The Role of ICT in a Constructivist Approach To the Teaching of Thinking Skills

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Introduction

Singapore has a strong education system and one that is widely recognised for having produced generally high levels of academic achievements among students. However, there has been a concern among the political leaders with regards to the kinds of students produced by the system. The general perception is that the system was producing students who were muggers rather than critical and creative thinkers. The increasing number of students scoring distinctions at the "O" and "A" level examinations indicated that the students were only "exam smart", extrinsically motivated by grades, and who relied heavily on teachers' support and home tuition. While a small number of Singapore's top students have participated in international competitions and have succeeded, there are also many more students who are lagging behind in the schools[1]. Gardner has lamented that "successful" students[2], in spite of their high grades and accolades from their teachers, "typically do not display an adequate understanding of the material and concepts with which they have been working" (1991: 3).

The political leaders believe that the economic well-being, even the survival, of the country depends on the people's ability to cope with the changes brought about by globalization and the rapid development in technologies. Singapore believes that the development of thinking individuals, and the learning of creative thinking and learning skills are essential[3]. Singapore "must get away from the idea that it is only the people at the top who should be thinking, and the job of everyone else is to do as told" (Goh, 1997). Another reason why students should become good thinkers is that good thinking is a prerequisite for good citizenship[4] (Nickerson, 1987; Glaser, 1985).

In 1997, the Ministry of Education undertook a fundamental review of its curriculum and assessment system to see how the schools can better develop the creative thinking and learning skills required for the future. Schools were encouraged to move students away from a mere mastery of content and to emphasise instead learning and thinking skills which would help them think critically and creatively[5]. Thinking skills, based on Bloom's (1956) taxonomy of educational objectives, are now being taught in primary schools (Burgdorf et al., 1999).

This article looks at what thinking skills are and how they can be taught in schools using a constructivist approach. The use of information and communication technologies (ICT) to teach thinking skills in a constructivist learning environment has not been explored by local schools. Indeed various types of ICT-based tools are available to help students to think, to learn, to collaborate and to communicate. The challenges facing the teachers who are experimenting with the constructivist approach in teaching learning skills will also be examined.

Taxonomies of Thinking

In the minds of many educators, the top three levels of Bloom's taxonomy (analysis, synthesis and evaluation) are the higher order thinking skills. Some educators feel that the next two levels, comprehension and application, should also be included as higher order thinking skills. Whatever it is, Bloom's taxonomy serves to remind that there is more that schools could be doing than just promoting recall (misleadingly called knowledge), comprehension and application. One of the more popular contemporary psychological conceptions of thinking is Gardner's multiple intelligences. Gardner's theory of multiple intelligences (Gardner, 1983) contends that there are seven different types of intelligences and most individuals use most or

all of these kinds of thinking, with varying skills. When people are involved in complex learning tasks, they use combinations of these different kinds of thinking.

The issue of critical thinking emerged during the 1970s as an antidote to reproductive, lower order learning (Paul, 1992). Reproductive learning, resulting from memorizing and regurgitating what the teacher or textbook says, leaves the students with fragments of information that are not well connected or integrated. Paul equates meaningful thinking with critical, logical thinking -- "disciplined, self-directed thinking" (ibid. : 9). Paul's conception of critical thinking, is very similar to the traditional model of Ennis[6] (1987). There are numerous other conceptions of critical thinking[7].

Jonassen et al. believe that the Iowa Department of Education's (1989) Integrated Thinking Model[8] is one of the most comprehensive and useful models of critical thinking. The model has three basic components of complex thinking: content/basic thinking, critical thinking and creative thinking. Complex thinking, the synthesis of content, critical and creative thinking includes the "goal-directed, multi-step, strategic processes, such as designing, decision-making and problem-solving. This is the essential core of higher order thinking, the point at which thinking intersects with or impinges on action" (Iowa Department of Education, 1989: 7). It makes use of the other three types of thinking in order to produce some kind of outcome – a design, a decision, or a solution.

Swartz et al. (1998) have mapped out five domains of thinking, namely, (a) critical thinking, which consists of skills in assessing the reasonableness of ideas; (b) creative thinking, which consists of skills at generating ideas; (c) classification and understanding, which consist of skills at clarifying ideas[9]; (d) decision making; and (e) problem solving. The first three domains are thinking skills[10] while the domains of decision making and problem solving are the thinking processes. Swartz and Parks observe that the teaching of the thinking skills will not be complete if students are not trained to use them in decision making and problem solving (1994 : 7-8). The thinking skills are not used in isolation. Many thinking tasks people face in their lives and professional work involve decision making and/or problem solving and that is when the three categories of thinking skills are required. Original solutions to problems need to be generated, decisions have to be based on relevant information and the reasonableness of each option has to be assessed in order to select the best one. Students should be shown how the thinking skills are connected with good decision making and problem solving.

Thinking Skills Programme in Singapore Schools

There was in fact an early attempt in 1987 to introduce Bono's CoRT programme into Singapore schools[11]. In 1995 a new programme based on Marzano's *Dimensions of Learning* (1992b) was introduced into five secondary schools as a pilot project. The aims[12] of the new programme were to enable students to: (a) acquire and understand core thinking skills and the processes involved in using them; (b) apply these skills in the learning of content subjects and in real-life decision making and problem-solving situations; and (c) develop positive habits which would help them become critical, creative and self-regulated learners (CPDD, 1998a). The new programme was considered more useful and effective because apart from the explicit teaching of thinking skills, these skills were to be infused into the respective subjects. The new programme also emphasised the kinds of positive habits and attitudes which would support and complement (Han, 1999: 681) the thinking skills that the students would acquire. This was a deliberate attempt to help students develop "critical, creative and self-regulated thinking" (Chua & Leong, 1998: 1). It was planned for all secondary schools to use this programme by the year 2000 (Han, 1999).

Eight core thinking skills[13] are incorporated into Marzano's *Dimension of Learning* framework (1992a, 1992b). Apart from teaching the skills, teachers will have to create a

conducive climate according to the framework. The framework is essentially a model of instruction based on the idea that learning involves five types of thinking[14] (Marzano, 1992a: 22). Marzano, like Swartz et al, believes that thinking skills make sense only in the context of domain-specific content and hence such skills should be taught in the context where students are learning about the content. To them, thinking skills should be infused into the teaching of the curriculum[15]. In contrast, de Bono and Beyer believe in direct or explicit instruction where teachers can make thinking the subject of instruction, focus on the key attributes of the cognitive operations that constitute thinking, and provide continued explicit instructions and guided practice in how to execute these operations in a variety of contexts for a variety of purposes (Beyer, 1987: 5). Beyer recommends that children engage overtly in metacognition. Teachers should follow specific steps in the explicit teaching of thinking skills[16] (ibid.: 59). It is interesting to note that Beyer's model is advocated as a substantial part of the new Thinking Programme in spite of the adoption of Marzano's framework and Marzano's preference for a content-related approach to teaching thinking[17].

The Thinking programme is designed so that the thinking skills will be taught to Lower Secondary schoolchildren over a two-year period. One part of the programme will be the explicit teaching of thinking skills in a non-curricular context. Schools are required to spend one period (35 minutes) a week on this. The other part of the programme involves the infusion of thinking skills into the core subjects like English, Science, Mathematics, Geography and History. The programme developers recommend that about thirty per cent of the curriculum be spent on this. The rationale is that, not only will these infusion lessons reinforce the thinking skills explicitly taught, these will also help students to acquire a deeper understanding of the core subjects.

Constructivist Learning Theories

Although innovative ideas on teaching and learning have been progressively introduced over the past few decades, traditional views have been difficult to change. Such views often consider students as "empty vessels" waiting to be filled with knowledge. Students are now learners who come to the classroom with their unique backgrounds, experience, conceptual understanding, learning styles and personal circumstances. Teachers now become learning facilitators rather than reservoirs of knowledge. Psychology of learning has shifted from behaviorism[18] to cognitivism[19] to constructivism. A brief review of constructivist theories will first be made before looking at what a constructivist learning environment for developing thinking skills should be like.

The guiding principle of constructivist learning theories is the learner's own active initiative and control in learning, and personal knowledge construction, i.e. the self-regulation of learning[20]. The student does not passively take in knowledge, but actively constructs it on the basis of his/her prior knowledge and experiences (Piaget, 1972). From the pedagogical point of view, the learner's learning activities should be directed at examining his own prior conceptions and relating it to the new knowledge. The learning environment should provide the learner with opportunities to test and try out his new conceptual understanding in various applied circumstances like problem solving. Constructivism can therefore be contrasted with objectivism, the traditional view that knowledge is an external entity with an absolute value which can be transferred from teacher to learner (CTGV, 1993; Duffy and Jonassen, 1992; Clayden et al., 1994).

Reflection is a psychological thinking process that relates to active learning experiences. Reflective thinking will help learners make sense of what they have experienced and what they know. A learner encounters a situation, acts on it and then thinks about what he has done, makes inferences from the experience, determines implications, and retains the experiences and reflections. According to Coombs and Smith (1998), reflective skills are considered to be a form of "conversational constructivism" requiring the person to

conversationally deconstruct and reconstruct his/her learning experiences in order to arrive at a new model of understanding. This process is considered to be the hallmark of "the reflective practitioner" by Schon (1987) and Boud (1985).

Radical constructivism (von Glasersfeldt, 1989) has been criticised for separating knowledge from the situations in which it is learned and used (Brown, Collins & Duguid, 1989). According to the so-called socio-constructivist perspective, knowledge, being a product of activity, is situated in context and culture. Knowledge is constructed and communicated through culture and social institutions, and therefore the dimensions of constructivist learning theories can be differentiated by examining the significance of the individual and the environment in the process of knowledge construction.

It was Vygotsky (1978) who pioneered a sociocultural approach to understanding cognitive processes in childhood development[21]. Instead of focusing his research on uncovering the dynamics of mental activity in a person, he studied how social and cultural interactions were critical to cognitive functions. In fact, he believed that it is the need to interact and communicate in sociocultural context that makes human cognitive development intellectual and distinct from animal cognition. By highlighting the effects of social interactions on cognitive development, Vygotsky revealed a critical role that external activities play in sparking internal mental constructions[22]. Understanding this interplay is at the heart of the paradigm of constructivism. Vygotsky's emphasis on the social level in all higher order functions has invited criticisms from constructivists arguing that many mental structures evolved before being exposed to the socio-cultural milieu (Bereiter, 1994; Carey & Gelman, 1991). It appears then that the social and the individual areas of intellectual development are both critical areas to consider. "Each of the two perspectives, the socio-cultural and the constructivist, tells half of a good story, and each can be used to complement the other" (Cobb, 1994: 17).

Vygotsky's (1978) *Zone of Proximal Development* (ZPD) emphasises his belief that learning is fundamentally a socially mediated activity. This zone is defined as the distance between a child's "actual developmental level as determined by independent problem solving" and the higher level of "potential development as determined through problem solving" under adult guidance[23] or in collaboration with more capable peers (Vygotsky, 1978: 86). Vygotsky argued that instruction should be tied more closely to the level of potential development than to the level of actual development.

Wilson's (1996) and other researchers' ideas on learning environment, adapted from the constructivist learning theory form a synthesis on the organization of learning and teaching. These ideas are mainly based on the concepts of situated learning (Lave & Wenger, 1991) and socially distributed cognition (Solomon, 1993) and they aim at turning learning situations into challenging and interesting projects for students to try to solve authentic problems in. Although it is the students themselves who construct and test their own conceptual understanding, the community of learners and interactions with different cultures and expertise have a notable bearing on the quality of learning (Brown & Campione, 1996). This view emphasises the significance of a communication environment : the aim here is to create the kind of community of learners that enhances the construction of new knowledge and skills instead of just trying to manage already acquired knowledge. A common misinterpretation of constructivism is that if learners end up with their own knowledge interpretations, there will be intellectual chaos. Social constructivists think that shared meaning naturally occurs through social negotiations. Social negotiations allow people to construct common interpretations of events and objects.

The recent ideas on situated learning (Brown, Collins & Duguid, 1989) have inspired researchers to consider the significance of the environment as a motivating factor. The research based on the sociocultural tradition (Lave and Wenger, 1991; Rogoff, 1990) has

criticised the fact that knowledge and skills learned in school are not directly, as such, applicable to situations outside school, in which case the commitment to learn is left inadequate and factitious. Instead they propose learning should take place in authentic and complex social contexts.

The academic usage of the word constructionism expands on the concept of constructivism (Shaw, 1996: 177). Constructionists claim that learners construct knowledge most naturally and completely while they are constructing some artifacts. Constructionism therefore differs from constructivism in that "it looks more closely …. at the idea of mental construction. It attaches special importance to the role of constructions in the world as a support for those in the head, thereby becoming less of a purely mentalist doctrine" (Papert, 1993: 143). Thus constructionism involves two intertwined types of construction: the construction of knowledge in the context of building personally meaningful artifacts (Kafai & Resnick, 1996 : 1).

Constructionism places a critical emphasis on particular constructions of the learner that are external and shareable (Papert, 1990: 3). Constructionism highlights the notion that through the construction of shared outcomes and artifacts, a learner engages in a developmental cycle in the social setting. Social constructionism extends the constructionist view by explicitly including as constructions the relations and social activities that become shared outcomes and artifacts at work in the developmental cycle[24]. Constructionism therefore offers an important bridge for the sociocultural and constructivist viewpoints by arguing that individual development cycles are enhanced by shared constructive activities in the social setting. Social constructionism shows the interplay of sociocultural and constructivist views by revealing that the social setting is also enhanced by the developmental activity of the individual (Shaw, 1996: 179).

The Traditional Classroom

Traditional non-constructivist classrooms are dominated by the teacher talking (Flanders, 1973; Goodlad, 1984). Teachers disseminate knowledge and generally expect students to identify and replicate the fields of knowledge disseminated. Student-initiated questions and student-to-students interactions are not typical. Most teachers rely on textbooks (Ben-Peretz, 1990). Often the information the teacher disseminate to students is directly aligned with the information offered by the textbooks. Students are provided with only one fixed view of complex issues and one set of truths. Although there is a growing interest in cooperative learning, most classrooms structurally discourage cooperation and require students to work in relative isolation[25] on tasks that require very little higher order thinking skills. When asking students questions, most teachers want the right answers rather than encouraging students to think through intricate issues. Schooling is premised on the notion that there exists a fixed world that the learner must come to know. The construction of new knowledge is not as highly valued as the ability to demonstrate knowledge of conventionally accepted understandings.

Much of the conventional educational practice is therefore not supportive of the construction that is actively going on in the minds of learners. If learning has a constructive character inherently, then teaching practices need to be supportive of the construction that must occur (Perkins, 1992: 49).

Constructivist Learning Environments

Perkins identifies the five facets of any learning environment (i.e information banks, symbol pads, construction kits, phenomenaria[26] and task managers)[27], which offer a perspective on the general structure and style of the environment and its underlying assumptions about the nature of teaching and learning. The environment of ordinary classroom instruction features

principally information banks (the teacher, the text), symbol pads (notebooks, scratch paper, worksheets), and task managers (the teacher, written instructions). In this profile of facets, a number of assumptions and premises lie tacit: (a) learning occurs through telling students about things (information banks rather than phenomenaria); (b) students cannot manage much of their own learning (little task management left to them); (c) working out problems rather than constructing entities is primary (symbol pads rather than construction kits). The more progressive learning environments emphasise phenomenaria and construction kits. In such environments, learners bear much more responsibility for their own task management and the role of the teacher shifts to that of a coach. Phenomenaria and construction kits are characteristic of learning "situated" in authentically complex and meaningful contexts (Brown, Collin & Duguid, 1989). These learning environments, however, need not be rich in technology. Apprenticeship settings, for example, inherently present learners with phenomena they are learning about.

Constructivist learning environments engage learners[28] in knowledge construction through collaborative activities that embed learning in a meaningful context and through reflection on what has been learned through conversation with other learners (Jonassen et al., 1995). The principles by which learning environments may be built should therefore focus on four general systems attributes: context, construction, collaboration and conversation (ibid.). Context includes features of the real-world setting in which the task to be learned might naturally be accomplished. These features which are replicated as faithfully as possible in the learning environment, may include the physical, organizational, cultural, social, political and power issues related to the application of the knowledge being learned. Attention to context, a central tenet of constructivist learning theories such as Situated Cognition and Cognitive Apprenticeships. Construction of knowledge is the result of an active process of articulation and reflection within a context (Brown, Collins and Duguid, 1989).. The knowledge that is created is a product of the mind and results from the individual's experiences with and interpretations of the context (Jonassen, 1991). Those experiences can be encountered in learning environments as well as in the real world. Learning environments are constructivist only if they allow individuals or groups of individuals to make their own meaning for what they experience rather than requiring them to learn the teacher's interpretation of that experience or content.

Collaboration among learners occurs throughout the learning process. Collaboration aids in developing, testing and evaluating different beliefs and hypotheses within learning contexts. Through the process of articulating covert processes and strategies, learners are able to build new and modify existing knowledge structures. Conversation is necessitated by collaboration. Individuals and groups must negotiate plans for solving situated problems before initiating those plans. This planning involves reflecting on what is known, what needs to be known, the viability of various plans, and their potential effectiveness. Conversation is an essential part of the meaning-making process because knowledge, for most people, is language mediated.

Grabinger and Dunlap (1995) have summarised the constructivist approach as essentially one that is providing a "rich environment for learning". It is characterised by five principles : (a) authentic assessment; (b) student responsibility and initiative; (c) generative learning strategies; (d) authentic learning contexts; and (e) co-operative support. Assessment must test the learning objectives. The assessment of skills must involve using the skills, not describing them verbally (Gagne, 1985). Assessment must be authentic: realistic in complexity, requiring students to conceptualise their knowledge, requiring knowledge in depth rather than breadth, and diverse in form to allow for students' differing intelligence and strength (Wiggins, 1989). Students should have initiative, responsibility and control in their learning. This self-regulation promotes a reflection on their own learning processes which is typical of adult learners (Ferrence and Vockell, 1994). This reflection will improve learning.

Active learning involves using knowledge and skills to "generate" a product, such as an essay, a concept/semantic map, or a physical artifact which embodies knowledge. This may also involve investigating to create a solution to a problem (Kafai and Resnick, 1996). A teaching strategy in tune with generative learning is cognitive apprenticeship (Collins et al., 1991; Henebein et al., 1993). Learning experiences should be realistic and faithful to the original phenomena, rather than abstract descriptions or "inert knowledge". Instruction should be anchored in real-world problems, events or issues which are appealing and meaningful to students. Realistic problems allow students to take ownership of their solutions, develop deeper, richer knowledge structures, require more systematic problem solving methods, and are more likely to benefit from collaborative efforts. Collaboration with fellow students can have several benefits to learning. Students can encounter different points of view which may identify ineffective solutions to problems, clarify misconceptions, and give rise to synergistic insights. Group members must understand their different roles and learn to accommodate conflicting ideas. This reinforces individual responsibility and has been shown to have positive effects on motivation to learn (Slavin, 1991; Covington, 1992).

To Jonassen, Peck and Wilson (1999), learning should also be meaningful. Meaningful learning has to be: (a) active, (b) constructive, (c) intentional, (d) authentic, and (e) cooperative. Learners interact with an environment and manipulate the objects in that environment, observe the effects of their intervention and construct their own interpretation of the phenomena and the results of the manipulation. Learners integrate their new experiences and interpretations with their prior knowledge about the world, and construct simple mental models to explain what they have observed. Learning is therefore constructive, articulative or reflective. Meaningful learning is also intentional since learners articulate their learning goals, what they are doing, the decisions they make, the strategies they use, and the answers that they have found. Learning tasks are situated and authentic because they are meaningful real-world tasks or are simulated in some case-based or problem-based learning environment. Meaningful learning is cooperative or collaborative in the sense that learners work in groups, socially negotiating a common expectation and understanding of the task and the methods they will use to accomplish it.

Swartz, Fischer and Parks (1998) have proposed various tools and techniques (non-ICT) to be used in a constructivist learning environment. These are used for different purposes in infusion lessons to teach the thinking skills and processes, to foster students' collaboration with others[29], and to foster thoughtfulness[30]. John Ingram (1998) has produced a compendium of practical constructivist classroom strategies which empower students to take ownership, responsibility and an active role in their learning processes. Knowledge construction strategies like brainstorming, concept maps, and concept ladders and Scaffolds which are available. Group learning and collaborative learning strategies like Round Tables, Rainbow Groups, Jigsaw Groups, Situational Groups, Peer Tutoring, Response Partners and Study Groups can be used in the classroom. Proflective Thinking[31], Negotiation Circle and K.W.DS.L. are practical strategies for self regulation and individual goal setting. Although these strategies are mainly for higher order teaching and learning of information communications technology in the negotiating classroom (Ingram and Worrall, 1993), they can be adopted for use in the teaching and learning of critical and creative thinking skills.

<u>Current Use of Information and Communication Technologies In the Classroom</u>

Singapore schools are pushing for IT to be introduced in many aspects of learning. A National Masterplan for IT in education expects 30 percent of lessons incorporating IT by 2002. This will cost about $2 billion over a five-year period. Although there are ample IT resources in Singapore schools, they are not fully used in ways that will facilitate the development of students' thinking skills.

Currently, the primary use of computers in education has been to deliver computer-assisted instruction (CAI), including drill and practice programs, computer-based tutorials and, more recently, intelligent tutoring systems. These computer software are used in schools to "teach" students, like what the teachers normally do. The most prominent form of CAI is drill-and-practice programs especially in the area of mathematics. Drills are based on behaviorist beliefs about the reinforcement of stimulus-response associations. Rewards (in response to correct answers) enhanced the likelihood that learners would make a particular response when presented with a specific stimuli. Unfortunately the behaviourist principles underlying drill and practice are unable to develop the complex thinking skills required for meaningful learning to take place. Although drill-and-practice applications train learners to perform the lower level subskills automatically (Merrill,et al., 1986), they do not facilitate the transfer of those skills to allow the solving of real and meaningful problems. Jonassen's view is that these drill programs "replicated one of the oldest and meaningless forms of learning, rote learning" (2000: 5).

Computer-based tutorials also do not allow learners to construct their own meaning but present learners with only a single interpretation of the world. Students are not encouraged or even able to determine what is important, reflect on and assess what they know, or construct any personal meaning for what they study. What students acquire from such tutorials is inert knowledge because they are not applying it. Intelligent tutoring systems (ITS) were developed by artificial intelligence researchers to teach problem solving and procedural knowledge in a number of small domains. What make tutorial systems intelligent is the presence of rules and knowledge bases in the forms of student models, expert models and tutorial models. This makes ITS more responsive to individual learner's needs and difficulties. An important issue is whether ITS should be used to diagnose learners' understanding. Many educators believe that the most important goal of education is for students to learn how to reflect on and diagnose their own performance. According to Schon (1983), students should be encouraged to become "reflective practitioners". ITSs are not widely used in schools because tools to produce these are hardly available. Building such intelligent knowledge-based systems will also involve lengthy processes of knowledge acquisition, elicitation, representation and model building. Jonassen (2000: 7) argues that ITSs benefit mainly the researchers who learn from their research and development work. Instead of letting computers simulate human intelligence, human should instead be made to simulate the computer's unique computing capability and come to use it a cognitive tool (Solomon, 1988). Self regulated learners should assume responsibility for setting their own goals, determining their own strategies and monitoring their own learning.

Computers are also used in schools to help students and workers in their work, that is, as productivity tools. Word processing software, spreadsheets, computer-aided design (CAD) tools and graphics packages are used as productivity tools. They are not being used as tools to learn with. Although database and spreadsheet packages can function as cognitive tools for enhancing, extending, amplifying and restructuring the way learners think about the content they are studying, they have been unexploited for such purposes in schools. Computers should also be employed as intellectual partners that enhance the learner's ability to think. Some available productivity tools can also be used as learning and thinking tools to significantly restructure and amplify the thinking of the learners or the capabilities afforded by that thinking. The WWW (World Wide Web) does not necessarily help to improve learning. Searching the WWW may provide learners with different perspectives or information but the WWW (have to be used in connection with other computer-based tools to facilitate the construction of knowledge bases by learners and to engage and facilitate critical thinking and higher order learning. Also, information searching ("surfing") without a purpose will not necessarily leads to meaningful learning. Learners are learning to access the WWW in order to download or copy material from, easily and quickly, rather than constructing and representing their own ideas.

Jonassen's view is that the role of technologies should also be changed from that of technology-as-teacher to technology-as-partner in the learning process (2000 : 8). Technologies should be used as engagers and facilitators of thinking and knowledge construction. Students learn with technologies when these can support (a) knowledge construction (i.e. representing learners' ideas, understanding and beliefs, and producing organized, multimedia knowledge bases by learners); (b) explorations (i.e. accessing needed information, and comparing perspectives, beliefs and world views); (c) learning by doing (i.e. representing and simulating meaningfully real-world problems, situations and contexts, representing beliefs, perspectives, arguments and stories of others, and defining a safe, controllable problem space for student thinking); (d) learning by conversing (i.e. collaborating with others, and discussing, arguing and building consensus among members of a community, and supporting discourse among the knowledge-building communities); and (e) learning by reflecting (i.e. helping learners to articulate and represent what they know, reflecting on what they have learned, supporting learners' internal negotiations and meaning making[32], constructing personal representations of meaning, and supporting mindful thinking. (Jonassen et al., 1999: 13).

<u>ICT-based Constructivist Learning Environments and Cognitive Tools</u>

Information and communication technologies (ICT), primarily computers and telecommunication networks, can be used as tools for developing thinking skills. Computer applications have been adapted or developed to facilitate critical thinking and higher-order learning. These tools enable learners to represent and express what they know. In doing so, students function as designers of artifacts. They construct knowledge bases, expert systems and multimedia presentations that represent personally relevant and meaningful knowledge, engaging them in higher-order, mindful thinking and learning (Salomon & Globerson, 1987). When students use technologies, an intellectual partnership between the student and the computer is established where the computer amplifies the student's thinking. Cognitive tools are designed to make learners think harder about the subject matter being studied while generating thoughts that would be impossible without the tool.

Educational technologies have too often tried to do the thinking for learners, to act like teachers and guide the learning. Derry and LaJoie argue that "the appropriate role for a computer system is not that of a teacher/expert, but rather, that of a mind-extension cognitive tool" (1993: 5) or what Jonassen calls Mindtool[33] (1999). Cognitive tools, according to Derry and LaJoie, are unintelligent tools, relying on the learner to provide the intelligence. This means the thinking and self-regulation of learning should be the responsibility of the learner, not the computer. Students cannot be correctly using cognitive tools without being engaging in higher order thinking skills (Jonassen, 1996). Instead of using only language to think and represent ideas, cognitive tools should be used to provide formalisms for students to represent what they know in ways that are more highly structured and visual. Teachers should select the formalism that is most effective for analyzing and thinking about domain knowledge rather than always relying on verbal accounts to reflect understanding. When learners use computers as partners, they off-load some of the unproductive memorizing tasks to the computer, while the software requires the learners to use new ways to think about what they are studying. Jonassen (2000) has classified ICT-based cognitive tools into the following categories : conversation tools, semantic organisation tools, dynamic modelling tools, interpretation tools and knowledge construction tools.

Synchronous conferences are made possible when two or more computers are connected to each other over a computer network to enable people to communicate with each other in real time. Synchronous conferences support networked learning communities consisting of teachers and students communicating with other teachers, students and experts who help to enhance both teaching and learning. Global network technology can provide students with the platform to develop their social, communication and collaboration skill through participating

in online discussions. With exposure to greater diversity in perspectives through participation in global discourse, the students' outlook will become less parochial. However, for live discussion to be productive, students must be focused in their conversation, like planning a project, debating an issue or resolving a problem. They will be more intellectually focused when they collaborate to create or construct an artifact like a report, a multimedia presentation or providing solutions to a problem. It is important for the success of synchronous conferences to pose interesting, engaging questions, problems or assignments for students to resolve in synchronous discusssions. Real and relevant contexts for learning should also be provided for more meaningful learning. If the topic of discussion involves higher order thinking, synchronous conferencing may well support critical, creative and complex thinking. Asynchronous communication is different from synchronous conferencing primarily in the level of reflective and constructive thinking that it allows. Synchronous conferencing does not require nor does it encourages reflection before speaking. Harasim (1990) found that learners see themselves as reflecting more while engaged in computer conferencing than when engaged in face-to-face or telephone conversations. Learners are involved in more analytical thinking when they have time to consider and construct responses. Computer conferencing supports social negotiation of ideas bout content that is being studied, as well as the collaborative construction of new knowledge. As groups of thinking individuals provide different perspectives and interpretations, debate, argue and compromise on the meanings of ideas and concepts, they are indeed deeply engaged in knowledge construction. Jonassen (2000) has cited numerous examples of the use of asynchronous and synchronous conferencing to engage learners in critical, collaborative and self-regulated thinking and learning.

Database construction is an analytical task that calls on a variety of critical, creative and complex thinking skills. Students will have to decide what information should be included and how to organize the information. Objects, their attributes and their relationships have to be carefully considered when building a data model. The students will then have to look for the information to be captured in the database. The searching and sorting of the database required to answer queries can generate a variety of comparisons and contrasts based on which fields are selected for searching and sorting. Intellectually these processes require the organization and integration of a domain of knowledge. There are software tools available for drawing semantic networks or concept maps. Semantic networks/maps are diagrams showing concepts and their interrelationships, very much representing the knowledge structures that people store in their minds (Jonassen et al., 1993). These maps are used by learners to represent what they know or are learning as networks of concepts. In fact semantic network software are visualization tools for externalizing or representing mental semantic network of schemas (ideas) as concept maps. When learners construct concept maps to represent their understanding of a knowledge domain, they reconceptualize the knowledge domain by continuously using new propositions to elaborate and refine the concepts that they already partially know. Kozma (1987) believes that semantic network tools are cognitive tools that amplify, extend and enhance human cognition.

Modelling tools allow students to show how ideas are dynamically related. Dynamic relationships are causal. Knowing the causes of events or conditions would help people predict them (although it may not be possible to prevent them) and try to avoid or minimize harmful effects. Spreadsheets, expert systems shells and simulation systems are examples of software tools for representing dynamic relationships. Spreadsheet construction and use involve a variety of mental processes that require learners to use existing rules, generate new rules describing relationships and organize information. The emphasis in constructing spreadsheets is on identifying relationships and translating those relationships in terms of higher order rules (or macros). When users develop spreadsheets to describe knowledge domains, they will be thinking deeply. Expert systems have been used in business to assist people with decision making and to provide advice. Software tools (called expert system shells) are available that allow people to build their own expert systems. Building expert

systems requires learners to synthesize knowledge by making explicit their own reasoning, thereby improving retention, transfer and problem solving ability. Lippert (1988) argued that letting students construct small knowledge bases is a valuable method for teaching problem soving and knowledge structuring for students from sixth grade onwards. Learning becomes more meaningful because learners evaluate not only their thinking processes but also   the product of those processes, the resulting knowledge base. Developing the knowledge base requires learners to isolate facts, variables and rules about relationships in a knowledge domain. Microworlds can assume many forms in different knowledge domains. However, they are essentially exploratory learning environments, discovery spaces and constrained simulations of real-world phenomena in which learners can navigate, manipulate or create objects and then test their effects on one another. Microworlds present students with a simple model of a part of the world (Hanna, 1986: 197). They have proven to be extremely effective in engaging learners in higher order thinking such as hypothesis testing and predicting. They are one of the best tools for engaging learners in constructing and testing internal mental models.

Knowledge construction starts with the learner articulating an intention to build knowledge. That may be stimulated by a question or problem, a failure to achieve something, a general curiousity, an argument or anything that perturbs a person's understanding enough to want to make sense out of it (Jonassen, 2000: 173). Having declared a desire to know, learners must then collect and interpret information that relates to the declared intention. There are tools available to support learners in this initial phase of the learning process. The internet is an enormous repository of information but aimlessly surfing the internet will not result in meaningful learning until and unless learners articulate an intention to use relevant information to do something meaningful. They will then need help to find useful sources of information. Search engines and intelligent search agents are available to help learners. Intelligent searching is likely to engage critical, creative and complex thinking. The primary skills engaged by intentional search are critical thinking skills especially those focused on evaluating information. Synthesizing skills are needed to formulate search strategies for use with search engines. Intentional information searching tools are intended to help learners find information that they need to better represent their ideas. Visualization tools have two major uses, interpretive and expressive (Gordin, Edelson and Gomez, 1996). Interpretative tools help learners view and manipulate visuals, extracting meaning from the information being visualised. Interpretive illustrations help to clarify difficult to understand text and abstract concepts, making them more comprehensible. Expressive visualization helps learners to visually convey meaning in order to communicate a set of beliefs. Visualization tools scaffold or support learners to express themselves visually so that their ideas will be more easily interpretable by other people.

Constructionism claims that learners construct knowledge most naturally and completely while they are constructing some artifacts. Perkins (1986) argues that knowledge acquisition is a process of design that is facilitated when learners are actively engaged in designing knowledge rather than interpreting or encoding it. People who learn most from instructional materials are the designers, not the learners for whom they are designed. Students should therefore become designers rather than learners and knowledge constructors rather than knowledge users. Hypermedia is a powerful design tool for learners to construct knowledge. Hypermedia composition places students in the designer's seat so that they may construct their own understandings, rather than interpreting the teacher's understanding of the world. Researching the information, organizing and designing the presentation and managing the construction project require critical, creative as well as complex thinking skills.

Conclusion

For teachers who are used to the traditional approach to teaching and learning, and who believe that students should understand the world as they do, that students should remember rather than apply and that they should conform to rigid learning schedule, then a constructivist approach and the use of ICT-based cognitive tools will be quite challenging. Teachers who are not familiar with constructivist approaches, using ICT-based cognitive tools may first require a change in educational philosophy (Healy, 1998). "For technologies to be used optimally, teachers must be comfortable with a constructivist or project-based, problem-solving approach to learning; they must be willing to tolerate students progressing independently and at widely varying paces; they must trust students to sometimes know more than they do … they must be flexible enough to change directions when technical glitches occur" (Foa, Schwab & Johnson, 1996). Healey's (1998) view is that even highly motivated teachers with access to state-of-the-art equipment will take five years or more to make the transition. Teachers must therefore be committed to learn and to change.

Teachers should be trained to use constructivist and cognitive tools and techniques well enough in order to facilitate their use by their students. Cognitive tools are not computer games and it is unrealistic to expect students to be able work with them without the teacher's support and guidance. Teachers can only model, coach, and scaffold learning if they understand the tools and their purpose. The importance of teacher preparation and support for successful implementation of constructivist approaches to the teaching of thinking skills cannot be overemphasised.

Teachers may have to develop new teaching skills. The teacher's role will have to be changed from that of purveyor of knowledge to instigator, promoter, coach, helper, model, and guide of knowledge construction. Teachers who are so used to showing students how to do things and providing them readily with the answers they want will find it painful to see the frustration experienced and expressed by their students as they learn to think for themselves. Teachers should try to avoid telling students what they have constructed are wrong. They should instead be less critical by "perturbing" the students' models (Jonassen, 2000: 276), not criticizing nor discouraging. It is the models that the teacher should be questioning, not the students.

Teachers must be willing to relinquish some of their authority, especially their intellectual authority. Teachers need not be experts in using the computer and all the software tools[34]. Schoenfeld (1985) has demonstrated that it is alright for teachers to admit that they do not know everything. However they can show their students how to go about discovering what they do not know and using the new knowledge to solve problems and make decisions. Teachers must become more willing to accept different perspectives and interpretations of the world and even allow students to challenge their perspectives while supporting the students'. Students should be permitted to express ideas in terms that are more meaningful to them. When students have ownership of ideas, they are more willing to generate and use them.

Writing and scoring assessments of higher order thinking is new and difficult to the teachers. Assessing learning with cognitive tools is also not going to be easy for teachers used to traditional assessment methods. If these tools are used to engage constructive, self-regulated, critical, creative and complex thinking, then teachers are obligated to assess those kinds of constructive outcomes and not reproductive learning (Jonassen, 1992;2000). If cognitive tools are used for instruction but learning outcomes[35] are assessed with recall measures, then students will fall back to their old routine of memorizing the content, because that is what the teachers want. This is what Petraglia (1998) has described as the domesticated version of constructivism, that is the application of a constructivist pedagogy to attain traditional goals. The changed instructional practices "are just changed means to attain old ends" (Salomon, 1998: 6).

Committed teachers are not enough if the political leaders and school administrators are not themselves committed to building a thinking school culture. Enough time must be given to help students develop their thinking skills. There must be adequate administrative support and computer resources. Parent understanding and support will also be needed. While all parents espouse the importance of constructive, self-regulated and critical thinking as important learning outcomes, most parents are really more interested in comparing their children's grades than in understanding what their children are learning and experiencing. In the secondary schools, the principals and teachers are still accountable to the Ministry of Education and the parents for the students' performance in the major "O" level examinations. Innovations in schools with the most highly educated parents in the US have failed, because the parents claimed that since they were obviously successful students themselves, what was good for them (i.e. the traditional approach) should be good enough for their children (Jonassen, 2000: 278). There were also suggestions that Asian values (especially Confucian values) are getting in the way of using a constructivist approach to the teaching and learning of thinking skills in Singapore schools[36] (The Straits Times, 26 Nov 1997). Becoming a constructivist teacher is therefore not an easy task[37].

Some sceptics believe that it will be difficult for Singapore schools to be transformed into constructivistic thinking schools. They refer to the experiences of schools in the United States where higher order thinking was identified as a goal of educational reform and constructivist teaching practices were promoted to achieve this goal. In most states, policymakers had to drop this goal or subsumed it into other goals because it was deemed too difficult to assess and quantify. Schools are held accountable for their test results and operating in such high-stakes accountability systems typically move their attention away from principles of learning, student-centred curriculum and constructivist teaching practices. They refocus instead on obtaining higher test scores, even though this does not necessarily indicate that there is increased student learning. Educators should be held accountable for their students' learning and not only for achievements on high-stake tests (Brooks & Brooks, 1999: 18). For Singapore, a country whose culture stresses so much on grades, ranking and competition, a constructivist approach to teaching and learning will be a challenge to both the teachers and the students.

Endnotes

[1] Rather than adapting the curriculum to students' needs, the usual response is too view those who have difficulty understanding the unaltered curriculum as slow, disabled, unmotivated or difficult to teach. These students are often separated from the mainstream classes, given remedial instruction, or retained.

[2] Katz (1985) and Gardner (1991) describe the discrepancy between perceived and actual success as the difference between learning and performance. Katz (ibid.) stresses that emphasis on performance usually results in little recall of concepts over time, while emphasis on learning generates long-term understanding. Under such a setting, these students, rather than seeking deep understanding, seek short-term strategies for accomplishing tasks or passing examinations. When asked several weeks or months later to apply what they supposedly had learnt, most of these students cannot.

[3] Singapore "cannot assume that what has worked well in the past will work for the future. The old formulae for success are unlikely to prepare our young for the new circumstances and new problems they will face. We do not even know what these problems will be, let alone be able to provide the answers and solutions to them. But we must ensure that our young can think for themselves, so that the next generation can find their own solutions to whatever new problems they may face" (Goh, 1997).

[4] Glaser suggests that critical thinking ability "helps the citizen to form intelligent judgements on public issues and thus contribute democratically to the solution of social problems" (1985: 27). Active citizens are "willing, able and equipped to have an influence in public life and with the critical capacities to weigh evidences before speaking and acting" (Citizenship Advisory Group, 1998: 7). Postman (1985) stated very simply that there can be no liberty for a community that lacks the critical skills to distinguish lies from truth. In order to have participatory and active citizenship, Singapore needs thinking schools to prepare thinking citizens. A thinking skills programme will definitely complement the current National Education programme, which many see as inadequate to produce

citizens who can think rationally and independently about national issues. The current National Education programme is seen by many as traditional citizenship education. This is one in which the knowledge of the country's history is taught and which encourages the development of loyalty and patriotism. This approach is grossly inadequate to develop thinking citizens who have the skills to think rationally and independently about national issues, and to act effectively in the social and political contexts. Even in the area of moral education, children must be educated to think for themselves about all ideas, including those of adults. Children must be invited to reflect on complex issues, to recast them in the light of their own experiences and questions, to figure out for themselves, and with one another, what kind of person one ought to be, which traditions are worth keeping, and how to proceed when two basic values seem to be in conflict (Kohn, 1998 : 31). "The required beliefs cannot by hammered in; the needed attitudes cannot be plastered on." (Dewey, 1966: 11).

[5] Schools were asked to cut back on the amount of content knowledge that students are required to learn. Teachers were also encouraged to spend more time on projects that can help develop thinking skills.

[6] Ennis has defined critical thinking has been defined as "reasonable reflective thinking that is focused on deciding what to believe or do" (1987: 10). This rather broad definition encompasses thinking skills in general. He divides critical thinking skills into two kinds: dispositions, which include attributes such as seeking a clear statement of the thesis or question, seeking reasons, and trying to be well-informed; and abilities (nine in all), which include attributes such as focusing on a question, analyzing arguments, asking and answering questions of clarification and/or challenge, and the like. Ennis 's taxonomy of thinking skills has greatly influenced teaching and the assessment of thinking. Ennis is clear that his definition includes creative thinking. Formulating hypotheses, alternative ways of viewing a problem, questions, possible solutions, and plans for investigating something are creative activities that come under this broad definition of critical thinking. Critical thinking is not equivalent to higher order thinking skills. According to Ennis, critical thinking, a practical activity, includes all of the practical higher order thinking skills (ibid.). Traditional conceptions describe a restricted set of tasks that can be applied to ideas that already exist, but they do not account for generating original thoughts and ideas, which is the hallmark of any conception of critical thinking. (Jonassen, 2000: 24). Walters (1990) believes that the outcomes of traditional critical thinking should be the vulcanization of students. Like Spock in *Star Trek*, their ability to stick to the evidence and draw logical conclusions should make them excel in problem solving and critical analysis. They will not succumb to prejudices, hidden agendas or emotional confusion. They will be devoid of imagination, intuition, insight and the capacity for metaphorical thinking. Although logical inference, critical analysis and problem solving are fundamental elements of superior thinking, they are practically useful only if they are supplemented by imagination, creativity, insight and intuition which are essential components of discovery. To Walter, critical thinking is more than logical thinking.

[7] There are still many other ways to categorize thinking skills but they can be divided into two major groups: creative thinking and critical thinking. This division is somewhat arbitrary because both types of thinking are closely and irrevocably intertwined – creative thinking has critical components and critical thinking has creative elements. The taxonomy proposed by Quellmalz (1985) has five categories, which are rather similar to Bloom's. The five categories are: recall, analysis, comparison, inference and evaluation. A common misconception is that taxonomies of thinking skills are arranged as a hierarchy from easy to difficult. Analysis, synthesis and evaluation are often thought of as higher order skills. This often leads people to believe that questions or tasks based on these skills are inherently more difficult than those based on recall or comprehension. Difficulty is not the criterion on which taxonomies are based. In fact they are categorized according to the type of thinking process required. Taxonomies merely describe the type of thinking required by a particular question or problem. Thinking skills can also be classified according to skills that acquire information and those that extend information; and also the skills required for inductive and deductive reasoning. Application, analysis, synthesis and evaluation may be said to extend information because the brain uses what it has learned to make new connections, generate creative applications and produces elegant solutions to problems. Knowledge and comprehension only become useful when they are applied in new and different ways in order to produce additional information. Students should become producers of information who use knowledge to create or extend learning and not consumers who merely acquire knowledge and retrieve it on demand to answer recall type questions. Litecky defines critical thinking as "active, mental effort to make meaning of our world by carefully examining thought in order to better understand content" (1992: 83). Resnick (1987) pointed out in his report to the US National Research Council that although high order thinking was difficult to define, it was easy to recognise. He advanced the following eight characteristics of high order thinking : (a) is not routine - the path of the action is not fully known in advance; (b) tends to be complex -- the total path is not visible from a single viewpoint; (c) yields multiple rather than unique solutions; (d) involves nuanced judgement and interpretation; (e) can involve application of multiple criteria which may conflict with one another; (f) involves uncertainty -- not everything about the task at hand is known; (g) involves imposing meaning -- finding structure in apparent disorder; and (h) is effortful -- considerable mental work is needed for the kinds of elaborations and judgements required.

[8] In fact it is this conception of critical thinking that he is using to compare and contrast the effects of various tools used to support critical thinking.

[9] One may argue that "classification and understanding" skills can be subsumed under critical thinking. It is therefore understandable why many writers would only make a distinction between critical thinking and creative thinking, although there are many definitions of the two terms (Treffinger, 1995).

[10] Swartz and Parks (1994) have provided a comprehensive list of the different kinds of thinking skills which include: sequencing and ordering of information; sorting, classifying, grouping; analyzing, identifying relationships, comparing and contrasting; making predictions and hypothesising; drawing conclusions, giving reasons for conclusions; distinguishing fact from opinion; determining bias and checking the reliability of evidence; generating new ideas and brainstorming; relating cause and effect, designing a fair test; defining and clarifying problems, thinking up different solutions, setting up goals and subgoals; testing solutions and evaluating outcomes; planning and monitoring progress towards a goal, revising plans; making decisions, setting priorities, weighing up pros and cons. What is included or excluded can be arbitrary, dependent on the age group, the degree of challenge and context/subject matter being taught.

[11] The programme was designed to teach the tools and techniques meant to encourage creative thinking. Children in the secondary schools where the programme was introduced were expected to acquire the "fluent and appropriate use" of the tools (de Bono, 1985: 208).

[12] The stated aims of the new Thinking Programme provide a clue as to why the CoRT programme was abandoned. de Bono does not advocate the infusing of his CoRT programme into specific content areas. He is also of the view that although critical thinking has its place and its value, it lacks generative, productive, creative and design aspects of thinking which are so vital (de Bono,1997: 15).

[13] These are information gathering, remembering, focusing, organizing, analyzing, evaluating, generating and integrating. To a large extent they cover only the two categories of skills which Swartz and Parks call "critical thinking" and "classification and understanding". It appears that the emphasis for Singapore schools is at present on critical thinking.

[14] Since positive attitudes and perceptions about learning play a fundamental role in the learning process, teachers should try to foster them. The thinking involved in acquiring and integrating knowledge (the second dimension) is based on the view in cognitive psychology that learning "is a highly interactive process of constructing personal meaning from the meaning available in a learning situation and then integrating that information with what the learner already know to create new knowledge" (ibid. : 22). This means that in order for students to have proper understanding of what they are taught, they need to be encouraged to go through a personal "organizing and shaping" process. Strategies that can be used to help students organized knowledge would be to teach them use physical and symbolic representations, organizational patterns and graphic organizers.The third dimension is thinking involved in extending and refining knowledge. Children do not merely acquire knowledge but also extend and refine what they know. They can be helped to do this through activities and strategies, such as thinking skills. The fourth dimension is thinking involved in using knowledge meaningfully. In order to do this, the kind of thinking that should be encouraged should be "extended over a long period of time, directed by students, and focused on realistic or authentic issues. The final dimension has to do with the productive habits of mind. Referring to the works of Perkins, Ennis, Flavell and Amabile, Marzano identifies a number of mental habits that would make learning effective and efficient. These are: being sensitive to feedback; seeking accuracy and precision; persisting even when answers and solutions are not apparent; viewing situations in unconventional ways; and avoiding impulsivity. The first and the fifth dimensions, while not affecting learning, do provide the backdrop for learning.

[15] There are three instructional approaches to teaching thinking that educators have taken: (a) direct instruction in thinking in non-curricular contexts; (b) restructuring content lessons for direct instruction in thinking (infusion); and (c) use of methods which promote thinking in curricular contexts. The teaching of thinking by direct instruction means that time is specially set aside for thinking instruction. Students learn how to use explicit thinking strategies, commonly guided by the teacher. Usually this occurs in separate, self-contained courses or programmes with specially designed materials and is taught outside the standard curriculum. In the infusion approach, thinking lessons are not conducted in separate courses outside the regular curriculum. Direct instruction in thinking skills and processes is blended into content lessons. Infusion lessons have two sets of objectives: learning to do a type of thinking skillfully; and achieving a deeper understanding of the content being taught. (Swartz et al., 1998: 10) The third approach involves employing methods merely to promote students' deep understanding of the content. Such methods include using cooperative learning, higher order questioning, Socratic dialogue and inquiry learning. While students may respond thoughtfully to the content, no thinking strategy is taught explicitly.

[16] The steps recommended by Beyer are: (a) Introduce the thinking operation in question by giving its name and a simple definition; (b) Have the students execute the operation as best as they can, using the material provided; (c) Then have the students recall how they carried out the operation, the steps in the procedure they used, and any rules, principles, or knowledge they knew or used to guide them through the task; (d) Next, have the students execute the operation again, keeping in mind the discussion about how they executed it previously; and (e) Finally

have them report how they carried out the operation the second time, seeking the same kinds of information as above about the operation and revising the tentative outline of its attributes to accommodate new information. The strategy will help students gain expertise in using all the thinking skills.

[17] It appears that therefore is no one explicated theoretical framework underlying the Thinking Programme. The programme designers themselves have admitted that since they are not theorists, their pragmatic approach is very much an eclectic one (Han, 1999).

[18] The behaviourist model of learning is derived from the stimulus and rsponse theory of Skinner. Under this paradigm, the learner is conditioned to respond to a stimulus. Behaviourism views organisms as a "black box" and the inner processes and functions are of no concern. Skinner (1974) argued that since it is not possible to demonstrate the inner processes with any scientific procedures, researchers should focus instead on "cause-and-effect relationships" that could be established by observations. Edward Tolman provided experimental evidence that animals formed certain patterns or "internal representations" of the mazes through which they were running. Noam Chomsky also argued that Skinner's model was inadequate for explaining the acquisition for language that required the notion of representations. Behaviourism evolved into neo-behaviourism (Bandura, 1989), and this in turn was gradually replaced or transformed into cognitivism where human cognition is perceived as an information-processor with a great emphasis on representations (Newell, 1990).

[19] Newell's model of problem-solving (thinking) consists of formal rules and operations on symbols which represent objects and their attributes with their relationships. One symbolic structure is transformed into another. An initial state is changed into a goal state through a plan consisting of rules. The system accomplishes its thinking by reorganising symbols in memory, receiving and outputting symbols, and comparing symbol structures for identity or difference. A cognitive being "gathers information" about these things and builds up a "mental model" which will be in some respects correct (a current representation of reality) and in other respects incorrect. Knowledge is therefore a collection of representations which can be called upon for use in reasoning and which can be translated into language. Thinking is a process of manipulating representations (Winograd & Flores, 1986). The human information processor has short-term and long-term memories, including a working memory. Proponents of information processing theories differ from the behaviourists' view that stimulus-response learning alone could form the basis for higher order learning. Instead they are concerned with the internal processes that went on during learning. Information processing theorists based their work on a model of memory and storage proposed by Atkinson and Shiffrin (1968). A fundamental tenet underpinning cognitivism is representationism (Bredo, 1994) where external reality is assumed to be objectifiable through symbolism or language. What is implied in cognitivism is that symbols mirror reality. The basic tenet of cognitivism is objectivism. The external world can be represented through language. Such a model advocates that there is reality "out there" and the goal of learning is to understand this reality and modify behaviour accordingly.The goal of learning based on this model is therefore transmissional, facilitating the transfer of knowledge which is comprised of abstract or decontextualised concepts, from the expert to the learner. Such an objectivist approach treats the activity and context in which learning takes place as merely ancillary to learning. Cognitivism advocates man and environment as related but distinct. Thinking is often conceived as something that goes on in the head and has nothing to do with any intimate physical interaction with the surroundings. What is implies is that students can learn by passively sitting still and absorbing knowledge rather than by actively manipulating things and testing the results of their inquiries.

[20] The cultivation of autonomy (self-determination as much as self-control) should be emphasized so that students come to experience themselves as "origins" rather than "pawns" (de Charms, 1983; Deci & Ryan, 1985), which are powerless and always under the control of others. Self-regulated learners are purposeful, strategic and persistent in their learning. They have also developed the ability to minitor and evaluate their progress in terms of their goals and to believe in their efficacy to regulate their own learning (Bandura, 1993).

[21] Vygotsky (1978) claimed that all higher mental functions evolve from social relations. Every function in a child's cultural development appears twice -- first between people (interpsychological) and then inside the child (intrapsychological). This applies to voluntary attention, to logical memory and to the formation of concepts. To Vygotsky, all the higher functions originate as actual relations between human individuals (1978: 57). The social orientation of constructivism commonly linked to Vygotsky (1978) and theories of practice (Lave and Wenger) have recently gained wide popularity. Vygotsky emphasized the cultural influences and social context influencing learning. His version of constructivism is called social constructivism because his emphasis is on the critical importance of interaction with other people (other children, parents and teachers) in cognitive development.

[22] Schaffer (1996), however, warned that there are considerable dangers in making strong claims for the part played by the social context. Interacting with others can facilitate cognitive development under many circumstances and under some circumstances may in fact be essential. He believes that it is unlikely that all skills acquired at all stages of development originate in social interactions and that there is a need to establish what kinds of social interactions promote what kinds of cognitive achievements at what age and in what manner.

[23] The romantic view that children can basically educate themselves so long that grown-ups don't interfere is not taken seriously by any constructivists like Dewey, Piaget, Kohlberg, or their followers (Kohn, 1998). In moral

education, for example, educators, parents and other adults are needed to offer guidance, to act as models, to pose challenges that promote moral growth, and to help children understand the effects of their actions on other people, thereby tapping and nurturing a concern for others that is present in children from a very young age (ibid.).

[24] Children apparently don't get ideas; they make ideas. Moreover, constructionism suggests that learners are particularly likely to make new ideas when they actively engaged in making some type of external artifact -- a robot, a program, a poem or even a sand castle -- which they can reflect upon and share with others.

[25] John Dewey remarked at the turn of the 20th century that anyone seriously trobled about rampant individualism among children would promptly target for extinction the "drill-and-skill" approach to instruction. He said "the mere absorbing of facts and truths is so exclusively individual an affair that it tends very naturally to pass into selfishness" (Dewey, 1990 :15).

[26] Phenomenaria in the classroom simulates real world phenomena (objects, events, activities, processes) and make them assessible to scrutiny and manipulation (Perkins, 1992: 47).

[27] An information bank is any resource that serves as a source of explicit information about topics. The classic information bank in the classroom is the text. Dictionaries and encyclopaedias are also familiar information banks. The teacher of course is the human information bank holding centre stage in the classroom. The internet allows learners to tap on quickly and conveniently, a large volume of information on almost any subject from many different sources. Symbol pads refer to the diverse resources to support the learners' short term memories as they record ideas, develop outlines, formulate and manipulate equations, and so on. The notebook, laptop computer and the electronic calculator are good examples of symbolic pads that help learners construct and manipulate symbols. Technology has expanded the power of such symbol pads. Wordprocessing software, for example, allows editing and formatting of large chunks of texts in the most productive ways. Construction kits of one sort or another are an essential component in any learning environment. Legos and TinkerToys are favourite examples. Laboratory apparatus provides a construction kit for conducting experiments. ICT has expended the range of construction kits possible in the classroom. Phenomenaria in the classroom include simulation games and microworld models of various sorts of environments. The classic task manager is the teacher who sets tasks to be undertaken in the course of learning, guide and sometimes help with the execution of those tasks, and provide feedback regarding process and/or product. Learners are expected to undertake a certain amount of their own task managing, the amount depending on the style of instruction. With ICT comes the possibility of electronic task managers. CAI systems and the more contemporary intelligent tutoring systems are good examples. It has to be noted that not all learning environment display all the five facets.

[28] In their 1993 paper, Jonassen et al. suggested that constructivist learning environments and methods are not appropriate for all learners. Although appropriate for stimulating thinking in younger, novice learners, constructivistic learning approaches most reliably support the advanced knowledge acquisition (university) stage. Universities are among the most appropriate venues for implementing constructivistic learning environment. Introductory learning occurs when learners have very little directly transferable prior knowledge about a skill or a content area. They have very little knowledge to use as foundations for building more personally meaningful knowledge representations. The initial schema development and knowledge acquisition normally must be guided more than the next stage. Jonassen et al. (ibid.) believe that the initial knowledge acquisition phase is better served by instructional techniques that are based upon classical instructional design techniques. Classical instructional design is predicated upon predetermined learning outcomes, constrained and sequential instructional interactions, and criterion-referenced evaluation. Constructivistic learning environments may used during the latter stages of knowledge acquisition. If we look at his later publications (Jonassen, 2000; Jonassen, et al., 1999), his view has changed somewhat. Now, he encourages the use in schools a constructivist approach to teaching and learning using ICT.

[29] All infusion lessons involve collaborative learning experiences in discussion with one or more partners, working independently, and whole class participation. Cooperative learning techniques help students reason together as a social endeavour and foster disposition of good thinking such as willingness to listen and respect the ideas of others. In collaborative group thinking sessions, students are stimulated by ideas that they might not otherwise developed. Prompted by the ideas of other students, they may modify their ideas in ways that they might not have considered if working on their own. Using collaborative and/or cooperative learning promotes thinking in the following ways: (a) prompts ideas through student interaction, (b) engages students in reflective collaboration, (c) promotes self-correction and confidence in expressing ideas, (d) confirms the value of students' own words and understanding, (e) engages students in reflective understanding of information, and (f) demonstrates usefulness of active listening for another's ideas. Strategies such as "Think/Pair/Share" provide opportunities for students to discuss and reflect on how they think through or comprehend some new concept or process. In whole-class information sharing sessions, a "Know/Think You Know/Need To Know" organizer helps promote thinking in the following way: (a) identifies and utilizing students' prior and current knowledge to establish a common knowledge base for examining an issue or concept; and (b) validates students' understanding of concepts and information.

[30] Instructional methods used in infusion lessons to foster thoughtfulness include: (a) higher order questioning, (b) using manipulatives, (c) writing for reflection, and (d) using content-oriented graphic organizers. Asking higher order questions commonly refers to posing questions that prompt students to be analytical, creative, or evaluative about the content that they are learning. This type of questioning contrasts with asking questions that require only recall. Manipulatives are concrete objects that the learner examines, moves or operates as he or she is learning concepts or processes. It is the students' own manipulation of specimens, artifacts or models that brings out their thinking. Manipulatives also provide students with more authentic contexts for learning. Writing for reflection allows the students to "think on paper". They are asked to reflect on their analysis, conclusions, or interpretations by writing their thoughts and the thinking involved in developing that understanding. Writing before discussion is especially helpful for students who are uncertain about their ideas. It allows them to gather their thoughts before expressing them in class. Writing out their thoughts clarifies meaning, promotes students' ownership and confidence in their conclusions and provides a record for reconsideration and restatement. After discussing their statement with their partner, they can rewrite their statement to make their ideas clearer. A variety of graphics (matrices, Venn diagrams, flowcharts, hierarchical diagrams, mind maps, fish-bone diagrams) depict how information is structured or related. They prompt the drawing of conclusions or interpretations by comparing pieces of information depicted on the graphic. Questioning is also one of the tools in a teacher's repertoire of skills. When handled carefully, questioning can enhance , clarify, extend and generally scaffold student thinking and meaning making. However, the ways in which teachers pose questions to students can detract from these abilities. The ways questions are normally asked create stress and this can significantly hamper the students' ability to think clearly. Some of the questioning strategies are: (a) extend wait time, that is give the student more time to think before answering; (b) using follow-up questions to encourage students to extend their thinking; (c) let student play the devil's advocate. Higher order questioning is another strategy commonly used to pose questions that prompt students to be analytical, creative or evaluative about the content that they are learning. There should be a longer wait time for students to respond to questions asked, so that the quality of discourse can be markedly improved.

[31] Proflective thinking or forward thinking is a strategy that supports the individual student to identify specific study outcomes before study begins (Ingram, 1998).

[32] People learn from experiencing phenomena (objects, events, activities, processes), interpreting those experiences based on what they already know, reasoning about them, and reflecting on the experiences and the reasoning. Jerome Bruner (1990) called this process *meaning making.* This is at the heart of the constructivists' philosophy of learning. Constructivists generally believe that : (a) knowledge is constructed, not transmitted; (b) knowledge construction results from activity; (c) knowledge is anchored and indexed by the context in which the learning takes place; (d) meaning is in the mind of the learner; (e) there are multiple perspectives of the world; (f) meaning making is prompted by a problem, question, confusion, disagreement, or dissonance (a need or desire to know) and requires personal ownership of that problem; (g) knowledge-building requires articulation, expression, or representation of what is learned; (h) meaning may also be shared with others and meaning making can also result from conversation and dialogue; (i) meaning making and thinking are distributed throughout a culture and a community; and (j) not all meaning is equally valid and shared ideas must be accepted and agreed upon by the knowledge-building community (Jonassen et al., 1999 : 2-6).

[33] To qualify as a Mindtool, the application software must satisfy a list of criteria. It must be (a) computer-based; (b) readily available; (c) affordable; (d) support knowledge construction; (e) usable in different areas or subjects; (f) able to engage learners in critical thinking about their subject; (g) able to facilitate the transfer of skills across domains; (h) easily laernable; and (i) embedded with simple but powerful formalism to allow learners to organize and represent what they know in different ways (Jonassen , 2000: 17-19).

[34] To Jonassen (2000: 14-15), learning to use the cognitive tools appears to be the least problematic. Only a few software packages need to be learned, most of which are already available in schools. These low-cost application software can be used across the curricula so that there is no need to learn to use different cognitive tools for different subjects.

[35] Salomon argued that one of the most important and interesting outcomes of constructivists learning environments might be the students' improved ability to work in a team to solve new, complex and ill-structured real-life problems, showing their coordinated abilities to access relevant information and turn it into viable knowledge. Students will have to be assessed on the constructive process as well as the constructed object (Salomon, 1998: 7).

[36] Confucian philosophy may be part of the reason Singapore students lack a spirit of inquiry. It discourages criticism of others or the status quo. This may be at odd with the effort to promote critical and creative thinking in schools (ST, 26 Nov. 1997).

[37] However, Jacquelin Brooks and Martin Brooks (1993) believe that it is not as overwheming as many teachers think; they have provided some useful pointers which can be used by teachers to experiment with this new approach. These provide a useable framework within which teachers can experiment with the constructivist

approach to teaching and learning : (a) Constructivist teachers encourage and accept student autonomy and initiative; (b) Constructivist teachers use raw data and primary sources, along with manipulative, interactive and physical materials; (c) When framing tasks, constructivist teachers use cognitive terminology such as "classify", "analyze", "predict" and "create"; (d) Constructivist teachers allow student responses to drive lessons, shift instructional strategies, and alter content; (e) Constructivist teachers inquire about students' understandings of concepts before sharing their own understandings of those concepts; (f) Constructivist teachers encourage students to engage in dialogue, both with the teacher and with one another; (g) Constructivist teachers encourage student inquiry by asking thoughtful, open-ended questions and encouraging students to ask questions of each other; (h) Constructivist teachers seek elaboration of students' initial responses; (i) Constructivist teachers engage students in experiences that might engender contradictions to their initial hypotheses and then encourage discussion; (j) Constructivist teachers allow wait time after posing questions; (k) Constructivist teachers provide time for students to construct relationships and create metaphors; (l) Constructivist teachers nurture students' natural curiousity through frequent use of the learning cycle model.

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