一、 計畫名稱

- 引導式發現學習育樂軟體之動機因素設計對學習歷程、成效、與態度影響之研究 (The Effects of Interaction Motivators on Learning Pathway, Achievement, and Attitude during Interactive CAL)
- 計畫編號：NSC87-2511-S032-005 (執行期限：86年8月1日至87年7月31日)
- 主持人：計惠卿
- 執行機構及單位:淡江大學教育科技學系

二、 關鍵詞

- 動機因素、劇情、挑戰計分、學習歷程、學習成就、態度
- Interaction Motivators, Episode, Scenario, Challenge Score, Learning Pathways, Learning Achievement, Attitude

三、 摘要

學習心理學者認為，學習成果是學習者與學習情境之雙向互動過程的結果。認知學派的學者認為學習是學習者主動將新的資訊與先備知識產生有意義連結的過程；因此，學習是人們搜尋知識合理解釋、以對知識不斷建立意義的一種過程。在CAL學習情境設計上考慮其劇情設計及融合遊戲挑戰等手法，可讓學習者更能投入學習活動中。而本研究所欲了解及探討的是劇情設計、場景變色、成績計分等有關動機因素之設計，對學習者所可能產生的影響如何。因此，本研究以八種不同版本的引導式發現學習CAL軟體作為研究實驗工具，藉由國小學生與此軟體互動的學習歷程及學習成效資料分析，來探討此類軟體中劇情遊戲之動機因素設計對學習歷程及學習成效可能造成的影響。同時亦可以實驗驗證與探知劇情及遊戲設計在育樂多媒體電腦輔助學習軟體的設計發展中應受之重視及定位。主要研究結果顯示，挑戰計分與情境變色設計對於低中成就組學習者之學習成就影響遠高於高成就者;劇情設計之有無則沒有顯著影響;學歷/探索歷程之程度也不會顯著影響學習成就。文末並依據研究結果，提出設計、實施、後續研究之建議。

Motivation of learning is the initial determining factor in a learning event. The research was designed to compare the effects of three strategies of interaction motivators on learning pathways and performance in a guided-discovery CAL. Six hundred and forty nine 6th graders were divided into eight experimental groups and interacted with the Chronotope Park multimedia courseware in addition to their regular classes. The major findings indicated that episode and challenge scores are effective treatment for achievement of different aptitude learners in edutainment CAL. Additionally, for lower (and medium) aptitude learners, challenge scores and color change of modules did affect their achievement scores more than the higher aptitude learners. Conclusions is made and suggestion for further studies is presented.

四、 計畫目的

Leaning is the outcome of ongoing changes in our mental frameworks while we actively make meaning out of our experiences. The principle benefit of interactive CAL

(computer-assisted learning) is the ability to adapt to individual needs through various learning pathways, personal pacing, and informative feedback in a multimedia enriched learning context. Technology-enhanced learning environment empowers learners to solve felt problems and to construct personal meanings (Saye, 1997). The interfaces or Human-Computer Interfaces (HCI) to an interactive 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.

Motivation of learning is the initial determining factor in a learning event (Keller & Burkman, 1993). Motivation is "the process whereby people set goals and engage in cognitive activities as well as behaviors to attain their goals."(Schunk, 1991). Motivation can be inferred from a person's choice of action, effort expenditure, phrases of expression, and persistence of tasks, though it cannot be observed directly.

People's achievement motivation is associated with incentives, on-task efforts, and information processing during learning (i.e., Figure 1). Incentives (either rewards or task demands) increase the motivation to achieve and effort on task of a learner (Locke, 1968). High achievement motivated learners tend to spend more time on tasks, engage more frequently, persist longer, put more efforts, and utilize more reflect abilities on information processing tasks (Atkinson & Birch, 1978). Effort is typically assessed by amount of time spent on task (duration), by the frequency of a task (number of nodes), and by persistence of a task (duration per node; Rovelle, 1988; Revelle & Michaels, 1976). Researches on learners' motivation shows that pupils' perceptions of challenge, choice, locus of control, as well as collaboration in learning activities are critical for continuing motivation and for promoting enjoyment, ownership, attributing significance, self-regulation, responsibility, and persistence of learners (Schiefele, 1991). Studies on impact of the scenario (Keegan, 1995) and color change as well as challenge score (Malone, 1987) factors on learning pathways and achievement help us to explore and explain human behaviors during learning processes.

Learning context of multimedia 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. Keegan (1995) proclaimed that Scenario educational software, which helps immersing learners into an interactive world-of-work situation, is a basic type of discovery CAL. Nevertheless, courseware with only scenario motivator won't make ideal learning process happen. One reason for the general failure of interactive courseware to dramatically improve learning may be that learners lack effective exploration of the content and function of courseware materials.

Past studies focus on the motivation factors of game (i.e., Malone et. Al, since 1981) or on visual literacy of science concepts (i.e., Rieber, 1996; ChanLin & Chan, 1996) Literature dealing with how learners interact with or navigate in an interactive "courseware" with various motivational strategies reveal that little empirical research has occurred to date.

Hence, there is an urgent needs for more experimentation on learners' navigation pathways. The aim of this study is to answer the research question: (a) Do the appearance of prologue episode, color change, and challenge scores have different effects on interaction pathways and learning achievement of learners? (b) Do learners interact with the CAL differently depending on their prerequisite level, and what relation does this have to their interaction pathways and learning achievement?

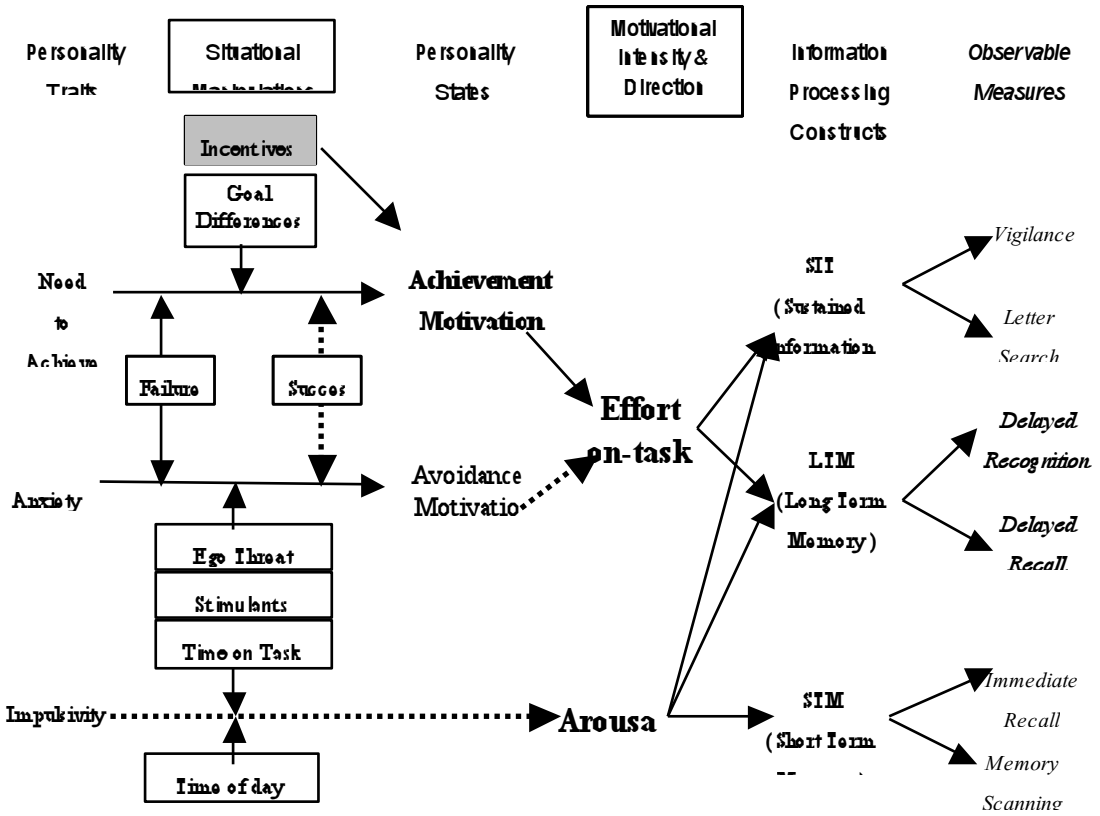
五、 研究方法

The research was designed to compare the effects of three motivation strategies (Prologue Episode, Color Change, and Challenge Score) on learning pathways, attitude, and achievement in a guided-discovery CAL. The learning content was a discovery multimedia CAL addressing a series of problem-based events regarding time and space concepts in elementary science.

To examine the effects of the CAL on learning pathways and achievement scores, a pretest-posttest (treatment: with or without Prologue Episode)*2 (treatment: with or without Color Change)*2 (treatment: with or without Challenge Score)*3 (higher vs. medium vs. lower science aptitude, within subjects) experimental design was used.

Six hundred and forty nine 6th grade pupils were randomly divided into eight experimental groups and interacted with the Chronotope Park multimedia courseware in addition to their regular classes.

Figure 1. Motivation Factors on Learners' Information Processing



(1998 © H.J.Jih adapted from Humphreys & Revelle, 1984)

六、 重要結果與討論

Differences of Gain Scores

A 3*2*2*2 treatment-by-aptitude randomized factorial design was employed for determination of the effect of prerequisite levels on interaction duration as well as achievement scores. The distribution of gain scores within each motivator strategies was analyzed by using four-way ANOVA (Table 3). There were significant differences in variance within the Aptitude levels (F=33.208, p=0.00) as well as the Color Change (F=6.636, p=0.10) and Challenge Score (F=6.6038, p=0.14) strategies at the .05 level. Follow-up posteriori multiple comparison by using Sheffe method indicated that the gain score of High Aptitude group and Medium Aptitude group were significantly higher than the Low Aptitude group at the .05 level. The gain score of Medium Aptitude group was significantly higher than the Low Aptitude group at the .05 level.

The second main effect, Episode treatment, (F=3.717, p=.054>.05), had no significant difference. However, the p value of episode treatment is approximating .05 and the large sample size of this data collection, it encourages us to pay more attention on the effect of Episode strategies.

There was significant interaction between Aptitude levels and Challenge Score groups (F=5.971, p=.003) as well as Episode and Color Change groups (F=7.643, p=.006). No significant interaction was found between Aptitude levels and Episode or Color Change

groups. Nevertheless, there were no significant differences between (unit) interaction/navigational nodes and duration of subjects on the gain scores. There were no significant differences between different aptitude subjects on the Unit Duration for Interaction or the Unit Duration for Navigation. However, there were significant interactions between the three treatment variables on the Unit Duration for Interaction (F=4.003, p=.046), Unit Duration for Navigation (F=15.323, p=.000), Duration for Interaction (F=9.231, p=.002), and Duration for Navigation (F=18.704, p=000).

Implications & Suggests

(1). The Color Change of modules and Challenge Score treatments have more impact on higher and medium aptitude learners than the lower learners in an edutainment CAL. Additionally, these three motivators interrelate with each other. These findings back up what Csikzentmihalyi (1975) proclaimed that a person can be truly engaged in activities only when the challenges are in balance with his/her abilities to response. Frustration, worry, or anxiety might result while challenges exceed 'moderate risk taking' level. For those higher or medium aptitude learners, the treatments of challenge score & color change might serve as a dynamic indicator for the risk as well as challenge levels and as an effective motivator for them. Challenging tasks with intrinsic competence motives (which are moderately difficult and on which a learner's effort will increase his/her competence; White, 1959) should form the major learning activities in an interactive CAL. If it is the case, "adaptive strategy" could be one ideal choice. For the purpose of promoting the motivating effects of challenge scores, to provide progressive clues, based upon learners' concurrent aptitude levels, in order to keep the risk levels staying in 'moderate' level are suggested by the researcher.

(2). The prologue episode treatment was not a significant motivator for learning achievement. This does not necessarily mean that episode for scenario construction is unnecessary. We could not conclude that this result is against the findings of Keegan's (1995) researches that context builders could motivate interaction. The reason why episode won't become a significant motivator might be that the Theme Park main menu as well as the other two motivational strategies (color change and challenge score) provide enough clues for learners on their construction of learning context. Hence, I'd rather adapt Paris & Turner's suggestion (1994) that situated motivation is a heuristic construct, external events as motivators are not uniformly motivating or un-motivating for learners.

(3). The Prologue Episode, Color Change of Modules, and Challenge Scores are effective motivators for promoting the depth of learners' interaction and navigation in term of the Unit Duration for Interaction, Unit Duration for Navigation, Duration for Interaction, and Duration for Navigation. The result of this study suggests that guided discovery CAL with context builder as well as challenge scores might provide an effective and enjoyable means of promoting duration of interaction and learning achievement through motivators. However, context build-up strategies and other motivational strategies that accounts for differences in competitiveness among other variables, such as individual differences, external support, available resources, etc. should be explored. In addition, ways to explicitly facilitate exploration behaviors to

all learners from within such courseware should be developed.

(4). The Challenge Score treatment can affect the self-estimated preference to courseware for learners. The motivation strategy is recommended for designers of edutainment CAL.

(5). Nevertheless, more interactions (or exploration/navigation) on the courseware did not bring about better learning outcomes. One possible reason could be that discovery is a time-consuming process. It is less possible for learners in this study accommodate their conceptual structure during the short period of time in this experimental study. The other possible explanation is learner's perspectives on schooling, computers, and value ...etc. Teacher and student's perception of their respective roles is critical to learning process and patterns (Grossman, & Stodolsky, 1995; Harris & Bell, 1990; Hooper & Reiber, 1994). Though the ultimate goal of science education is the production of independent, skilled learners (Dewey, 1938), the most open-ended learning environment may not be the best option to allure learners toward effective independent explorations (Land & Hannafin, 1996). CAL often used for drill-and-practice as well as tutorial applications, not for self-directed explorations. On the other hand, most teachers refuse to admit technology into their instruction. Existing beliefs and cultural expectations about schooling seem to determine whether and how teachers and students will use technology (Bliss et al., 1986; Cohen, 1988; Cuban, 1986; Harvey et al., 1990; Saye, 1997). Researchers suggested that real change in school culture is unlikely to occur without changes in the larger culture's conceptions of teaching and learning (Cohen, 1988; Sheingold, et al., 1990). To provide fruitful, multimedia learning resources alone won't promise empowering teaching and/or learning. More efforts and teacher tolerance for risk-taking should be a major factor influencing the success of learning by discovery approach. Hence, teachers and students perspectives toward technologies in education, personal factors of their perspectives (i.e., self-felt role, life experiences, beliefs, dispositions, ... etc.), and culture factors of exploration should be essential research directions on discovery learning via CAL technology. Learning outcomes of CAL tended to be interpreted via posttest scores, attitude scales, learner interviews & observations of navigational processes, and instructor/research interpretations. Seldom studies have asked to what degree the learner empowered in terms of the degree that a learner is immersed in and makes meaning of a technology-empowered learning environment (Hannafin, 1992). These should be interesting directions for further studies.

(6). Studies on differential sensibility to cues for rewards and punishments in order to further understand individual differences in learning an interactive learning environment, either stand-alone PCs or networked ones.

(7). To answer the research question: "How does a learner's learning style, personality (such as, introversion vs. Extraversion, impulsivity vs. anxiety),and situational manipulations in technology-enhanced learning environment are related to his/her arousal level, learning efforts, and various learning outcomes?"

(8). Research issues on motivation could be broader, for instance, the consideration of preferred actions, the cognitive representation of an intention, and possible action alternatives that might or might not be compatible with the currently dominant

motivational preference.

(9). The relationship of cognition, meta-cognition, motivation, and meta-motivation in an interactive learning environment could be another interesting issue.

七、 參考文獻

Arnone,M. P., Grabowski, B. L., & Rynd, C. P. (1994). Curiosity as a Personality Variable Influencing Learning in a Learner Controlled Lesson With and Without Advisement. *Educational Technology Research & Development* , 42(1), 5-20.

Atkinson, J. W. (1974). Strength of motivation and efficiency of performance. In J. W. Atkinson & J. O. Raynor (Eds.), *Motivation and achievement*. New York: V. W. Winston.

Barber, R. L. (1988). The user interface: Window to an informational world. In T. Bernold (Ed.), *User interfaces: Gateway or bottleneck?* New York: Elsevier Science.

Bliss, J., Chandra, P., & Cox, M. (1986). The introduction of computers into a school. *Computers and Education,* 10(1), 49-54.

Brown, J. S. (1989). Toward a new epistemology for learning. In C. Frasson & J. Gauthia (Eds.), *Intelligent tutoring systems at the crossroads of AI and education*. Norwood, NJ: Ablex.

Bruner, J. S. (1973). *Beyond the information given*. New York: Norton.

ChanLin, L. J., & Chan, K. C. (1996). *Computer graphics and metaphorical elaboration for learning science concepts*. ERIC ED 392 390.

Cohen, D. K. (1988). Educational technology and school organization. In R. Nikerson & P. Zodhiates (Eds.), *Techology in education: Looking toward 2020*. Hillsdale, HJ: Lawrence Erlbaum.

Covington, M. V. (1992). *Making the grade: A self-worth perspective on motivation and school reform*. Cambridge, MA: Cambridge University Press.

Csikzentmihalyi, M. (1975). Beyond boredom and anxiety. San Francisco, CA: Jossey-Bass.

Cuban, L. (1984). *How teachers taught*. New York: Longmans.

Dewey, J. (1938). *Experience and education*. New York: Macmillan.

Gaffney, J. S., & Anderson, R. C. (1991). Two-tiered scaffolding: Congruent processes of teaching and learning. In E. H. Hiebert (Ed.), *Literacy for a diverse society: Perspectives, practices, and policies*. New York: Teachers College Press.

Grossman, P. L., & Stodolsky, S. S. (1995). Content as context: The role of school subjects in secondary school teaching. *Educational Researcher*, 24(8), 5-12.

Hannafin, M. (1992). Emergin technologies, ISD, and learning environments: Critical perspectives. *Educational Technology Research & Development*, 40(1), 49-63.

Harris, D., & Bell, C. (1990). *Evaluating and assessing for learning*. (2nd ed.). London: Kogan Page.

Harvey, G., Kell, D., & Drexler, N. (1990). *Implementing technology in the classroom: Paths to success and failure*. Paper presented at Association of Educational Research for American, Boston, MA, USA.

Hooper, S., & Reiber, L. P. (1994). *Teaching with technology*. Paper presented at the 1994 AECT, Anaheim, CA, USA.

Humphreys, M. S., & Revelle, W. (1984). Personality, motivation, and performance: A theory of the relationship between individual differences and information processing. *Psychological Review,* 91, 153-184.

Jih, H. J. (1997). *Empowering interactivity through metaphor interfaces*. Paper presented at the 1997 AECT, New Mexico, USA.

Keegan, M. (1993). Design and effects of scenario educational software. *Educational Technology*, 33(6), p.19-25.

Keegan, M. (1995). *Scenario educational software: design and development of discovery learning*. Englewood Cliffs: Educational Technology Publications.

Keller, J., & Burkman, E. (1993). Motivation principles. In M. Fleming & W. Levie (Eds.), *Instructional message design: Principles for the behavioral and cognitive sciences.* Englewood Cliffs: Educational Technology Publications.

Land, S. M, & Hannafin, M. J. (1997). Patterns of Understanding with Open-Ended Learning Environments: A Qualitative Study. Educational Technology Research and Development, 45(2), 47-73.

Land, S., & Hannafin, M. (1996). A conceptual framework for the development of theories-in-action with open-ended learning environments. *Educational Technology Research & Development*, 44(3), 37-53.

Lepper, M. R. & Malone, T. W. (1987). Intrinsic Motivation and Instructional Effectiveness in Computer-Based Education, 255-286.

Lepper, M. R., Keavney, M., & Drake, M. (1996). Intrinsic Motivation and Extri nsic Rewards : A Commentary on Cameron and Pierce's Meta-Analysis. *Revi ew of Educational Research*, 66(1), 5-32.

Locke, E. A. (1968). Toward a theory of task motivation and incentives. *Organizational Behavior and Human Performance,* 3, 157-189.

Malone, T. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science*, 4, 333-369.

Malone, T. W. & Lepper, M. R. (1987). Making Learning Fun: A Taxonomy of Intrinsic Motivations for Learning. In R. E. Snow & M. J. Farr (Eds.), *Aptitute, learning, and instruction. Volume 3: Creative and affective process analysis*. Hillsdale, NJ: Lawrence Erlbaum. P. 223-253.

Osborne, M., & Freyberg, P. (1985). *Learning in science: Implications of children's knowledge*. Auckland, New Zealand: Heinemann.

Paris, S. G., & Turner, J. C. (1994). Situated motivation In P.R. Pintrich, D. R. Brown, & C. E. Weinstein (Eds.), *Student motivation, cognition, and learning: Essays in honor of Wilbert J. McKeachie.* Hillsdale, NJ: Lawrence Erlbaum Associateds, Inc.

Park, O. (1994). Dynamic visual displays in media-based instruction. *Educational Technology*, 34(4), p.21-25.

Pintrich, P. & De Groot, E. (1990). Motivational and self-requlated learning components of classroom academic performance. *Journal of Educational Psychology, 82*, 33-40.

Revelle, W. & Michaels, E. J. (1976). The theory of achievement motivation revisited: The implications of inertial tendencies. *Psychological Review,* 83, 394-404.

Revelle, W. (1988). Personality, motivation, and cognitive performance. In R. Kanfer, P. L. Ackerman, & R. Cudeck (Eds.), *Abilities, motivation, and methodology*. The

Minnesota Symposium on Learning and Individual Differences. Hillsdale, NJ: Lawrence Erlbaum Associates.

Rieber, L. (1996). Animation as feedback in a computer-based simulation: Representation matters. *Educational Technology Research & Development*, 44(1), p.5-22.

Rieber, L. P. (1996). Seriously Considering Play：Designing Interactive Learning Environments Based on the Blending of Microworlds, Simulations, and Games. *Educational Technology Research & Development* , 44(2), 43-58. Schunk, D. H. (1991). *Learning theories: An educational perspective*. New York: Macmillan Publishing Co.

Rieber, L. P., & Kini, A. (1991). Theoretical foundations of instructional applications of computer-generated animated visuals. *Journal of Computer-Based Instruction*, 18(3), p.83-88.

Savery, J. R., & Duffy, T. M. (1995). Problems based learning: An instructional model and its constructivist framework. *Educational Technology*, 35(5), p.31-38.

Saye, J. (1997). Technology and educational empowerment: Student's perspectives. *Educational Technology Research & Development*, 45(2), 5-25.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational Pshychologist, 26*, 299-323.

Schunk, D. H. (1991). *Learning theories: An educational perspective*. New York: Macmillan Publishing Co.

Sheingold, K., Hawkins, J., & Char, C. (1990). I'm the thinkist, you're the typist: The interaction of technology and the social life of classrooms. In O. Beyd-Barret & E. Scanlon (Eds.), *Computers and learning*. Washington, England: Addison-Wesley.

Shin, E. C., Schallert, D. L., & Savenye, W. D.. (1994). Effects of Learner in a Hypertext Environment. *Educational Technology Research & Development*, 42(1), 33-46.

Teslow, J. L. (1995). Humor Me：A Call for Research. *Educational Technology Research & Development*, 43(3), 6-28.

Towne, D. M., Jong, T., & Spapda, H. (Eds.). (1993). *Simulation-based experiential learning*. New York: Springer-Verlay.

Ullmer, Eldon J. (1994) . Media and Learning：Are There Two Kinds of Truth? *Educational Technology Research & Development*, 42(1), 21-32.

White, R. W. (1959). Motivation reconsidered: The concept of competence. *Psychological Review*, 66, 297-333.

附件一、Tables & Figures.

Figure. Attitude Values toward Elementary Science and the Courseware

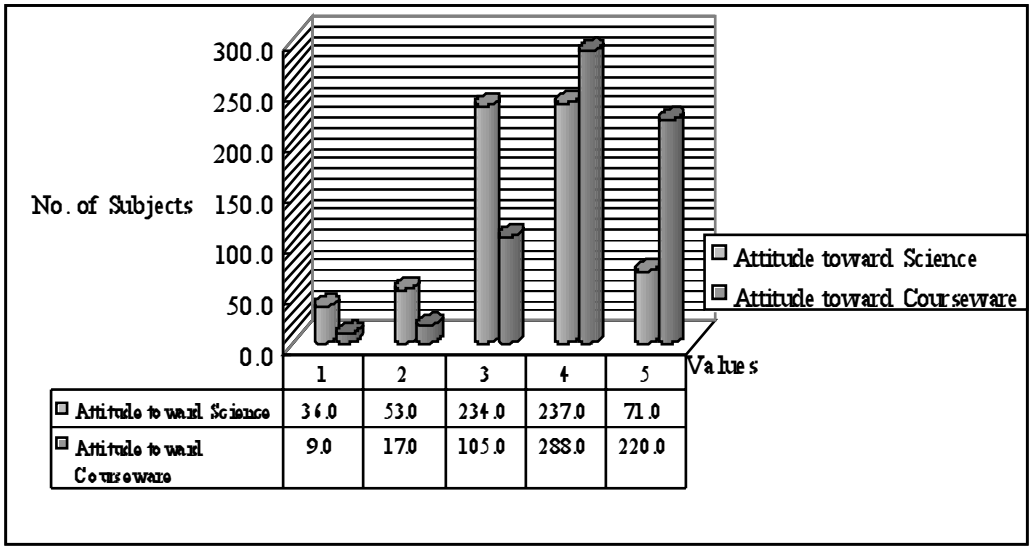


Table. The Distribution of Interactive Data for Subjects.

	All 5 modules	Modules 1~3	Modules 4~5
Duration for Interaction (sec.)	5761.44±3411.42 (0.0~28000.0)	3804.92±3000.01 (0.0~22273.0)	1956.52±1913.95 (0.0~26237.0)
Duration for Navigation (sec.)	1572.50±63.57 (12.0~13051)	1211.34±1538.37 (0.0~13050.0)	361.16±732.03 (0.0~11730.0)
Nodes of Interaction (no.)	173.85±190.96 (0.0~1445.0)	28.19±41.78 (0.0~393.0)	145.66±190.76 (0.0~1431.0)
Nodes of Navigation (no.)	122.68±65.23 (0.0~484.0)	41.55±32.76 (0.0~345.0)	81.13±60.17 (0.0~465.0)
Unit Duration for Interaction (sec.)	77.34±87.19 (0.0~736.3)	193.58±34.57 (0.0~984.5)	53.93±90.35 (0.0~795.1)
Unit Duration for Navigation (sec.)	17.52±28.19 (0.07~368.1)	34.63±43.44 (0.0~362.5)	6.94±16.92 (0.0~189.2)
Frequency of guidance/help	73.85±85.71 (0.0~635.0)	7.94±34.57 (0.0~635.0)	65.92±81.82 (0.0~586.0)
Frequency of question statements	81.85±163.37 (0.0~1618.0)	5.68±38.28 (0.0~687.0)	76.17±161.19 (0.0~1614.0)
Frequency of retry activities	183.69±307.61 (0.0~2574.0)	12.33±64.04 (0.0~842.0)	171.36±306.61 (0.0~2572.0)
Frequency of mis-click	119.265±94.73 (0.0~638.0)	32.61±39.12 (0~292.0)	86.659±89.40 (0~620.0)

p.s. Modules 4 & 5 are the major content. Modules 1~3 contents is for prerequisite knowledge.

Table. Cell Means for Subjects' Gain Scores

Strategies/Treatment	Low Aptitude	Medium Aptitude	High Aptitude	
	11.35±12.52 (n=206)	7.11±10.79 (n=213)	2.72±9.96 (n=230)	
0 Episode *(in Prologue)*	12.66 (n=100)	8.38 (n=104)	3.04 (n=120	7.73 (n=324)
1 Episode *(in Prologue)*	10.11 (n=106)	5.89 (n=109)	2.37 (n=110)	6.08 (n=325)

0 Color Change *(in 5 Modules)*	13.14 (n=114)	8.32 (n=125)	2.67 (n=125)	7.89 (n=364)
1 Color Change *(in 5 Modules)*	9.14(n=92)	5.39 (n=88)	2.79 (n=105)	5.64 (n=285)
0 Challenge Score *(each nodes)*	12.25 (n=90)	5.97 (n=114)	.02 (n=116)	5.58 (n=320)
1 Challenge Score *(each nodes)*	10.66 (n=116)	8.42 (n=99)	5.48 (n=114)	8.19 (n=329)

Table. ANOVA Source Data for Gain Scores

Source	SS	df	MS	F	p
Main Effects	9990.895	5	1998.179	17.145	.00
AptitudeLevel	7740.472	2	3870.236	33.208**	.00
Episode	433.189	1	433.189	3.717	.054
ColorChange	773.371	1	773.371	6.636*	.010
Challenge Score	703.668	1	703.668	6.038*	.014
2-Way Interactions	3227.478	9	358.609	3.077**	.001
AptitudeLevel*Episode	313.488	2	156.744	1.345	.261
AptitudeLevel*ColorChange	338.186	2	169.093	1.451	.235
AptitudeLevel*Challenge Score	1391.787	2	695.8	5.971**	.003
Episode*ColorChange	890.717	1	890.717	7.643**	.006
Episode*Challenge Score	324.486	1	324.486	2.784	.096
ColorChange*Challenge Score	3.771	1	83.771	.719	.397
3-Way Interactions	1137.388	7	162.484	1.394	.205
AptitudeLevel*Episode*ColorChange	24.481	2	12.240	.105	.900
AptitudeLevel*Episode*Challenge Score	183.488	2	91.744	.787	.456
AptitudeLevel*ColorChange*Challenge Score	848.578	2	424.289	3.641	.027
Episode*ColorChange*Challenge Score	69.698	1	69.698	.598	.440
4-Way Interactions	432.931	2	216.466	1.857	.157
AptitudeLevel*Episode*ColorChange*Challenge Score	432.931	2	216.466	1.857	.157
Explained	14764.700	23	641.943	5.508	.000
Residual	72841.260	625	116.546		
Total	87605.959	648	135.194		

***Significant at á=.01* **Significant at á=.05*

Table. Four-Way ANOVA Summary Data for Interactive Pathways within Major Modules

Source of Variation	F	p
Nodes of Interaction		
AptitudeLevel*ColorChange	4.561*	.011
ColorChange*Challenge Score	11.716**	.001
Nodes of Navigation		
AptitudeLevel	3.867*	.021
Challenge Score	54.365**	.000
AptitudeLevel*Episode	3.433*	.033
AptitudeLevel*ColorChange	4.153*	.016
Duration for Interaction		
AptitudeLevel	4.869**	.008
Episode	14.787**	.000
Episode*ColorChange	24.262**	.000
Episode*Challenge Score	14.872**	.000
ColorChange*Challenge Score	6.282*	.012
Episode*ColorChange*Challenge Score	9.231**	.002
Duration for Navigation		
Episode	19.955**	.000
ColorChange	12.024**	.001
Episode*ColorChange	19.687**	.000
Episode*Challenge Score	15.499**	.000
ColorChange*Challenge Score	19.666**	.000
Episode*ColorChange*Challenge Score	18.704**	.000

Unit Duration for Interaction		
Episode	5.469*	.020
ColorChange	7.488**	.006
Challenge Score	6.207*	.013
Episode *Challenge Score	5.809*	.016
ColorChange *Challenge Score	18.990**	.000
AptitudeLevel *Episode *Challenge Score	3.532*	.030
Episode *ColorChange *Challenge Score	4.003*	.046
Unit Duration for Navigation		
Episode	21.514**	.000
ColorChange	25.283**	.000
Challenge Score	17.918**	.000
Episode *ColorChange	23.036**	.000
Episode *Challenge Score	13.169**	.000
ColorChange *Challenge Score	23.125**	.000
Episode *ColorChange *Challenge Score	15.323**	.000
Frequency for Guidance/Help		
ColorChange	4.407*	.036
Challenge Score	5.691*	.017
AptitudeLevel *ColorChange	4.484*	.012
ColorChange *Challenge Score	6.218*	.013
Frequency of Question Statement		
AptitudeLevel	3.551*	.029
ColorChange	8.390**	.004
Challenge Score	11.176**	.001
ColorChange *Challenge Score	5.136**	.024
Frequency of Retry the Activity		
Challenge Score	17.587**	.000
ColorChange *Challenge Score	6.648**	.010
Frequency of Mis-clicks		
AptitudeLevel	4.008*	.019
ColorChange	7.574**	.006
Challenge Score	29.790**	.000
ColorChange *Challenge Score	8.244**	.004

**Significant at α=.05; ** Significant at α=.01*

附件一、出席ED-MEDIA/ED-TELECOM'98資料.

- 出席ED-MEDIA/ED-TELECOM'98國際學術會議心得報告
- 發表ED-MEDIA/ED-TELECOM'98之論文