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The Effects of Different Feedback Reinforcements on Computer-Assisted Learning on Engineering Drawing*

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This investigation looks at the effectiveness of computer assisted learning with different feedback reinforcements, cognitive styles and spatial abilities on the performance of engineering drawing. The study sample involved 176 students enrolled in the Department of Mechanical Engineering at the Industrial Vocational Senior High School in central Taiwan during fall semester of 1998. It was found that the students who had more positive computer attitudes also had significantly more positive attitudes towards engineering drawing. When feedback reinforcement of pictures, characters, and sound was given, students whose cognitive style belonged to field independence achieved higher achievement in engineering drawing than did those students whose cognitive style belonged to field dependence. When feedback reinforcement of pictures, characters and sound was given, students with high spatial ability achieved higher achievement of engineering drawing than did students with low spatial ability. Also, students with high spatial ability whose cognitive style belonged to field independence achieved higher achievement of engineering drawing than did students with low spatial ability whose cognitive style also belonged to field independence.

INTRODUCTION

Teachers are supposed to develop or provide different teaching materials and strategies for different learners based upon the concept of teaching according to the student's ability. There are some specific models of teaching that can facilitate learning by a group of students. Some teaching models may be as suitable for one group of learners as another [1].

Winn emphasised that if the teaching method can meet a learner's specific learning style, then it will facilitate achievement [2]. The question is how does one identify the learners learning style, which is part of the field of cognitive style [3]?

Cognitive style refers to the methods and habits pertaining to information processing by individuals that present the behaviour models of perception, thought, memory, logical judgment and problem solutions of learners. Saracho contended that cognitive style contains stable attitudes, preferences, or habitual strategies that distinguish the individual styles of perceiving, remembering, thinking and solving problems [4].

In short, cognitive style refers to the ways individuals react to different situations. Moreover, the cognitive style usually mirrors the personal traits and social behaviours that can be identified through objective assessment. In addition, some cognitive styles that are imposed in some specific learning environments could contribute to much better learning achievements. As such, appropriate teaching methodologies and strategies can be selected to facilitate the understanding of the individual learner's characteristics. After that, the learning effectiveness can be advanced as long as the learners' cognitive styles can be realised.

With the exception of learning style, the spatial ability of learners can also affect their achievements. This has not received much attention from researchers. According to Tai, the influence of spatial ability on engineering drawing probably surpasses other factors typically studied in relation to achievement in engineering drawing [5].

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Previously, there was little research related to achievement in engineering drawing and spatial ability that investigated the effects of Computer-Assisted Learning [6]. Waldrop postulated that the effectiveness of Ccomputer-Assisted Learning (CAL) is closely related to the implementation of feedback reinforcement skills [7]. Swanson and Anderson (1982) also contended that to provide the positive reinforcement after accurate reactions come out not only gives an impetus for the continuous appearance of accurate reactions but also encourages the learner's learning interest [8]. There were dozens of scholars that came to these same conclusions (eg Ref. [9]).

Jaeger stated that learners' attention might be spread out if complicated reinforcements are employed [10]. Obviously, different feedback reinforcements and different Computer-Assisted Learning systems require different resources input. A complicated positive reinforcement CAL needs much more resource input than a simple one [10]. Thus, how to work out different CAL systems with positive reinforcements in an economical and effective way to meet the different cognitive styles and spatial abilities of learners in order to improve their achievements is an issue that deserves investigation.

PURPOSE

This study investigated the effectiveness of Computer-Assisted Learning with different reinforcements, cognitive style and spatial ability on the performance of engineering drawing. More specifically, the purpose of this study was to test the following three research hypotheses:

1. There is a significant difference in the performance of engineering drawing between different attitudes towards computers after eliminating the effects of covariates.
2. There are significant differences in the performance of engineering drawing between different feedback reinforcements, cognitive styles and the interaction between both of them.
3. There are significant differences in the performance of engineering drawing between different cognitive styles, spatial abilities and the interaction between both of them.

THE CAL SYSTEM

Architecture of the CAL System

According to the theoretical analysis and related research findings, four components for building the CAL system with interactive multimedia that need to be combined are: the learning theory foundation, the information technology, the contents of subject of matter and the learning environment.

The six stages of the Life Cycle Approach consist of analysis, planning, designation, development, assessment and amendment. These elements were utilised to develop the CAL system by means of iterating feedback and amendments. The architecture of the CAL system with interactive multimedia is illustrated in Figure 1.

Flowchart for Developing the CAL System

The six stages of the Life Cycle Approach were used as the scaffold for developing the CAL system. In the analysis and planning stages, learners and current resources were analysed first to establish the teaching plans. Then, the system specifications were identified and vehicles selected and developed. Lastly, teaching objectives were determined.

Initially, at the designation stage, curriculum experts, pedagogy experts, programme designers, art designers and music designers were gathered as a team to develop the contents of the subject matter. Secondly, teaching strategies, activities and setting could be worked out based on the contents of the subject matter developed previously. Finally, software scenario, art on screen and feedback and executive interfaces were designed.

In the developmental stage, developing software, compiling an operational manual and testing and amending the CAL software were the main purposes of this stage. Ultimately, assessment and amendment were the final stages that sought to assess and amend the developed software in order to assure that its functions could work well. Figure 2 shows the flowchart for developing the CAL system.

Designation of System Procedure

The CAL system with different feedback was designed to connect the screens of the scenario and display the order and structure among the screens. The system procedure is exhibited in Figure 3.

METHODS

The sample for this study was comprised of students enrolled in the Department of Mechanical Engineering of the Industrial Vocational Senior High School in Taiwan during the fall semester of 1998. In total, four classes (176 students) were randomly selected to serve as samples.

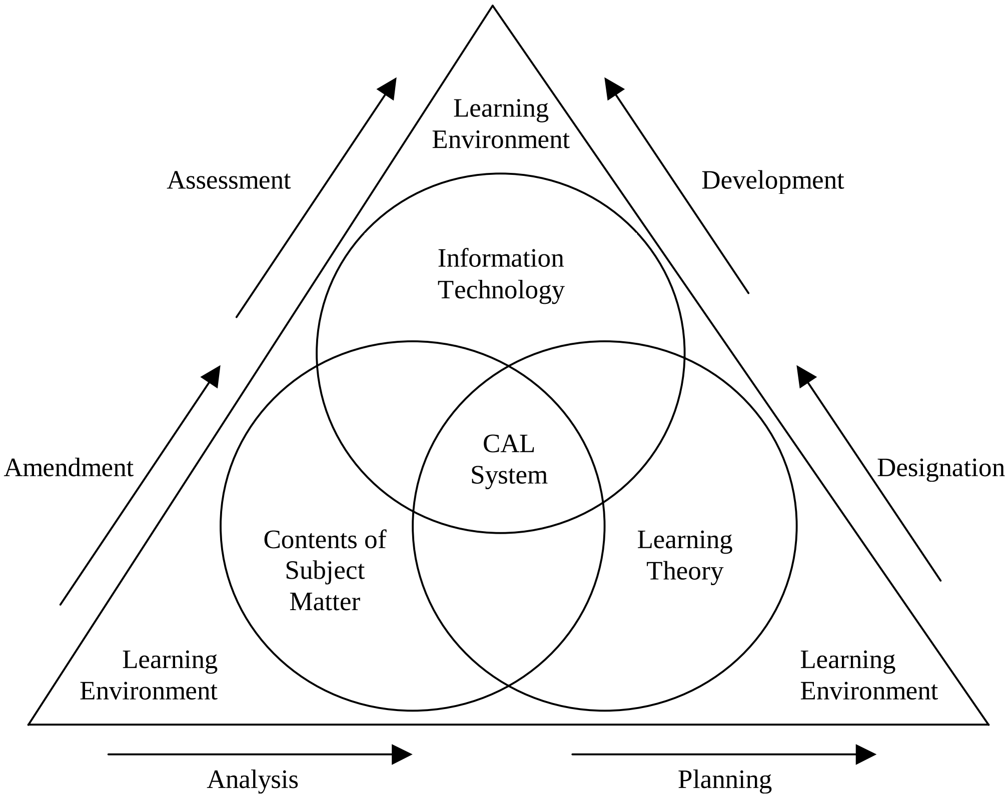

Figure 1: Architecture of the CAL system with interactive multimedia.

Procedure

The experimental design adopted for this study was a quasi pre-test/post-test design. Pre-tests were administered to all subjects to collect information with respect to students' prior attitudes towards the use of computer and engineering drawing, to measure students' existing spatial abilities and cognitive styles and also to measure previous drawing performance. The students of each class was randomly selected into one of three groups to be treated respectively with three different kinds of positive reinforcements of CAL during the experimental period, namely:

- Pictures and characters.
- Pictures, characters and sound.
- Pictures, characters, sound and animation.

Post-tests of performance in engineering drawing and spatial abilities were administered following the treatments.

Instrumentation

Five instruments were utilised in this study. Both the computer and engineering drawing attitude scales consisted of the following four dimensions: interest, confidence, anxiety, and effectiveness. The engineering drawing achievement scale is composed of *transfer pictorial drawing to orthographic drawing, transfer orthographic drawing to pictorial drawing, sketching missing line of orthographic drawing* and *sketching missing view of orthographic drawing* dimensions. The spatial ability scale includes *spatial relation*, *spatial rotation (2D)*, *spatial rotation (3D)* and *spatial organisation* dimensions.

The contents of the treatment of this experiment was orthographic drawing and included features of orthographic projection, basic projection, interpreting pictorial images of object multiple view projections and pictorial drawing.

Treatments were applied for one month. This is the normal period of time used during the semester for presenting the concepts of orthographic projection.

During the experimental period, all three groups received the traditional lecture and utilised the same amount of instructional time. However, different kinds of positive reinforcements of CAL were treated for each group. The contents of the post-test of achievement was the same as that of the pre-test except that parallel drafting achievement items were used. Also, the Group Embedded Figures Test was employed to examine field-dependence and field-independence.

Data Analysis

An analysis of covariance was applied to test the research hypotheses; the covariates were the engineer-

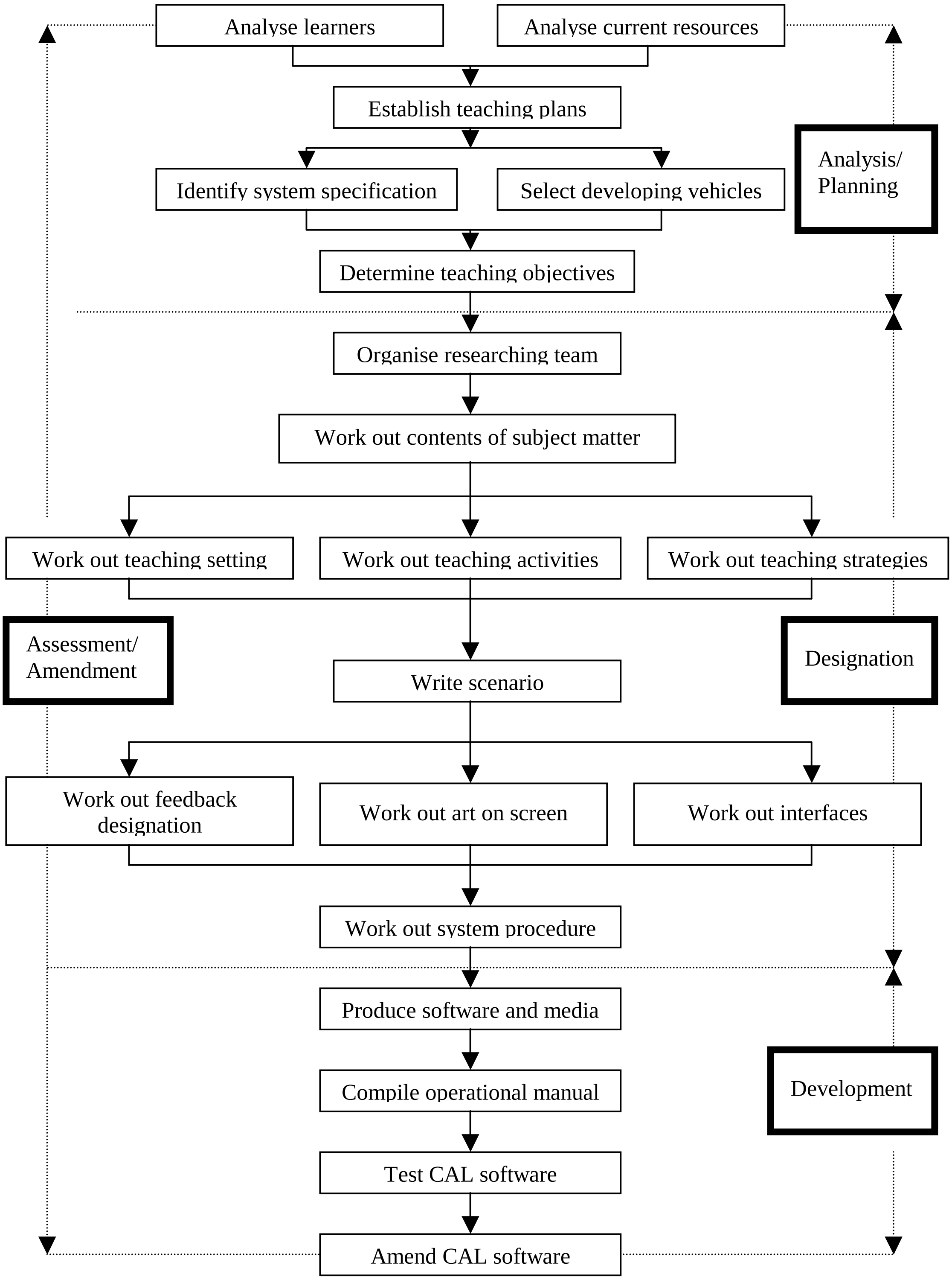

Figure 2: Flowchart for developing the CAL system.

ing drawing achievement pre-test, the engineering drawing attitude pre-test and the computer attitude pre-test. The test of Multi-colinearity and homogeneity of within-class regression coefficient were made as well. ANOVA, MANOVA and Scheffe's test were also utilised to test the research hypotheses. In addition, LISREL 8.30 was used to conduct the goodness-of-fit measures [11].

The reliability coefficient of instruments ranged from 0.79 to 0.93. The fit of the model to the data produced the following: $c^2 = 3.719$ ($p = 0.0538$), normed fit index = 0.949, comparative fit index = 0.957, incremental fit index = 0.962, root mean square residual = 0.0333 and the goodness-of-fit index = 0.992. All of these indices suggest a good fit of the model to the data.

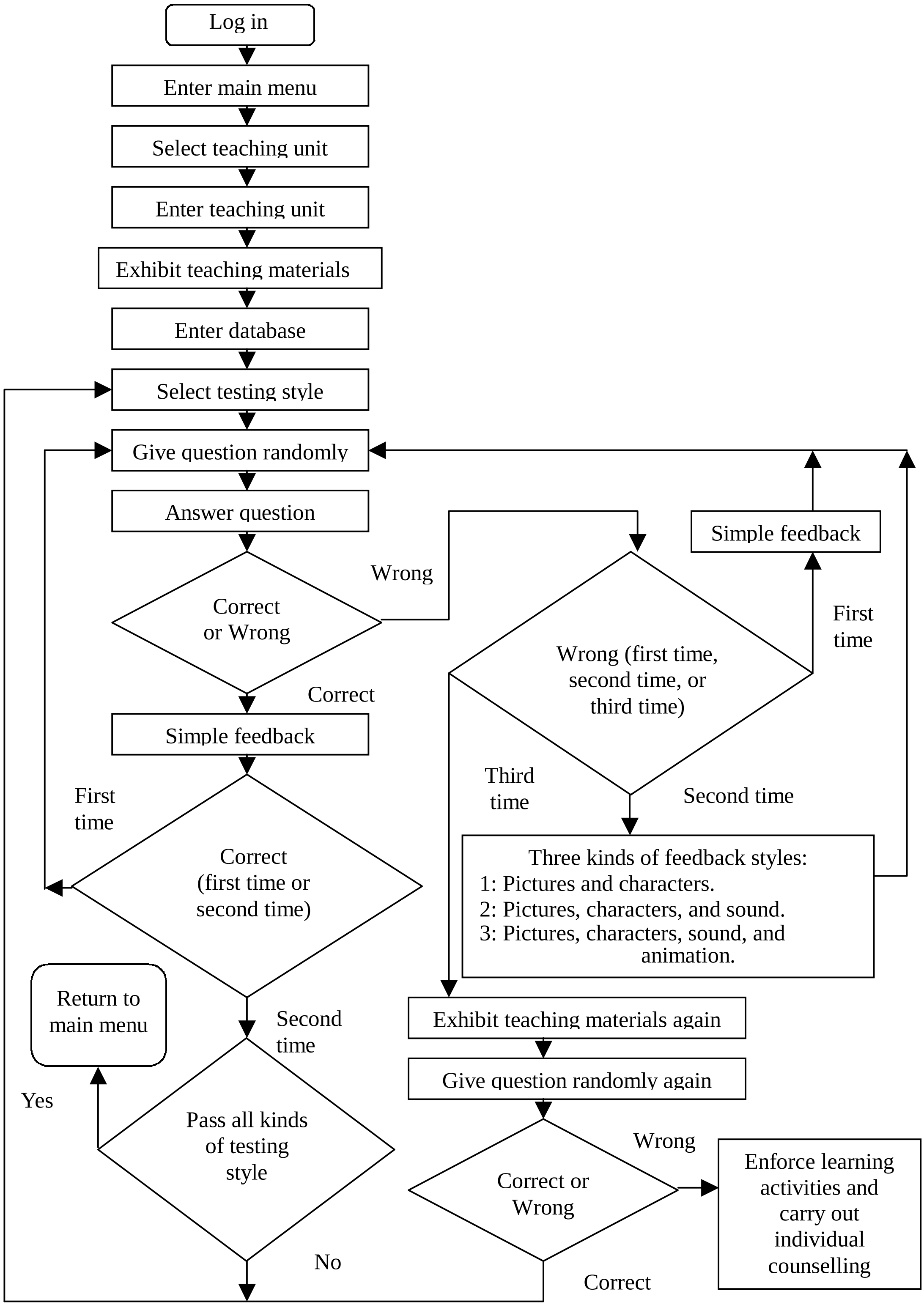

Figure 3: Flowchart of the CAL system with different kinds of feedback style.

FINDINGS

Attitudes and Learning Performance

The analysis pertaining to different attitudes towards computer and learning performance of engineering drawing is shown in Table 1. A significant difference was found in the performance of engineering drawing between different attitudes toward the computer after eliminating the effects of covariates (Wilks' $\Lambda = 0.95$, $p < 0.05$).

After further analysis with ANOVA, a significant difference was found in the performance of engineering drawing between different attitudes toward the computer ($F = 4.17$, $p < 0.05$). Yet there was no significant difference in the performance of engineering

Table 1: Analysis of the performance of engineering drawing between different computer attitudes.

Source of Variance	df	SSCP A	SSCP B	Wilk's Λ	F-Value A	F-Value B
Main Effect (attitude)	1	$\begin{bmatrix} 9.18 & 3.01 \\ 3.01 & 0.98 \end{bmatrix}$		0.95*	0.61	4.17*
Covariate	2	$\begin{bmatrix} 52.81 & -0.20 \\ -0.20 & 3.98 \end{bmatrix}$		0.79*	1.76	8.44*
Residual	86	$\begin{bmatrix} 1257.36 & 24.447 \\ 24.447 & 9.80 \end{bmatrix}$				
Total	90					

*p < 0.05
A: Achievement; B: Attitude.

drawing between different learning achievements (F = 0.61, p > 0.05). Table 2 shows that students who belong to the high-score group of computer attitudes will exit with more positive post-test attitudes towards the computer than students who belong to the low-score group of computer attitudes.

Table 2: Scheffe's test to the engineering drawing attitude between different computer attitudes.

Computer Attitude	Engineering Drawing Attitude	t-test
High-Score	3.86	2.04*
Low-Score	3.59	

*p < 0.05

Feedback, Cognitive Styles and Their Interaction

The analysis of performance of engineering drawing pertaining to different feedback reinforcements, cognitive styles and the interaction between both of them, is displayed in Tables 3 and 4. It was revealed that there were no significant differences in the performance of engineering drawing amongst different feedback reinforcements, the interaction of cognitive style and different feedback reinforcements (Wilks' Λ = 0.99, p > 0.05).

Table 3: Means of performance for different cognitive styles and feedback reinforcements.

	I		II		III	
	A	B	A	B	A	B
Field dependence	16.85	3.71	17.50	3.67	18.37	3.71
Field independence	16.60	3.83	18.27	3.77	18.38	3.69

I: Pictures, characters, sound, and animation.
II: Pictures, characters, and sound.
III: Pictures and characters.
A: Achievement; B: Attitude.

Table 4: Analysis of performance for different cognitive styles, feedback reinforcements and their interaction.

Source of Variance	df	SSCP A	SSCP B	Wilk's Λ	F-Value A	F-Value B
C	1	$\begin{bmatrix} 81.81 & -1.05 \\ -1.05 & 0.01 \end{bmatrix}$		0.96*	6.60*	0.04
D	2	$\begin{bmatrix} 7.87 & -1.22 \\ -1.22 & 0.20 \end{bmatrix}$		0.99	0.31	0.35
C*D	2	$\begin{bmatrix} 5.25 & -0.91 \\ -0.91 & 0.25 \end{bmatrix}$		0.99	0.21	0.43
Residual	88	$\begin{bmatrix} 2107.2 & 58.22 \\ 58.22 & 49.96 \end{bmatrix}$				

*p < 0.05
A: Achievement; B: Attitude; C: Cognitive Style; D: Feedback Reinforcement.

Nevertheless, there was a significant difference detected in the performance of engineering drawing between different cognitive styles (Wilks' Λ = 0.96, p < 0.05). As shown in Table 4, the ANOVA was statistically significant for achievement (F-value = 6.60, p < 0.05), but was not significant for attitude (F-value = 0.04, p > 0.05).

After further analysis with Scheffe's test, Table 5 shows that when feedback reinforcement of pictures, characters and sound was given, students whose cognitive style belonged to field independence executed higher achievements in engineering drawing than that of students whose cognitive style belonged to field dependence.

Table 5: Scheffe's test for different cognitive styles and feedback reinforcements.

Cognitive style	I	II	III
Field dependence	_	_	_
Field Independence	_	-2.53*	_

*p < 0.05
I: Pictures, characters, sound, and animation.
II: Pictures, characters, and sound.
III: Pictures and character.

Feedback, Spatial Abilities and Their Interaction

The analysis of performance of engineering drawing concerning different feedback reinforcements, spatial abilities and the interaction between both of them is shown in Tables 6 and 7. The analysis indicated that there were no significant differences in the performance of engineering drawing between different feedback reinforcements, the interaction of spatial abilities and different feedback reinforcements

Table 6: Means of performance for different spatial abilities and feedback reinforcements.

	I		II		III	
	A	B	A	B	A	B
High Spatial Ability	16.97	3.76	18.33	3.79	18.57	3.75
Low Spatial Ability	16.93	3.68	17.00	3.60	17.96	3.79

I: Pictures, characters, sound, and animation.
II: Pictures, characters, and sound.
III: Pictures and characters.
A: Achievement; B: Attitude.

Table 7: Analysis of performance for different spatial abilities, feedback reinforcements and their interaction.

Source of Variance	df	SSCP		Wilk's	F-Value	
		A	B	Λ	A	B
E	1	$\begin{bmatrix} 80.07 & 5.04 \\ 5.04 & 0.31 \end{bmatrix}$		0.96*	6.43*	1.08
D	2	$\begin{bmatrix} 3.00 & -0.93 \\ -0.93 & 0.29 \end{bmatrix}$		0.99	0.12	0.49
E*D	2	$\begin{bmatrix} 2.54 & -0.48 \\ -0.48 & 0.09 \end{bmatrix}$		0.99	0.10	0.15
Residual	88	$\begin{bmatrix} 2116.53 & 50.31 \\ 50.31 & 49.74 \end{bmatrix}$				

*$p < 0.05$
A: Achievement; B: Attitude; C: Cognitive Style; E: Spatial Ability.

(Wilks' $\Lambda = 0.99$, $p > 0.05$).

Nonetheless, there was a significant difference in the performance of engineering drawing between spatial abilities (Wilks' $\Lambda = 0.96$, $p < 0.05$). As shown in Table 7, the ANOVA was statistically significant for achievement (F-value = 6.43, $p < 0.05$), but was not significant for attitude (F-value = 1.08, $p > 0.05$).

Further analysis with Scheffe's test (see Table 8) shows that when feedback reinforcement of pictures, characters and sound was given, students with high spatial ability realised higher achievements in engineering drawing than students with low spatial ability.

Table 8: Scheffe's test of achievements for different spatial abilities and feedback reinforcements.

Spatial Ability	I	II	III
High spatial ability	_	2.45*	_
Low spatial ability	_		_

*$p < 0.05$
I: Pictures, characters, sound, and animation.
II: Pictures, characters, and sound.
III: Pictures and characters.

Performance, Spatial Ability, Cognitive Style and Their Interaction

The analysis of performance of engineering drawing pertaining to spatial ability, cognitive style, and the interaction between both of them is illustrated in Table 9. This indicates that, by utilising a two-way MANOVA, there was a significant difference detected in the performance of engineering drawing between different cognitive styles (Wilks' $\Lambda = 0.96$, $p < 0.05$).

After further analysis with two-way ANOVA, there was a significant difference found in the achievements of engineering drawing between different cognitive styles (F-value = 6.64, $p < 0.05$). However, there was no significant difference in the attitude between different cognitive styles (F-value = 1.09, $p > 0.05$).

Table 9: Analysis of performance for different cognitive styles, spatial abilities and their interaction.

Source of Variance	df	SSCP		Wilk's	F-Value	
		A	B	Λ	A	B
C	1	$\begin{bmatrix} 80.07 & 5.04 \\ 5.04 & 0.31 \end{bmatrix}$		0.96*	6.64*	1.09
E	1	$\begin{bmatrix} 48.27 & -1.90 \\ -1.90 & 0.07 \end{bmatrix}$		0.97	4.00	0.25
C* E	1	$\begin{bmatrix} 1.44 & -0.33 \\ -0.33 & 0.07 \end{bmatrix}$		0.99	0.12	0.26
Residual	86	$\begin{bmatrix} 2072.36 & 51.55 \\ 51.55 & 49.97 \end{bmatrix}$				

*$p < 0.05$
A: Achievement; B: Attitude; C: Cognitive Style; E: Spatial Ability.

Further analysis with Scheffe's test, shown in Tables 10 and 11, showed that students with high spatial ability, whose cognitive style belonged to field independence, achieved higher scores on learning achievement of engineering drawing than the students with low spatial ability whose cognitive style also belonged to field independence.

Table 10: Means of performance of engineering drawing for different cognitive styles and spatial abilities.

	Field dependence		Field independence	
	A	B	A	B
High spatial ability	17.54	3.65	18.78	3.77
Low spatial ability	16.63	3.72	17.51	3.78

A: Achievement; B: Attitude.

Table 11: Scheffe's test of achievement for different cognitive styles and spatial abilities.

	Field dependence	Field independence
High spatial ability	–	1.96*
Low spatial ability	–	–

*$p < 0.05$

DISCUSSION

The students who had more positive computer attitudes also had significantly more positive attitudes toward engineering drawing. It is generally accepted that the learner's attitude is closely related to learning achievement. In general, the learners with more positive attitudes are superior to the learners with less positive attitudes in learning achievement. Therefore, according to the findings of this study, the students who had more positive computer attitudes also had significantly more positive attitudes towards engineering drawing. Cultivating students' computer attitudes will give an impetus to promote their learning achievements in engineering drawing.

When feedback reinforcement of pictures, characters and sound was given, students whose cognitive style belonged to field independence gained higher scores on learning achievements in engineering drawing than did those students whose cognitive style belonged to field dependent.

Witkin et al stated that field dependent students need salient cues to help them learn concepts more effectively [12]. In other words, field independent students tend to rely on internal cues and are more able to differentiate an embedded figure from an organised field. Wey and Waugh also investigated that in the text-only group, the field independent students performed significantly better than the field dependent students [13]. In addition, Gordon stated that those who had a field-independent learning style tend to view the world more analytically, solve problems more easily, and favour inquiry and independent study [14]. They are also more likely to provide their own structure to facilitate learning. The finding concerning cognitive style in this study was congruent with the other researchers' findings stated above.

When feedback reinforcement consisted of pictures, characters and sound, students with high spatial ability achieved higher scores on learning achievement of engineering drawing than did the students with low spatial ability. According to Hays' study, students with low spatial ability benefited from animated presentations [15]. Jaeger also stated that learners' attention might be spread out if complicated reinforcements are employed [10]. Finally, Manrique et al pointed out that learners with high spatial ability respond significantly faster and are more accurate on the rotation task than those with low spatial ability [16]. The findings regarding learning achievements found in this study for different feedback reinforcements and spatial ability were consistent with the other researchers' findings described above.

Students with high spatial ability whose cognitive style belonged to field independence performed better in engineering drawing than did students with low spatial ability whose cognitive style also belonged to field independence. It is commonly accepted amongst researchers that cognitive style and spatial ability are the factors influencing learner educational performance [14-17]. With respect to the effects of spatial ability on learning achievements, there were several studies that indicated that there were no significant differences in academic course performance [18]. However, the findings of this study demonstrated that there are indeed close connections to be found amongst feedback reinforcement, cognitive style and spatial ability.

CONCLUSION

It is generally accepted that different teaching models should be offered for different learners and there are dozens of factors affecting learning achievements. Of all the affecting factors, particularly in Computer-Assisted Learning (CAL) for engineering drawing, different feedback reinforcements, cognitive styles and spatial abilities have been the major focus of attention for researchers.

To some extent, the findings of this study were congruent with the other research results. In addition, this study investigated the interaction between different feedback reinforcements, cognitive styles, and spatial abilities simultaneously, rather than focus on each of them respectively. However, sufficient attention has not been giving to field-mixed group in most of the literature. This may result in different findings when field-mixed is added to the classification of cognitive styles.

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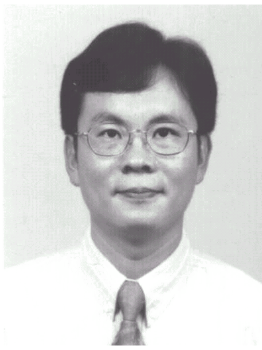
BIOGRAPHIES

David Wen-Shung Tai was born in July 1951 and is a Professor in the Department of Industrial Education at the National Changhua University of Education (NCUE) in Changhua, Taiwan. He completed his undergraduate degree in the Department of Industrial Education at the National Taiwan Normal University in Taipei, Taiwan, and earned his MS degree from the Department of Industrial Technology at the University of Wisconsin-Platteville in the USA. He earned simultaneously his MS degree from the Department of Computer Science at Iowa State University in the USA and his PhD from the Department of Industrial Education and Technology at the same University in 1987.

From 1987 to 1993, he was an Associate Professor at the NCUE and was awarded a professorship in 1993. From 1999 to 2001, he has been Chairman of the Department of Industrial Education. He was appointed the Dean of the College of Technology at National Taiwan Normal University as of 2001.

Prof. Tai's research experience includes engineering drawing, computer-assisted learning, spatial ability and problem solving. His latest projects include the study of promoting student spatial abilities and the problem solving abilities of orthographic engineering drawing in vocational high schools.



Frank Ming-Che Chen received his Bachelor degree in Economics from Soochow University, Taiwan, in 1983, followed by an MBA degree in Insurance in 1985 from Fengchia University, Taiwan. After that, he spent 12 years lecturing at college before entering the National Changhua University of Education in Changhua, Taiwan, to work on his doctorate. He is currently a doctoral candidate specialising in human resources management.

Since 1989, he has been an Associate Professor at the National Taichung Institute of Technology, Taiwan. In 1996, he earned his Fellow, Life Management Institute (FLMI) title from the Life Office Management Association (LOMA) in the USA. His research interests lie in workplace instruction in the insurance industry and the international business field.

Tzu-An Tsai gained his BS degree in information and computer education from the National Taiwan Normal University, in 1990. He also holds an MBA from the Institute of Business and Management at the National Chiao Tung University, achieved in 1993. Dr Tsai earned his PhD in industrial education and technology at the National Chunghua University of Education in Changhua, Taiwan, in 2000.

He is currently a teacher at the Senior Commercial School, which is affiliated to the National Taichung Institute of Commerce in Taichung, Taiwan. His research interests have been focused on information and computer education and their applications in the business field.