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OCTR: A Model of Learning Stages[1,2]

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ABSTRACT

This paper describes a model of learning stages called OCTR. Learning under OCTR advances gradually as the degree of social context increases. Furthermore, OCTR can also serve as a framework for describing the cognitive development and motivation of students, categorizing many existing teaching strategies, and better understanding how to introduce meta-cognition and attitude in systems for education.

Keywords: computer aided instruction, intelligent tutoring systems, cognition, meta-cognition, learning strategy, motivation, attitude, system design

I. Introduction

Our learning theories have affected the our design of computer systems for education, and the artifacts we make reflect our theories. For example, being influenced by behaviorism and realizing that the computer can provide an interactive learning environment, many educators adopted the stimulus-response approach in the development of early Computer Aided Instruction systems (CAI). Sometimes, our theories are implicit in our designs. For example, starting in the seventies, Intelligent Tutoring Systems (ITSs), which drew attention of many computer scientists and cognitive psychologists, have been basically modeled after the idea of private tutoring. This model promised to pay better attention to individual student needs (Bloom, 1984); therefore, a substantial amount of ITS research in the eighties was devoted to the study of student modelling. However, since the mid-eighties, the tutor-tutee model has been challenged.

Self and his colleagues first argued that the role played by the computer as an authorized teacher for transmitting certified knowledge should be de-emphasized. They suggested that the computer can be treated as a collaborator (or a co-learner) (Self 1985; Gilmore & Self, 1988; Cumming & Self, 1990; Dillenbourg & Self, 1992). Later on, as an alternative to the one-on-one model, Chan and Baskin (1988; 1990) proposed that the computer can be simulated as two coexisting agents, a teacher and a learning companion. The addition of the learning companion to the traditional ITS model yields collaboration as well as competition. More recently, an inverted ITS model which treats the computer as a student and the human learner as a teacher was suggested by Pathepu, Greer, and McCalla (1991). In summary, whether a collaborative system such as People Power (Dillenbourg & Self, 1992), a learning companion system (LCS) such as Integration-Kid (Chan, 1991), or a learning by teaching system, these approaches all suggest: (i) the computer should personify learning activities explicitly; in particular, one can model an *artificial*

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learner in a system (by simulation or machine learning); (ii) human students make cognitive gains by collaboration, competition, or teaching the *artificial* learner; and (iii) the computer can model multiple agents with different roles, like LCS, forming a small society in learning.

The latter concept seeks to recover the social context that has been lost in most computer-based learning environments. Despite the existence of an artificial learner in the system, this line of research coincides with the current interest in distance learning and computer supported collaborative learning via computer network. Moreover, the advancement of multimedia platforms has provided powerful devices for supporting complicated peer dialogue, gestures or facial expressions, and so on, and makes complex social learning systems more viable than before. But when we began to design a social learning system, LISA[3] (Learning IS Active), that intended to cover the whole repertoire of the student's learning process, we soon discovered that there are occasions when one-on-one tutoring is more effective. Thus, the need for a learning model of learning that incorporates both tutoring and social learning to facilitate system design becomes apparent.

Apprenticeship learning (Collins, Brown, & Newman, 1989; Collins 1991), which has influenced the design of many learning systems, resembles the skill acquisition process of an apprentice from a master. It consists of a set of teaching methods: (i) *modelcing*, where the student repeatedly observes how the teacher carries out a task; (ii) *scaffolding*, where the student is given a support to carry out a task and the support is gradually removed once the student is able to perform the task; (iii) *coaching*, where the teacher involves a whole range of activities: choosing tasks, modelling, providing hints and scaffolding, challenging and offering encouragement, etc.; (iv) *articulation*, where the teachers have a variety of methods for getting students to articulate their ideas and thinking process and; (v)*reflection*, where the student observes his own learning process and makes comparisons with others. While the master-apprentice model of learning does not seem to fit well into the paradigm of sociology of learning, the OCTR model introduced in this paper can be viewed as an extension of the apprenticeship learning model with a richer social context, mimicking the intensive knowledge communication nature of the modern society. Our study differs from other studies of learning, such as the three modes of learning by Rumelhart and Norman (1978), in its emphasis on learning stages and the articulation of a number of learning perspectives.

II. OCTR: A Staged Learning Model

The OCTR model views learning as a staged process. In these stages, learning objectives are defined and social context is incrementally embedded in the learning activities. The model is composed of four stages:

Orientation: in this first stage, the system helps the students relate their prior knowledge of the domain to be learned;

Coaching: this second stage is the same coaching activities as in apprenticeship learning;

Tuning: in this third stage, knowledge tuning is exercised via peer interactions and the teacher plays a less active role; and

Routinization: in this last stage, students solidify their knowledge by continuing to practice, perhaps under some forms of peer pressure.

In the rest of this section, we shall discuss how OCTR can serve as a framework for studying a number of aspects involved in learning; a summary of this is given in Table 1.

1. Cognitive Development

The foremost goal of OCTR is to try to describe the cognitive process of learning. There seldom exists a piece of completely isolated knowledge; or else it could hardly be learnt. As Piaget (1967) pointed out, a student is an active agent who seeks equilibrium between what he/she understands and what he/she experiences in the environment. Thus, in the orientation stage, the objective is to bridge what the student knows and what he/she shall learn by reviving the student's prior knowledge of the subject as it relates to the target task. The related old knowledge can be used as a theory for the student to interpret the new knowledge.

In the coaching stage, the system helps the student establish an initial mastery skill, and the

[3] LISA is an inter-university project sponsored partially by the National Science Council. LISA intends to teach a set of small pedagogical languages for freshmen (Chan & Wang, 1991). The vision of the project is described in Chan (1993).

Table 1. Summary of OCTR

	Orientation	Coaching	Tuning	Routinization
Cognitive Devemopment	prior knowledge connection	knowledge growth	knowledge articulation	knowledge solidification
Motivation	attention, curiosity, excitement	competence, moderate risk	sharing success, self-confidence	drive for survival, challenge, competence, external reward
Teaching Strategies	metaphors, story telling, etc.	modeling, scaffolding, fading	reflection, peer collaboration, retrospection, learning by teaching	assigning rank, compeition game, etc.
Meta-cognition	none	learning strategies, learning stages, meta-knowledge (strategic, control, heuristic), etc.	self knowledge (by teaching peers or self explanation)	self-knowledge (by monitoring peer working)
Attitude	goal, task, expectation, responsibiltity, etc.	enthusiasm, disposition, etc.	open, seek help & input from others, sharing success and failure, accepting making errors, etc.	effort

emphasis here is accretion of knowledge. Scaffolding and fading are essentially the system's control over the student's intellectual functioning: Fading is the cause of the student's internal disequilibrium and scaffolding is the support for reaching an equilibrium state. This process fosters cognitive development.

After the coaching stage, the student should have acquired some initial skill and reached a state of equilibrium again. Once the equilibrium state is reached, what will upset the equilibrium in order for the student to achieve higher levels of intellectual development? There are two ways: (i) By sequencing learning tasks with increasing complexity and diversity so that misconceptions or mistakes are revealed; and (ii) by placing the student in a social learning setting where "cognitive conflict" in the form of different ideas, views, and opinions emanating from peers will force the student to examine his/her thinking and look for alternative perspectives. The first way forces the student to apply what has been learned to multiple contexts. The second way provides an environment where meaning can be negotiated from multiple perspectives. In both ways, students modify their cognitive structure and the environment to their own ends, resulting in better articulated knowledge and a developing abstraction of acquired knowledge. This is the tuning stage.

Several points of social learning worth noting here. First, many details overlooked due to hastiness and first encounter in the coaching stage may be recovered in the tuning stage by shifting the most compelling elements in the stimulus from the coaching stage. This 'decentration' (Piaget, 1967) helps what used to be the secondary aspects be incorporated into the modified and more accurate total perception. Second, collaborative learning is a form of scaffolding since it is the distribution of thinking loading. The result of social interactions such as comparing, evaluating, justifying, and criticizing becomes part of the student's individual knowledge. Finally, peers' different perspectives on the subject can be considered as various versions of the student's own knowledge and are thus another form of reflection in apprenticeship learning. In short, as argued by Vygotsky (1978), the cognitive development process in such an environment is the gradual internalization and personalization of what was originally a social activity.

If tuning is aimed at making the target knowledge a robust part of the student's knowledge, then routinization or automatization through continuous practicing helps the student establish ownership and retention of that knowledge. Routinization empowers students by freeing their minds to be more attentive to other things (Collins, 1992).

2. Qualitative Explanation

We offer a simple qualitative model that explains cognitive development in the OCTR model. The model stems from constructism view (Bednar, et al., 1991; Jonassen, 1992), which holds that there is a real world that we experience. Learners create personal interpretations of the world based upon their past experiences and interactions with the world. Learning is a constructive process of building up an internal representation of knowledge. This representation is free to change constantly and its structure and linkages form the basis of new knowledge development and other knowledge attachment. The emphasis of constructism is on how we *construct* knowledge, rather than on studying the object of our knowledge.

First, we assume that knowledge consists of *units* and *links* (Figure 1). Units are pieces of knowledge and links connect these units. There are strong and weak units (represented by solid and hollow dots respectively) and links (represented by solid and dashed lines respectively). A strong unit represents a piece of fully fledged knowledge[4] and a strong link represents a strong relationship between two units of knowledge. Units can be created. If a unit has no link connected to it, then it can be regarded as deleted. Also, links can be created, deleted, strengthened, or weakened.

In the orientation stage, proper old knowledge is invoked to interpret newly created knowledge; that is, new but weak units are created with weak links connected to prior knowledge units in a similar structure of the prior knowledge. In the coaching stage, knowledge is expanded; that is, many weak units and links are created. Meanwhile, existing units and links are strengthened. In the tuning stage, knowledge restructuring is the main concern; that is, many links must be strengthened, weakened, and even deleted so that units created in the first two stages are better structured and more strongly related to prior knowledge. Finally, in the routinization stage, both units and links are strengthened to ensure their accessibility or usability in the future. Note that when multiple nodes and links are merged to form a strong node, we refer to this node-link model as a recursive model where abstraction can be described as the formation of strong nodes. Also, while we have not considered motivation in this qualitative model, we can regard it as a factor that affects the rate of acquiring knowledge in all of these stages.

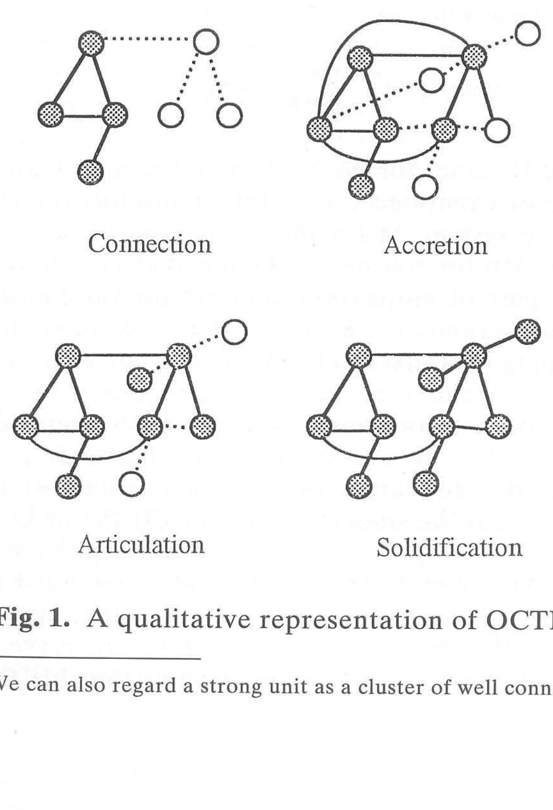

Fig. 1. A qualitative representation of OCTR.

Viewing learning as different stages of constructing knowledge may play a role in interpreting situated learning (Brown, Burton, & DeKleer, 1988). Situated learning addresses domain-dependent learning in a rich context, practical knowledge, authentic activities in realistic settings, etc. In the first two stages of OCTR, situated learning addresses the help of knowledge construction to become 'anchored' (CTGV, 1990) at the proper 'site'. However, on the other hand, the last two stages of OCTR should provide domain dependent learning, abstract and theoretical knowledge by self-explanation or teaching by the learner, and allow decontextualization (Merril, 1991) by justifying knowledge via multiple perspectives given by peers and repetitive use of knowledge in multiple contexts, etc. It is this process that enables the student's knowledge to be 'transferable' from site to site. Contextualization and decontextualization applied at proper learning stages are both essential in preventing acquiring 'inert' knowledge — encapsulated knowledge that is rarely accessed or used again in the future (Whitehead, 1916).

3. Motivation

Motivation is a factor that determines

[4] We can also regard a strong unit as a cluster of well connected units.

whether the students *will* do, not just whether they *can* do. The general goal of motivation is to design learning environments engaging enough so that the students are able to learn without feeling that they are making effort to learn, and students will learn even better if the system can trigger achievement-seeking behavior. In the orientation stage, the key to motivation is to draw the students' attention, promote their initial interest in the subject, and to revive them as curious, reaching-out, and experimenting individuals. Also, an atmosphere of readiness involving focusing attention and developing expectation can be acquired at this stage, like a prelude that helps the audiences prepare their minds to better enjoy a piece of music. To foster intrinsic motivation towards the subject in this stage, self-paced activities such as exploration or discovery games can be used, letting the students can actively produce effects on the environment (Woodworth, 1918). In addition, helping the students understand the importance and significance of the material and how it relates to real life may create a sense of excitement.

In coaching, the goal is to nurture the student's intrinsic motivation towards the subject. Intrinsic motivation, in the view of some researchers, is the need to encounter a moderate difference between the student's experience and his/her environment (Berlyne, 1978), while others (Woodworth, 1918) see it as the need to feel competent; that is, the ability to deal effectively with the surroundings. To this end, it is important to sustain a moderate risk in the learning task while still keeping it within the capacity of the student.

In the tuning stage, social learning protocols such as peer collaboration and discussion can be adopted. During collaboration, success in solving a problem is considered to be the success of each participating student and is thus a shared achievement. Also, collaboration contributes to students' self-confidence because it relieves insecurity when students see others struggle and realize that difficulties are not unique to them. Although it is still not clear what role motivation can play in social learning settings, the existence of a peer in learning may constantly stimulate a moderate difference which in turn arouses the student's innate need of competence (Chan, 1992).

In the routinization stage, learning tasks are not as challenging as before. Incentive is needed. Applying extrinsic motivation such as external rewards is one way. Another way is by means of competition that forces the students to evaluate their ability relative to their peers' in a social comparison process while at the same time provoking them to quest for survival — a phenomenon of the Darwinian "survival of the fittest." Higher competence information leads to higher intrinsic motivation while lower competence information results in lower intrinsic motivation. A recent informal evaluation of the Distributed West system shows that three times more students prefer learning under human competition to collaboration (Chan, et al., 1992; Chan, Chung, & Hue, 1992). This shows that competition is a powerful motivator. Finally, the relative perception of the student, which determines his/her motivational state, has to be modeled for guiding the system.

4. Quantitative Explanation

If knowledge can be constructed, then it must exist in some quantity that is measurable. For this reason, we propose a quantitative OCTR model that embodies both cognitive and motivational perspectives. *Learning load* (LL) defined by the formula below is a simple relationship of cognition and motivation. Although the formula is not ready to be actually measured operationally, it helps explain an individual's learning ability in the stages of coaching, tuning, and routinization.

$$\text{Learning Load} = \frac{(\Delta D - S)}{D \times M} + M_p$$

Here D stands for the background domain knowledge or experience, S for the scaffolding offered by the system, M for the motivation of the student, Mp for the peer pressure that is regarded as a part of motivation, and ΔD for the knowledge increment. Suppose that the maximum learning load that can be attained by an individual is a constant, then the overall objective of the system is, at any time, to maintain the detected LL as close to the student's maximum as possible, but not larger than the maximum (which means that the student cannot handle the task).

In all stages, we would like to keep the student highly motivated; that is, M is intended to be as large as possible. At the beginning, that is, during the orientation stage, we try to increase D by relating or activating as much as possible the student's prior experience. This strategy agrees with Kolodner's observation (Kolodner, 1983) that a domain expert learns faster than a novice does. Thus, one can learn more effectively if one has stronger experience. Note that, from the formula, if D and M are large, ΔD can be increased considerably. Thus, orientation seeks to enhance LL and prepare for the next three stages.

The purpose of coaching is to let students learn to tackle a complete task. However, according to Martin's law (Winston, 1992), one cannot learn anything unless one almost knows it already. This means that coaching has to be in small steps. However, if the steps are too small, we can hardly teach anything new. The problem is how to maintain ΔD, the knowledge increment, at a level where the student can learn without degenerating intrinsic motivation from the task. However, at the beginning of this stage, ΔD is too large for the student to handle a complete task alone; thus, an appropriate amount of scaffolding, S, should be exerted to reduce LL. Note that, modelling where S is very close to ΔD can be regarded as the extreme case of scaffolding. Also, fading begins as coaching proceeds, which means that S decreases.

Next, in the tuning stage, strengthening the integration of new knowledge with prior experience is the area of concern. There are two aspects here. First, peer collaboration (task sharing) can be regarded as a form of scaffolding, S, especially when the learning tasks are getting complex during this stage. Second, through peer discussion, ΔD in the form of cognitive conflicts is generated. This ΔD is a part of the personal domain knowledge D regarded as 'biased' in the social community (Sack, Soloway, & Weingrad, 1993). Through reconciliation, ΔD vanishes and is absorbed into D, and the process repeats when other issues arise. Note that, ΔD is no longer as large as during the coaching stage; yet, each student has to think and contribute a piece of the discourse. This mutual responsibility and expectation yields a certain amount of peer pressure. That is, when the first term of LL lessens, the second term, M_p, emerges.

In the routinization stage where the emphasis is to solidify the learned knowledge, both ΔD and S have declined; that is, the first term of LL vanishes. To maintain the momentum of learning, M_p, emanates to become a dominant term. In other words, students are engaged in a competitive environment where their innate instinct for survival drives them to face the challenge.

5. Teaching Strategies

The stages of OCTR bring together most useful teaching strategies, and place them in a learning repertoire with increasing social elements. It begins with teacher-controlled description or self-paced exploratory learning, and advances to one-on-one coaching, and then to complex social learning settings.

For orientation, we may carefully choose examples in real life or use metaphors to bridge the gap between a new concept and prior knowledge. Similarly, we can organize the material in a story form to invoke the students' experience and enable them to preliminarily grasp the concept with an analogical model. Perhaps the most preferred way in this stage is discovery learning in which students explore and gain experience on their own through a simulation game or microworld.

As for coaching, it personalizes the interaction first by modelling, then by scaffolding and fading alternatively. In a computer-based learning environment, scaffolding can be in the form of specially designed devices, depending on the particular material to be learned or the help or hints offered by the system.

Reflection, a part of apprenticeship learning, is a form of tuning by replaying and reviewing the student's learning process and achievements. Another form of tuning is through social interaction where social context can be structured by various protocols with a broad spectrum of possible variations on the number and identities of the agents (Chan & Baskin, 1990). Each of these variations gives rise to particular cognitive issues in the student's learning. Finally, retrospection, rather than reflection, should also be instituted in this stage in the form of abstract reformulation of what has learned.

Apart from external rewards, a method for routinization is to design a problem solving game in which the acquired knowledge is a part of the means to solve the problem, such as the classical West program (Burton & Brown, 1979). We may also assign a rank to the student's ability or use a score board to record the achievements of different students as an explicit way for the student to compare himself or herself with others. An intensive competitive method is to apply real time social pressure in a distributed learning environment such as the Distributed West system (Chan, et al., 1992). In such environments, group-to-group is preferable to one-to-one since success and failure can be shared, instead of having an individual take full responsibility.

6. Meta-Cognition

Due to the rapid progress of new technologies, what we learn today will inevitably become obsolete someday in the future. Learning "how to learn" in preparing for future job training is thus becoming more important than ever. Within the framework of OCTR, meta- and self-knowledge can be learned in the last three stages. In the coaching stage, meta-knowledge such as strategic, control, and heuristic knowledge can be made explicit by the coach in modelling. Learning strategies such as those discussed above and learning stages of OCTR can all be introduced by the coach as part of the student's learning experience. Learning self-knowledge seems to be best realized in the tuning stage where the student can see how peers deal with the same problem and compare different ways of doing things. This allows the students to develop new ways of seeing and talking about what they do (Collins, 1992). An interesting protocol at tuning is reciprocal teaching (Palincsar & Brown, 1984) where an implicit cognitive task is partitioned into several explicit sub-tasks performed by different students who take turns undertaking each of these sub-tasks. This is an effective form of peer discussion protocol. Learning by teaching to encourage self explanation can be utilized at this stage too. Finally, for routinization, the Sophie game protocol (Brown, Burton, & DeKleer, 1982) may be adopted where one student is working on one computer while his/her activity is monitored by another student, probably via another computer.

7. Attitude

There is an old Chinese adage stating that the Five Educational Objectives are *Ethics*, *Knowledge*, *Athletics*, *Sociability*, and *Art*. Among them, knowledge has become so important that schools merely function as factories to produce massive numbers of graduates equipped with necessary knowledge to meet the demands of society. One characteristic of the apprenticeship learning used in the old days was that the student could learn things like personality, temperament, disciplines, etc., directly from his/her master. A mission of future intelligent learning systems is perhaps to embody ethics, sociability, attitude, etc. However, this mission would be controversial because these elements are beyond our domain knowledge. This is analogous to the well-known debate a thousand years ago in China during the Tang Dynasty on whether literary work was for the sake of morals or just for literature itself. It is also potentially difficult to implement such as scheme, for it is not easy to identify what is right or wrong in ethics and sociability, etc.; since these elements are on the brim, they can only be touched at opportune moments while learning the domain knowledge.

In the orientation stage, the system helps the student set up goals and expectations, so that learning becomes a clearly defined task to achieve an aim. In the coaching stage, the coach is talking around the student and may encourage the student to try more difficult problems without being afraid of failing. Besides, the coach's valuable learning experience, enthusiasm, vigour, etc., can also be passed on to the students. In the tuning stage, collaboration helps the student develop an attitude that is more open and willing to seek out help and input from others, and also helps the student learn to share success and failure with others. In addition, by observing peers at work, the student will learn that making errors is a natural phenomenon in learning. In the last stage, routinization, some students may be inhibited or discouraged rather than motivated by competitive situations if they believe that making errors makes them 'dumb' (Collins, Brown, & Newman, 1989). Thus, the value of effort, not ability or results, should be emphasized (Anderson, 1992). Society is indeed filled with competition and collaboration, and students have to learn to face them.

Students' attitude is the outcome of their internal beliefs. Apart from the didactic instruction discussed above, it is important to represent and detect students' wrong beliefs (such as making mistakes makes one dumb) in the system.

III. System Design with OCTR

There is a firm link between a learning model and the prescriptions for practical system design. We show this by highlighting the OCTR-Tree architecture that we are building for the LISA project. OCTR adopts the assumptions of

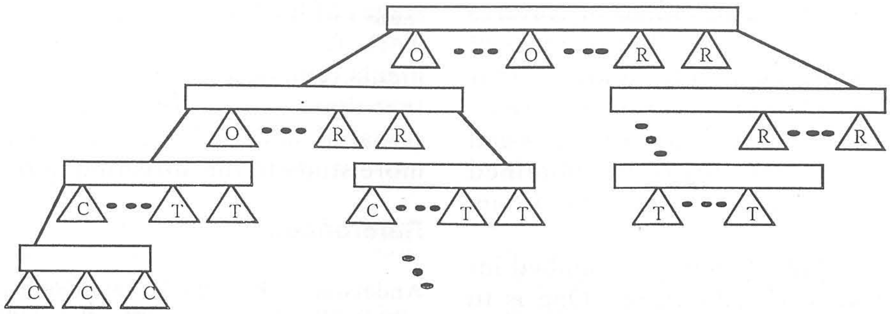

Fig. 2. OCTR-tree architecture.

Curriculum-Tree knowledge-based architecture (Chan, 1992) where the domain knowledge structure is isomorphic to the learning goal hierarchy.

In this curriculum hierarchy, each node can possess a cluster of episodes. An episode is a small unit of learning activity, usually having a beginning and an end. Based on different stages of the OCTR model, these episodes are classified into O, C, T, and R. There is no strict distinction among different stages of OCTR and the distribution of the episodes in the tree is iteratively spiral (Figure 2).

IV. Discussion

We have shown that OCTR is a common thread of more specific learning theories such as motivational considerations, situated learning, and social learning, and it makes them easier to present, analyze, and contrast. In addition, OCTR can be used to compare some phenomena. For example, from the functional point of view, traditional CAI systems seem to focus on orientation and routinization, and ITS research concentrates more on coaching. This is the case for ITS partly because there are more intriguing AI issues, such as student modelling in the coaching stage than in the orientation and routinization stages. Social learning, on the other hand, may contribute to tuning and routinization. Thus, if all stages are equivalently significant in learning, then OCTR unifies the different addresses of these communities.

OCTR can also serve as a framework to compare different educational practices in the East and the West. In the competitive educational systems developed in some Asian countries, where survival in public examinations is the main objective of almost all students, the emphasis is mainly on modelling (the first part of coaching) and routinization, leaving other parts of coaching and tuning unattained. However, many Asian families employ private tutors for their children. In the West, orientation and tuning seem to be key parts of the classroom teaching. While orientation and tuning encourage independent thinking and innovative ideas, inadequate emphasis on routinization will result in the decline of the students' performance in examinations. This difference in educational philosophies partly reflects the cultural difference between the West and the East.

It is interesting to note that no system known has ever paid equivalent attention to all four stages of OCTR. The generative learning illustrated in the Jasper series (CTGV, 1990), for example, emphasizes on the orientation stage of OCTR. It is a sequence of videodisc based adventures designed to motivate students to think and reason about complex, real life problems. These problems are embedded in the contexts of the adventure stories presented in the videodisc. 'Anchored' in these contexts, students' curiosity is aroused and they search data from the story, analyze data, and solve problems, usually with the help of a human teacher. Thus, while the contexts of the adventures effectively supports the orientation stage, the coaching stage requires human teachers. However, a recently developed intelligent tutoring system, Adventure Player (Crews, Biswas, & Bransford, 1995), supplements this need at the coaching stage when students solve the Jasper problems. Nevertheless, Jasper's experiments do not touch much about the tuning and the orientation stages. KIE (Bell, Davis, & Linn, 1995), a learning environment on Internet, on the other hand, stresses on the tuning stage. It provides a set of tools to help students access information and receive social supports in discussing complcx scientific ideas. In fact, on Internet, it is possible to develop various kinds of features to facilitate the development of all four stages of OCTR. This is because any feature that standalone systems provide can also be transferred to the Internet, in addition to the social learning experience that might be obtained through Internet (Chan & Chou, in press; Chan, in press).

There seems to have two ways to embed intelligence in a system for education. One is to facilitate system designers to build systems that can take into account our learning theories in a general architecture, such as the OCTR-Tree. The other is to ensure individualization by student modelling. Constructivism considers learning a construction process of personal interpretation of the world. This implies that the content of a cognitive structure is unique to an individual student; hence this assumes infinite variations and, therefore, does not favor strong student modelling unless experience of all students can be modelled or constrained. However, we feel that there is at least a need of weak student modelling to detect and bring individual students' 'biased' knowledge back to within the boundary accepted by the larger community. Furthermore, the horizon of student modelling research should be broadened: student modelling = cognition + motivation + meta-cognition + attitude, like our discussion of the OCTR model above. For motivation, there have been some initial attempts (Soldato, 1992); for social learning, even though there are a number of prototypes, many problems remain; for meta-cognition, some discussion can be found in the literature, but few systems have been implemented; and for attitude, not much discussion is even available in literature. Therefore, this extended notion of student modeling is undoubtedly more challenging.

Perhaps, from the system design's point of view, the most important contribution of OCTR is that it offers *learning completeness.* By this we mean that a model of learning that subsumes all the learning sub-processes of the student; and shows how learning is taking place with clear and objective indications, both microscopically and macroscopically. Moreover, this learning completeness underlies *learning soundness.* By this we mean during the design process, the model facilitates identification of goals and justification of teaching strategies in developing an approach toward the goals. Of course, whether the OCTR model can accurately and sufficiently describe the stages of human learning and be a 'useful' framework for designing effective learning environments remain to be tested. Nevertheless, we feel that there is a pressing need for this direction of research, and we hope that our work will initiate more study in this direction in the future.

References

Anderson, J. R. (1992). Intelligent tutoring and high school mathematics. *The Proceedings of 2nd International Conference of Intelligent Tutoring Systems* , Lecture Notes in Computer Science, Springer-Verlag.

Bednar, A. K., Cunningham, D., Duffy, T. M., & Perry, J. D. (1991). Theory into practice: How do we link? In G. Anglin (Ed.), Instructional Technology: Past, Present, and Future, Denver, CO: Libraries Unlimited.

Bell, P., Davis, E., & Linn, M. (1995). The Knowledge Integration Environment: Theory and Design, *The first International Conference on Computer Support for Collaborative Learning*, Indiana, USA, 14-21.

Berlyne, D. E. (1978). Curiosity and learning. *Motivation and Emotion*, Vol. 2, 97-175.

Bloom, B. S. (1984). The 2 sigma problem: the search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher*, Vol. 13, 4-16.

Brown, J. S., Burton, R. R., & DeKleer, J. (1982). Pedagogical, natural language and knowledge engineering techniques in SOPHIE I, II, and III. In D. Sleeman & J. S. Brown (Eds.), *Intelligent Tutoring Systems, New York*: Academic Press, 227-282.

Brown, J. S., Collins, A., & Duguid, P. (1988). Situated cognition and the culture of learning. *Educational Researcher*, **18**(1), 32-42.

Burton, R. & Brown, J. S. (1979). An investigation of computer coaching for informal learning activities. *International Journal of Man-Machine Studies* , Vol. 11, 5-24.

Chan, T. W. (1991). Integration-Kid: a learning companion system. *The Proceedings 12th International Joint Conference on Artificial Intelligence* , Sydney, Australia, Morgan Kaufmann Publishers, Inc., 1094-1099.

Chan, T. W. (1992). Curriculum tree: a knowledge-based architecture for intelligent tutoring systems. *The Proceedings of 2nd International Conference of Intelligent Tutoring System*s, Lecture Notes in Computer Science, Springer-Verlag, 140-147.

Chan, T.W. (in press) Learning Companion Systems, Social Learning System, and Global Social Learning Club. Invited Talk, World Conference on Artificial Intelligence in Education, Washington, DC, USA, *Journal of Artificial Intelligence in Educaion* , to appear.

Chan, T. W. & Baskin, A. B. (1988). Studying with the Prince: the computer as a learning companion. *Proceedings of International Conference of Intelligent Tutoring Systems*, June, Montreal, Canada, 194-200.

Chan, T. W. & Baskin, A. B. (1990). Learning companion systems. In C. Frasson & G. Gauthier (Eds.) *Intelligent Tutoring Systems: At the Crossroads of Artificial Intelligence and Education*, Chapter 1, New Jersey: Ablex Publishing Corporation, 6-33.

Chan, T.W. & Chou, C.Y. (in press). Exploring the Design of Computer Supports for Reciprocal Tutoring. *Journal of Artifical Intelligence in Education*, to appear.

Chan, T. W., Chung, Y. L., Ho, R. G., Hou, W. J. & Lin, G. L. (1992). Distributed learning companion systems — WEST revisited. *The 2nd International Conference of Intelligent Tutoring Systems*, Lecture Notes in Computer Science, Springer-Verlag, 650-643.

Chan, T. W., Chung, Y. L. & Hue, C. W. (1992). Evaluation of distributed learning companion system. *Proceedings of East-West Conference on Emerging Computer Technologies in Education*, Moscow, 56- 59.

Chan, T. W. & Wang W. C. (1992). Problem-solving model approach for teaching multiple introductory programming languages. *Proceedings of East-West Conference on Emerging Computer Technologies in Education*, Moscow, 51-56.

Cognition and Technology Group at Vanderbilt (1990). Anchored instruction and its relationship to situated cognition, *Educational Researcher*, **19**(3), 2-10.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: teaching the craft of reading, writing and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser*, Hillsdale, NJ: Lawrence Erlbaum Associates Publishers 121-138.

Collins, A. (1992). Design issues for learning environments. In S. Vosniadou (Ed.) *Psychology and Educational Foundations of Technology-Based Education*, New York, Springer Verlag.

Crews T., Biswas, G. & Bransford, J. (1995). AdventurePlayer: macrocontext plus microworlds. *The proceedings of 7th World Conference on Artificial Intelligence in Education*, Washington, DC, USA, AACE, 381-388.

Cumming, G. & Self, J. (1990). Collaborative intelligent educational systems. In D. Bierman, J. Breuker, & J. Sandberg (Eds.), *Artificial Intelligence and Education*, Amsterdam: IOS, 73-80.

Dillenbourg, P & Self, J. (1992). People Power: a human-computer collaborative learning system. *The Proceedings of 2nd International Conference of Intelligent Tutoring Systems*, Lecture Notes in Computer Science, Springer-Verlag, 651-660.

Gilmore, D. & Self, J. (1989). The application of machine learning to intelligent tutoring systems. In Self, J. (Ed.) *Artificial Intelligence and Human Learning, Intelligent Computer-Assisted Instruction*, New York: Chapman and Hall, 179-196.

Jonassen, D. H. (1992). Objectivism vs. constructism: do we need a new philosophical paradigm? *Educational Technology: Research and Development*. Vol. 39, No. 3, 1992, 5-14.

Kolodner, J. L. (1983). Maintaining organization in a dynamic long-term memory. *Cognitive Science*, **7**, 243-280.

Merril, M. D. (1991). Constructism and instructional design, *Educational Technology*, May 1991, **31**(5), 45-53.

Palincsar, A. S. & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and monitoring activities. *Cognition and Instruction*, **1**, 117-175.

Palthepu, S., Greer, J., & McCalla, G. (1991). Learning by teaching. *The Proceedings of the International Conference on the Learning Sciences*, AACE, 357-363.

Parkes, A. P. & Self, J. A. (1988). Video-based intelligent tutoring of procedural skills, *International Conference of Intelligent Tutoring Systems*, June, Montreal, Canada, 454-461.

Piaget, J. (1967). *Biology and Knowledge*. Paris: Gallimard.

Rumelhart, D. E., & Norman, D. A. (1978). Accretion, tuning, and restructuring: three modes of learning, In J. W. Cotton & R. L. Klatzky (Eds.), *Semantic Factors in Cognition, Hillsdale, NY: Lawrence Erlbaum Associates*, 37-53.

Sack, W., Soloway, E., & Weingrad, P. (1993). Re: Writing Cartesian student models, *Journal of Artificial Intelligence in Education*, Vol. 3, No. 4., 381-400.

Soldato, T. D. (1992). Detecting and reaction to the learner's motivational state. *The 2nd International Conference of Intelligent Tutoring Systems*, Lecture Notes in Computer Science, Springer-Verlag, 567-574.

Self, J. A perspective on intelligent computer-assisted learning. *Journal of Computer Assisted Learning*, Vol. 1, 159-166.

Whitehead, A. N. (1916). *Address to the British Mathematical Society*. Manchester, England.

Winston, P. H. (1992). *Artificial Intelligence*, 3rd Edition. Addison Wesley.

Woodworth, R. S. (1918). *Dynamic Psychology*. New York: Columbia University Press.

OCTR: A Model of Learning Stages

OCTR：一個學習階段的模型

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摘　　要

此論文描述一個稱爲OCTR的學習階段模型，在此模型下，學習過程中不同階段的社會內涵會逐漸增加。此外，OCTR並可作爲一個架構，用在電腦輔助學習系統上來描述學生的認知發展及動機，並可以把教學策略分類，以及增強了解如何引入後設認知及學生的學習態度。