行政院國家科學委員會專題研究計畫成果報告

CAL 人機互動中學習者思維理解模式之研究：(II)學習者視覺表徵之解讀與認知建構研究

Studies on Learners' Mental Models in Human-Computer Interactions: (II). Learner's Interpretation of Visual Representations and the Cognitive Construction in a Multimedia Learning Context

計畫編號：NSC88-2520-S-032-005

執行期限：87 年 8 月 1 日至 88 年 7 月 30 日

主持人：計惠卿 Hueyching Janice Jih　執行機構及單位名稱：淡江大學教育科技學系

摘 要

當學習者與學習環境互動的過程中，個體所覺知的外在環境資訊與內在既有認知結構相異時，認知衝突於焉產生；而藉著自控的同化與調適過程，將輸入（發現）的新資訊與既有之認知結構聯結、進而建構成（再發現）新的知識。因此，學習者與外在環境之互動、個體對操作行動（hands On）之省思（minds on）、以及個體與其它文化個體之社會性互動是影響知識建構的重要步驟。所以，環境應當提供充份且良質的探索操作機會，以容許學習者為自己所需而發現訊息之間的關係、組織訊息、理解概念。

網路學習環境中人機互動介面所營造的情境及所提供、蘊含的學習機會是位居影響其求知態度的第一線尖兵。因此，如何促進學習者的感受性遂成為情境認知學習環境提供之媒體操弄的重要特質之一。也正因如此，使得人機介面的品質成為研究者與設計者共同關切的焦點。本研究運用地球之心網路超媒體 CAL 教材，針對國小高年級學童進行其互動過程之非結構性觀察、小老師敘述法、深入訪談、學習路徑紀錄等資訊之綜合分析，並提出學習者身處多元網絡電腦輔助學習環境中，所構築之思維理解模式的認知、情緒、與操作等種種構面之特質，以作為後續研究或研發充份發揮效能之網路教材的參考。

關鍵詞：視覺表徵、思維理解模式、人機互動

Abstract

Web-based courseware is an alternative approach to provide ideal learning opportunities that empower the symbol systems and mental processing capabilities of learners. The interfaces to an interactive courseware is the only channel in which a learner has access to the learning opportunities provided by the courseware in terms of information content, medium elements, interactive learning activities, and functionality. Therefore, the quality of interface to courseware is a matter of vital importance to its learning effectiveness.

The overall purpose of this study is to contribute to the understanding of how primary students learn in web-based courseware with respect to learners' interaction and their mental models (personal construct of interfaces) of the courseware. There is largely an exploratory study. Specifically, this study utilized document analysis, observation, and interview methods for gaining insight into the learners' background information, their mental models of the construct of learning activities in the courseware, their actual interactive behaviors during use of web-based courseware, and the results of that use. Both computer screen and learners' interaction were video taped for supplemental data. Qualitative analysis based on learners' behaviors and their explanations of the specific learning activity frame were used to explore the nature of their interactive behaviors, their instances of mental models in web-based learning environment. A summary of the study, discussion of the conclusions, implications of the study, and recommendations for further research form the focus of this report.

Keywords: Visual representation, Mental models, Human-computer Interaction

Background and Purpose

Interactive Learning on the Web

Advocates of active learning, collaborative learning and authentic projects make compelling arguments, but integrating these ideas with educational technology is a challenge. Internet technologies of e-mail, listservs and the web are remarkable vehicles for thrilling educational journeys. Human beings are information processing systems and have a huge learning potential in a dynamic and irreversible changing world. Novak (1964) suggested that exploratory oriented learning is "the set of behaviors involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious." Though the learning process involves hands-on activities and learning skills, "the focus is on the active search for knowledge or understanding to satisfy a curiosity" (Haury, 1993).

To arrive at an effective learning process and result has always been an ideal for educational technology professionals with the goal of conveying knowledge efficiently and accurately. Leaning is the outcome of ongoing changes in our mental frameworks while we actively make meaning out of our experiences (Osborne & Freyberg, 1985).

After reviewing tons of researches on technology-based learning, Kozma suggested that learning materials won't deliver learning by themselves, rather they provide opportunities for learning (1991). Active learners collaborate with web materials to perceive signals, interpret messages, and construt unique understandings. Therefore, the interaction performance play a crucial role in learning processes (Land & Hannafin, 1996).

Current theories on learning focus on the "active agent" role of learners who do not passively receive message delivered via instructional channels but who do actively explore phenomena and construct knowledge by themselves. Web-based learning environment is an option of such goal.

Learning context of web-based courseware can evoke learner's creation of analogies from previous experiences. Learners are likely to make meaning out of their interactive experiences, to interpret the verbal as well as visual information, to construct their mental frameworks, and to understand the natural facts as they work directly with virtual phenomena in the learning context.

HCI & Mental Models

Interactive learning is an emphatic concept and strategy for web-based learning; a learning party plays an active role in such process of learning. External events, learning activities on the web, might initialize or allure internal events in the learners.

Learners' perception and understandings of interfaces in terms of mental models is an important issue in investigations of web-based courseware performance (Shackel, 1997). Learners interact with the learning activities of any instructional media/technology to construct a mental model (symbolic representation) of the specific domain and to make inferences based upon representation processing. Kozma (1991) proclaimed that "Learning with media can be thought of as a complementary process within which representations are constructed and procedures performed, sometimes by the learner and sometimes by the medium. While some learners with appropriate prior knowledge can construct and use representations on their own with information obtained from any medium, other students can not benefit from media that are capable of providing representations and performing or modeling operations on them."

The human-computer interfaces to an courseware is the only channel, a window, an agent through which a learner has access to the learning opportunities provided by the courseware in terms of information content, medium elements, interactive learning activities, and functionality. An interface might facilitate, hinder, or totally block the desired interaction between a learner and the learning context. Therefore, the quality of interface to courseware is a matter of vital importance to its learning effectiveness.

The better we understand the ways learners interact with interactive courseware, the more we can develop effective and efficient courseware (Jih & Reeves, 1992). Research on mental models can identify salient characteristics of cognitive processes and help in the development of research-based guidelines for the design of effective courseware, thus linking the technology and instruction fields together.

Research Design

The aim of this study is to explore the attributes of learners' interpretations of visual representations and their cognitive construction in a web-based learning context with respect to cognitive, affective, as well as operational aspects of mental models in order to gain a deeper insight into the interaction processes within a web-based guided-discovery courseware.

The suitable four candidates for this study were selected from two elementary schools in Taipei metropolitan by Snowball technique. The term 'suitalbe' pertains to 5th-graders and 6th-graders whose schedule meets with those of this study with the consent of the subjects and their parents.

The web-based courseware, named The Heart of Earth, used in this study utilizes guided-discovery environment where learner can constructs personal meaning via attempting to interpret and explain time and space concepts of Earth Science from personal exploration, experiences, and understanding.

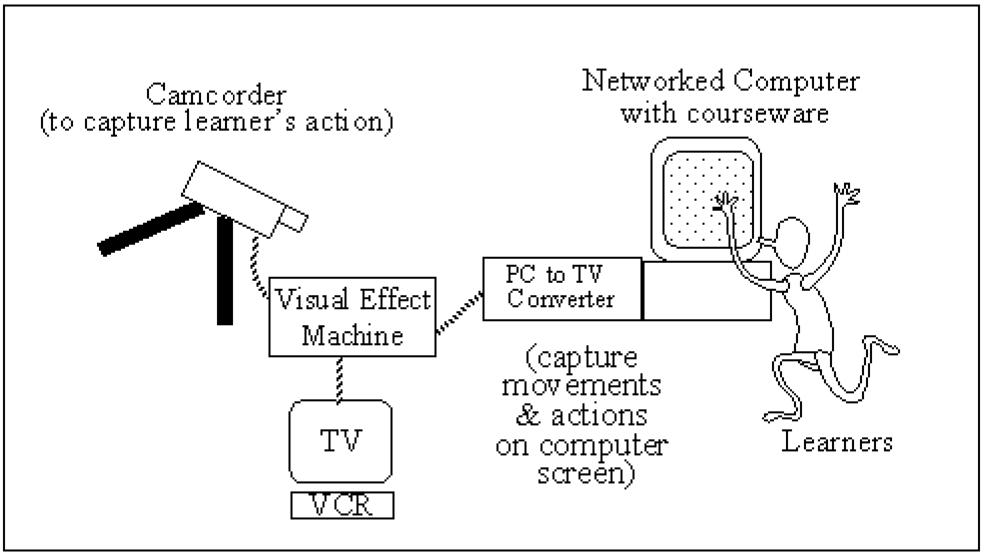
Solomon (1983) proclaimed that major function of science education is to encourage learners learn how to find answers in various contexts. Science in context could elaborate the theoretical practice of science. Be demonstrating scientific concepts or thoeries in learning activities within particular context, meanings of science can be illuminated. Hence, learners thought processes are actively engaged in the content (Rogoff, 1984). Learning pshychologists contend the importance of content and context in learning rocesses (Rowell & Dawson, 1989).

Representation medium in interfaces of the "The Heart of Earth" are designed for the following purposes (Jih & Wang, 1998): An Attention Guide, A Context Builder, An Interaction Motivator, A Record Keeper, A Visual Reasoning Anchor, The Invisible Behaviors Manifestation, and A Message/ Feedback Provider.

Accepting the suggestions by Sasse (1991), the researcher used different approaches to measure learners' mental models: observing learners interacting with the courseware, asking learners to explain the courseware to a new learner (the teach-back technique), asking learners to predict feedback of the courseware, asking learners to describe interacting with the courseware, and observing learners interacting with the courseware with a co-learner.

Information collected from subjects includes their level of prior domain knowledge, observation and video-taping on their interaction processes, in-depth interviews, teach-back results, and their audit trials. Figure 1 presents the research settings of this study.

Figure1. Research Settings



Findings and Conclusions

Multidimensional data analysis revealed the dynamics of mental-model development as subjects learn Earth science via the courseware.

Each learner simultaneously shape and being shaped by the meaningful learning opportunities encountered in the learning ecosystem, which consists of the web courseware, the participants, and related resources.

This study shows that a few tasks require learners shared decision-making and mutual dependence. High motivation among learners, which is a key to participate interactive tasks actively, can be achieved by presenting a current status of each one's progress. When learners are highly motivated, competitiveness develops spontaneously among different persons in the same class.

Learners interact with the content based upon personal intentions, the objectives of guiding tasks, and individual interpretation of messages. Learners with different interpretations, or different intentions, or different perceived tasks, lead to have different interaction performance and, in turn, different learning experiences.

Purposeful engagement learners took interctive activities seriously and try to get maximum benefits, rather than merely getting by or doing the minimum amount of reaction required. Interactive behaviors are heavily influenced by learners thinking about what they perceive as interested, related, and important and what they believe they can accomplish. If a learner recognizes he/she can accomplish the request, then they will hehave in ways that will accomplish the task correctly with the best try. If a learner perceives that there is little chance for 'ideal' achievement, then he/she might face the task with trial-and-error manner. Learners who have higher science term scores are likely to have high expectations of being able to perform well in the 'Heart of Earth' courseware. Besides, learners' self-evaluation on competence are influenced by social comparisons via the top scores in the virtual 'Hero Hall.' Learners tended to observe and compare the success of others while they get to certain milestone in the courseware.

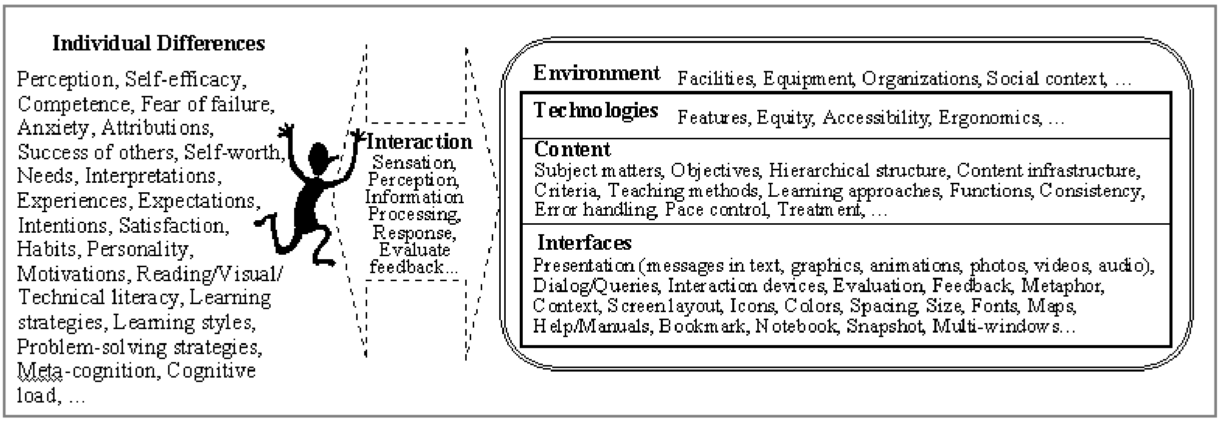
Cognitive strategy is 'mental processes that learners can deliberately recruit to help themselves learn and understand something new' (Brandt, 1988/1989; p.12) Perception and reasoning are the fundamental one, permeating and sustaining the change of knowledge on learning process. Learners' perception of message is active, selective and prejective in nature. It could be affected by the location of message, the formate of media, and the preference of learners.

The interactive activities of the 'Heart of Earth' courseware shape a learner's perceptions of tasks, which leads into various use of (meta)cognitive strategies by learners.

- Rehearsal To activate short-term memory.
- Elaborating To create analogies or to integrate new information into existing knowledge schemata.
- Organizing To organize messages provided on the courseware into interrelations among concepts/ideas.
- Monitoring To monitor achievement level and to figure out failure or weakness in attention or comprehension.
- Regulating To re-listen audio information and/or to review visual representation to modify action or pace.

In summary, learning is a function of the learner's individual differences, the interaction behaviors, the interfaces of courseware, the content to be learned, the technology issues, as well as the facilities, equipment, organizations, social context within a learning environment/organization/community (cf. Figure 2).

Figure 2. Factors Influencing Learning



Learners have a variety of responses to computer interfaces, e.g., reflective, thoughtful, and changing. While questions concerning mental models in human-computer interaction are simple, the answers are complicated, involving three dimension of factors (Abou Khaled et. Al., 1998; Ackerman, Sternberg, & Glaser, 1989; Ayersman & Reed, 1998; Iiyoshi & Hannafin, 1998; Keefe, 1982; Nahl, 1998; Stark, Renkl, Gruber, & Mandl, 1998; cf., Figure 2).

The characteristics of learners' mental models toward interfaces included exploration, topology, pattern, preference to audio/visual elements, and pictographic representation. In each learning activity within the courseware, specific patterns emerged. The mental model of the learners can be structured in representing objects to operate on, operations (actions and their syntax), content structure, functions or features, and the courseware states.

- Cognitive factors such as aptitude, ability, skill, prior knowledge, concepts, perspectives, educational level, experiences, and learning styles;
- Affective factors such as, values, self-efficacy, motivation, attitude, preferences, expectations, and anxiety; and
- Psychomotor factors such as eye-hand coordination and visual acuity.

Active participation is limited to those who are literate, those who have access to the technology, and those who are able to use the technology to filter information of value, bringing order out of chaos. This ability involves meta-cognitive skills that are not automatic. Consequently, no one perspective can be applied to every situation. Each one is insufficient by itself, and thus many factors must be considered simultaneously, in order to take action that will stretch and expand a learner's active engagement in learning.

Implications and Suggestions

World Wide Web has facilitated an exciting way to engage learners in active learning. Exploration and discussion over the web might inspire learners to locate useful resources in order to accomplish certain intentions. In order to increase the learner's satisfaction and performance and to create high-quality web courseware, designers must take human factors in learner-courseware interaction into account with specific reference to perceptual, physiological, and psychological aspects (Corry, 1998; Suess, 1997). The following are some suggestions derived from the above discussion.

- To increase efficiency as well as effectiveness for web exploration, teachers should examine learners' interactive logs about what they have experienced and how well they perform/learn.
- Since there is a preference for moderately difficult yet reachable, meaningful objectives/tasks, the challenge for designers/teachers is to make sure when

learners perceive tasks/requests as modertely difficult and worth learning.

- Learners can be allured to greater engagement of higher achievement via more appropriate interfaces in terms of interactive activities, message design, and screen layout of web courseware. To develop better interfaces, designers and/or researchers have to answer three basic questions first: (a) What initiates a learner's arousal? (b) What causes a learner to interact with the learning opportunity? And (c)What encourages a learner to persist in striving toward acoomplishing a task/goal?
- To improve learners' independence by supporting them with appropriate in-lab and after-lab assignments as well as information-seeking habits, and skills for 'learning to learn' is crucial for enabling pupils becoming effective life-long, self-initiated learners.

It is argued that virtual learning in cyberspace possess new features of learning environments. Benefits of emerging virtual learning environments include new metaphors for navigation, better opportunities for knowledge construction, and better opportunities for knowledge transfer. However, future research is called for to more fully understand the potential impact of these features (Oliver, 1997).

Research issues on human-computer interaction could be broader. More studies on various factors, as shown on Figure 2, in order to further understand learners' mental models in an web-based learning environment are encouraged on answering following questions: (a) Why not all learners use effective learning strategies? (b) What kinds of learning strategies are essential for web-based learning? (c) Is there any presumable relationship between learners' performance goal and (meta)cognitive strategy used in web-based courseware?

Learning happens via knowledge connection, which could be wither intra-conceptual or inter-conceptual oriented (Cobern, 1991; Magoon, 1977). Intra-conceptual connectedness is the primary focus of current individual and classroom learning to date. Web-based learning draws attention to the importance of inter-conceptual connectedness in cyber learning space. Therefore, further researches on epistemological connectedness focussing on external affairs of individuals and inter-conceptual connections are encouraged by the researcher.

Acknowledgement

This article describes research supported by the National Science Council under contract number NSC88-2520-S-032-005. The opinions expressed herein do not necessarily reflect the position or policy of the NSC nor the Tamkang University, and no official endorsement by any group should be inferred. The author wishes to deliver special thanks to teachers of Hsin-Der and Tang-Kon Elementary Schools for their collaboration in consulting subjuct mattters and arranging data collection environments. Special thanks go to Miss H. K. Wang and S. L. Cheng for courseware design and development, and to Miss S. L. Cheng and K. C. Lin for cooperation in collecting as well as analyzing the data.

References

Abou Khaled, O., Pettenati, M. C., Vanoirbeek, C., & Coray, G. (1998). MEDIT: A Distance Education Prototype for Teaching and Learning. Paper presented at the 3rd WebNet 98 World Conference of the WWW, Internet, and Intranet, Orlando, FL, November 7-12, 1998.

Ayersman, D. J., & Reed, W. M. (1998). Relationships among Hypermedia-Based Mental models and Hypermedia Knowledge. Journal of Research on Computing in Education, 30(3), pp.222-238.

Brandt, R. (1988/1989). On learning research: A conversation with Lauren Resnick, Educational Leadership, 46(4), 12-16.

Cobern, W. W. (1991). Contextual constructivism: The impact of culture on the learning and teaching of science. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Lake Geneva, WI, April 7-10, 1991.

Corry, M. D. (1998). Mental models and Hypermedia User Interface Design. Educational Technology Review, 9, pp.20-24.

Hannafin, M. J. (1996). Emerging technologies, ISD, and learning environments: Critical perspectives. Educational Technology Research and Development, 40(1), 49-63.

Iiyoshi, T., & Hannafin, M. J. (1998). Cognitive Tools for Open-Ended Learning Environments: Theoretical and Implementation Perspectives. Paper presented at the Annual Meeting of the

American Educational Research Association, San Diego, CA, April 13-17, 1998.
Jih, H. J, & Whang, S. K. (1998). Emporing interactive learning with contextual interfaces in the Heart of Earth web course. Paper presented at the WebNet98 (World Conference of the WWW, Internet, & Intranet), by Association for the Advancement of Computing in Education (AACE), Orlando, Florida, USA, November, 7-11, 1998.
Jih, H. J., & Reeves, T. C. (1992). Mental Models: A Research Focus for Interactive Learning Systems. Educational Technology, Research and Development, 40(3), 39-53.
Kozma, R. B. (1991). Learning with media. *Review of Educational Research, 61*(2), 179-212.
Land, S. M., & Hannafin, M. J. (1996). A conceptual framework for the development of theories-in-action with open-ended learning environments. Educational Technology, Research and Development, 44(3), 37-53.
Magoon, A. J. (1977). Constructivist approaches in educational research. Review of Educational Research, 47(4), 651-693.
Nahl, D. (1998). Learning the Internet and the Structure of Information Behavior. *Journal of the American Society for Information Science,* 49(11), pp.1017-1023.
Novak, A. (1964). Scientific inquiry. Bioscience, 14: 25-28.
Oliver, K. M. (1997). A Critical Analysis of Hypermedia and Virtual Learning Environments. ERIC ED412925.
Osborne, M., & Freyberg, P. (1985). Learning in science: Implications of children's knowledge. Auckland, New Zealand: Heinemann.
Rogoff, B. (1984). Introduction: Thinking and learning in social context. In B. Rogoff and J. Lave (Eds), Everyday cognition. Cambridge, MA: Harvard University Press.
Rowell, J. A., & Dawson, C. J. (1989). Towards an integrated theory and practice in science teaching. Studies in Science Education, 16, 47-73.
Sasse, M. (1991). How to t(r)ap users' mental models. In M. J. Tauber & D. Ackermann (Eds.), Mental models and human-computer interaction 2. Human Factors in Information Technology No. 7. Amsterdam, North-Holland: Elsevier Science Publishers B.V.
Shackel, B. (1997). Human-Computer Interaction--Whence and Whither? Journal of the American Society for Information Science, 48(11), pp.970-986.
Stark, R., Renkl, A., Gruber, H., & Mandl, H. (1998). Indeed, Sometimes Knowledge Does Not Help: A Replication Study. Instructional Science, 26(5), pp.391-407.
Suess, A. P. (1997). Designing the User Interface. Journal of Interactive Instruction Development, 10(2), pp.28-33.