Constructivism oriented	Intermediate users	Active, Nonlinear	Dictionary or Manual Searching, DB Application
Drill and practice	Objectivism oriented	Novice users	Passive, Sequential	Memorization
Information system	Constructivism oriented	Expert users	Active, Creative	Discussion or Survey
Distance learning	Both Objectivism and Constructivism	Intermediate users	Linear or Nonlinear	Available to the various types of contents

An interactive simulation can demonstrate the conditions of actions and events in the real world. It is a flexible learning tool, and from a pedagogical point of view, supports a constructivistic learning philosophy. With simulations, developers attempt to provide a rich environment in which learners can explore freely. Simulation enables two or more learners simultaneously in a learning session, and this encourages cooperative works as a activity of learning. Such an environment places more initiative and control in the hands of the learners. Because the controlling of the learning process is in the hands of learners, the level of learners must be higher than any other kinds of CAI.

Tutoring systems descend directly from the linear programs developed in the 1950s for computer-aided instruction. These systems are encouraged in a dialogue with the learner in preprogrammed steps, and each step represents a different learning goal. The system frequently tests whether the learner has reached the goal, and if so, advances the next learning step. They cover a wide spectrum of different learning applications. By selecting an item on the list, the learner accesses the first of an organized linear series of masks, each of which presents information on the chosen topic step by step. The learner can navigate forward and backward in the actual series. At the end of the series, the learner is tested and receives performance feedback, including error corrections and suggestions to repeat some parts of the session. Tutoring systems support the objectivistic learning philosophy. That is, learners learn by being told and that knowledge is objective and exists independently of the learners. The sequential teaching structure is familiar to learners insofar as it resembles the structured design of a book. The major drawback to such systems is that learners don't have enough control over the procedure.

Hypermedia refers to a multimedia style of hypertext in which nodes may contain graphics, audio, video, and other items in addition to text. This linking capability of hypertext allows a nonlinear organization of the information. The links let learners navigate through the hypertext data set with a pointing device. From a pedagogical point of view, hypertext or hypermedia can support knowledge acquisition in a constructivistic way. This structure lets learners explore an environment for information acquisition according to individual strategies and needs. The feature that learners can explore the system freely is thought to be an advantage of that system and at the same time it could be the greatest disadvantage. Nonlinear navigation can easily result in a lost in hyperspace feeling. This inhibits learning and full use of the knowledge contained in the system. The learner expends cognitive effort to explore the system rather than on the learning material itself. This navigation problem still impedes applying such systems to education.

In drill and practice systems, the computer act as a tester and the learner gives answers one by one. The strategy promotes learning by rewarding correct associations between questions and answers. Such systems prove useful for learning material that requires memorization more than deep understanding.

Information systems present learners with information on a special topic. Users can specify the information shown. Such systems can have a simple structure based on different cards in a data bank, for example. A more complex variant is the example of an intranet in a company, in which different kinds of information that can be utilized in similar projects can be retrieved about the process of certain tasks. This system can be used as a very useful source of information for the expert users, and be a good solution at the last part of curriculum.

Distance learning environments are becoming a normal part of education in many universities. Distance learning environments let learners take part in study programs from remote locations. Opportunities for networked communication and the availability of simple design tools have reduced implementation barriers to distance learning. But distance learning has some technical problems, which are the speed and quality of the transferred

information. Apart from these technical problems, the nature of distance learning systems may harbor two potential traps – the transmission style of teaching, and learning in isolation.

The relation of educational goals and learners' activities is shown in Figure 3, x-direction represents educational goals as applicable or memorable and y-direction represents learners' activities as active or passive. CAI systems in Figure 3 can be classified into two groups, upper-left section and lower-right section. One group is described as applicable attributes of the educational goal and active learner participation in the process of learning, and this group is based on the constructivistic learning theory. While the other group is described as memorable attributes of the educational goal and passive learner participation, and this group is based on the objectivistic learning theory. But memorable-active, and applicable-passive combinations of groups are not appeared yet.

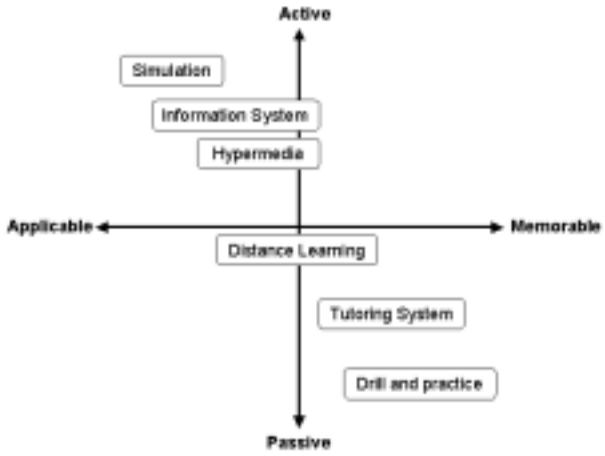

Figure 3. Relation of educational goals and learners' activities

The CAI trend today is toward hybrid learning system, and many different combinations are feasible from the systems mentioned above. For example, the information system functions as the base program and hypermedia and simulation can be integrated in information system. A hypermedia system can serve as an underlying information base and simulations can illustrate and enhance understanding of certain aspects of the material. Combining a simulation system and a tutoring system can mitigate the disadvantages of each system alone. Simulation based systems run the danger of giving the user too much freedom. A simulation alone can be backed up with tutoring information in some form, either by traditional class teaching or by integrating the simulation in CBT system. Tutoring system and simulation support different knowledge structures. Both types of systems impart the same knowledge, but in different ways. The differences are inherent in the design of the systems and the teaching philosophies behind them. Simulation based training induces intuitive knowledge representations from the perspective of experts, whereas tutoring systems induce representations more suited to the novice. Experts are good at doing, but not always in explaining, while novices are good at explaining exact knowledge, but not always in applying it. A combination of the two systems could impart the benefits of both.

5. Conclusions

In this research, the framework such as learning theories and multimedia representation for the development of CAI was carried out, and consideration factors for the appropriate selection of multimedia was applied to various forms of CAI. In general, the learning theory that educational system adopts decides fundamental structure of that system. In CAI, objectivism and constructivism can be identified as comparative approaches, and theses are so different but related each other closely. So it is possible to select the optimal learning theory that most appropriate

for the properties of learners and contents. But considering the sociological and technological changes in our learning environments, recent education values constructivism above objectivism. On the emotional side, multimedia presentations can motivate, challenge, and appeal to learners who like technological innovation and design. Because of the greater motivation provided by the learning environment, learners could be encouraged to spend more time in learning. As in the case of hypermedia system where learners may expend their cognitive effort to explore the system, learners are interested in these emotional effects more than the contents.

Overall, this research proposes optimal methods for CAI according to properties of learners and contents, and these properties consist basic factors for the appropriate representation of multimedia. In the process of learning, simulation, information system, and hypermedia system are appropriate to the group of applicable attributes of the learning goal and active participation of learners, and tutoring system and drill and practice to the group of memorable attributes of the learning goal and passive participation of learners.

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