IMPROVING LEARNING RESULTS AND REDUCING COGNITIVE LOAD THROUGH 3D COURSEWARE ON COLOR MANAGEMENT AND INSPECTION INSTRUCTION

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ABSTRACT
This study intends to solve the problem that schools in Taiwan lack of the equipment for color management and inspection instruction and seek ways to improve learning results and reduce cognitive load. The researchers developed 3D courseware for color management and inspection through a research and development process. To further scrutinize the learning results generated by this courseware, 80 students were given 10-week-long experimental instructions into four groups each consisting of 20 students. Data collected from the experiment was subject to MANCOVA, and the findings suggested that students receiving lecture and instructions enabled by 3D courseware noticeably outdid the other three methods in learning results. The courseware developed for this study improved learning results while lowering the cognitive load. Findings from this study may benefit color management and inspection related trainings in colleges and industry.
Keywords: color management and inspection, 3D, cognitive load, learning results

INTRODUCTION

1. Research background and motivation

Colors are the basic building blocks of human perception and memory (Johnson, 1994). Color management is an important core technology in displaying or controlling images (Executive Yuan, 2006), and great importance is attached to how colors are applied (Juan & Guan, 2010). As the demand for printing services grows along with human civilizations (Luo & Li, 1983), color management systems or digital-image output equipment complying with international standards are a required competitive advantage of printing houses (Lin, 2009).

The academic institution where the authors work can only afford one complete color management and inspection system, because it is very costly and as a result has to be shared by many students, resulting in lackluster learning results. In this study, the research team discussed the dual-code theory proposed by Paivio (1990); the information processing theory by Atkinson and Shiffrin (1968); the multimedia learning theory by Mayer (2001); the situated instruction theory by Brown, Collins and Duguid (1989); the cognitive load theory by Paas and Van Merriënboer (1994) among other arguments concerning 3D (virtual reality). Based on the review of literature, a 3D courseware was developed for self-initiated learning of color management and inspection anytime and anywhere, in hopes of effectively solving the lack of instructional equipment. To further examine whether this innovative piece of courseware efficiently improved students' learning results while reducing their cognitive load, the research team provided experimental instructions in a 10-week program on color management and inspection.

2. Research objectives and questions

Given the afore-mentioned, this study was conducted with the following objectives:
(1) To develop 3D courseware for color management and inspection;
(2) To determine the students' learning results of 3D courseware;
(3) To realize the students' cognitive load of 3D courseware.
A. Research questions
To understand the effectiveness of the 3D instruction method the following research questions developed from above questions number (2) and (3).
(1) Are the learning results of the lecture with 3D instruction method superior to the other instruction methods?
(2) Are the cognitive loads of the lecture with 3D instruction method superior to the other instruction methods?
B. Research hypotheses
The following null hypotheses were developed for this research:
(1) In comparison of learning results, there are no significant differences between lecture with 3D courseware color management and inspection and lecture teaching method.
(2) In comparison of learning results, there are no significant differences between lecture with 3D courseware color management and inspection and lecture with image-assisted instruction.
(3) In comparison of learning results, there are no significant differences between lecture with 3D courseware color management and inspection and lecture with video-aided instruction.

(4) In comparison of cognitive loads, there are no significant differences between lecture with 3D courseware color management and inspection and lecture teaching method.
(5) In comparison of cognitive loads, there are no significant differences between lecture with 3D courseware color management and inspection and lecture with image-assisted instruction.
(6) In comparison of cognitive loads, there are no significant differences between lecture with 3D courseware color management and inspection and lecture with video-aided instruction.

REVIEW OF LITERATURE

Over the past three decades, the extensive use of information and communications technologies in education and training has resulted in considerably changing the way people teach and learn (Brandsford et al., 1999). That indicates to teachers that most learners are no longer satisfied with the usual one-way knowledge-receiving model, and that greater emphasis should be placed on interaction, fun and inter-personal communications in learning experiences (Sweller, 1988). Breaking away from the teacher-dominated lecturing style, the instructional patterns and teaching aids of soft skills are now combined with a more interactive and efficient learning method (Bancino & Zevalkink, 2007).

1. Color management and inspection

Abhay (2004) indicated that color management and inspection is a relatively new technology, and there is a need for students and industry to understand and get up to speed with the new way of working (and thinking). Color management and inspection is a collection of utilities and resources for calibration and automating color conversions between all input and output devices within an image processing chain (Maja, Darko & Lidija, 2007) and it is a way of controlling color in digital imaging using software, hardware, and some systematic procedures (Abhay, 2004).

The goal of color management and inspection is to establish reliability, predictability, and consistency of color when transferring or reproducing any image (Shelly, 2004). As printers, it is important to be able to produce accurate proofs before going to press (Kudzai, Paul & Abhay, 2005). Miro, Paul and Abhay (2005) believed that properly color-managed workflow, where correlations between different printing devices are established via device profiles, and characteristics. Color management includes the use of software to automatically determine the color reproduction characteristics of input devices, monitors, and output devices (Hong, Luo & Rhodes, 2001) including ICC profile, light booth, scanner, monitor, plotter and EyeOne I/O devices, etc. (Figure 1).

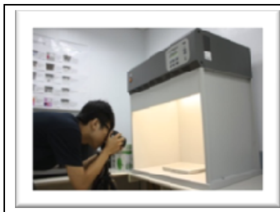
			
Light booth	Scanner	Plotter	EyeOne I/O

Figure 1. Typical equipment used in a color management and inspection teaching laboratory.

2. Cognitive psychology and information-processing theory

People tend to have better learning achievements and absorb messages more efficiently when they are surrounded by information that matches their respective cognitive styles (Carlson, 1991; Dunn & Dunn, 1993; Jonassen & Grabowski, 1993). According to what Messick (1976), Keefe (1987) and Jonassen and Grabowski (1993) concluded from their studies regarding cognitive styles, when people perceive images, texts, illustrations, written or verbal language, they obtain information using visual- or language-oriented processing approaches. Richardson (1977) found that visual-oriented people have a subjective, self-oriented pattern of thinking, which is why a person's cognitive style does not change drastically over time or in different situations (Jonassen & Grabowski, 1993; Keefe, 1987), and also why people react differently to the same stimulation, causing varying results (Jonassen & Grabowski, 1993). When a massage enters an individual's sensory system and draws attention, he/she would process it using a series of measures such as encoding, interpretation, organization, storage and extraction (Lindsay & Norman, 1977). It is therefore imperative that an instructional designer allows learners to obtain optimized information using methods that suit their respective needs, so the instructions given will enter the long-term memory before being converted into knowledge.

3. Situational instruction theory

Bredemeier and Greenblat (1981) argued that, among all instructional approaches, the one enabled by situational simulations made conservation of knowledge more easily while offering learners knowledge-constructing opportunities. According to Alessi and Trollip (2001), not only do situational simulations draw a learner's attention with audio/visual effects (e.g., images, texts and animated cartoons), they also provide learning-relevant situations. Schank (2002) put forth the concept of goal-based scenarios learning (GBS) with a focus on "learning by doing" and how convincing the learning situations are. Alessi and Trollip (2001) divided iterative simulations into procedural and situational simulations; they emphasized the simulated situations that enable learners to solve problems using a specific skill (Alessi & Trollip, 2001; Shyu & Dai, 2007). Consequently, courseware enabled by situational simulations is expected to include capabilities regarding continuous experiments, exploration, operations, contemplation and corrections, so as to transform the instructional situation into a learner-guiding 3D (virtual reality).

4. e-Learning

e-Learning is conducted by means of digital media resources (e.g., computer, radio, audio recording and the Internet). The objectives of e-Learning are achieved through learning experiences created out of a given collection of digital content and instructional methods (Hodson, 2002). Clark and Mayer (2002) defined e-Learning as content digitally transmitted and the corresponding instructional methods that are intended to encourage learning. Hodson (2002) argued that instructors should emphasize interactivity to enhance the interest in learning, and motives to learn. In order to provide expert performances, the online learning environment needs to provide access to expert thinking and the modeling of processes, access to learners in various levels of expertise, and access to the social periphery or the observation of real life episodes as they occur (Brown et al., 1989; Collins et al., 1989; Lave & Wenger, 1991). The on-line model has been used extensively for the design of multimedia (Herrington & Oliver, 2000), but it is also appropriate to other learning modes, in particular, online learning environments (Oliver & Herrington, 2000; Pennell, Durham, Ozog & Spark, 1997).

5. 3 Dimensional (3D)

3D (virtual reality) is a simulated world created out of computer technologies (Kalawsky, 1993). It offers users simulated senses of sight, hearing and touch in a realistic setting while supporting various learning styles (Strice, 1987). In a virtual-reality learning environment, people are more likely to learn by doing, or by watching and listening (Kolb, 1976). Because images and animated cartoons are suitable to teach descriptive articles and procedural content, respectively (Large, Beheshti, Breuleux & Renaud, 1995), interactive teaching materials are supposed to take the form of step-by-step instructions and displayed in a sequential order (Pollock, Chandler & Sweller, 2002). Those who learn in a 3D environment report better spatial abilities (Fuys, Geddes & Tischler, 1988) and interactivity (Rogers, 1986). Not only does 3D enable inspections and reviews to be performed with all ramifications considered (Brooks & Brooks, 1993; Savery & Duffy, 1995; Trop & Sage, 2002), it has the merit of "trial-and-error learning available at any time or repeatedly" (John & Scott, 1996). A 3D environment enables learners to directly construct knowledge without any abstract symbolic systems (Winn, 1993); it consequently serves as a bridge that helps learners convert tangible matters into abstract laws (Salzman et al, 1998; Winn & Bricken, 1992). From the perspective of cognitive science, 3D is instrumental in a learner's cognitive processing (Byrne, 1996).

6. Cognitive load theory

The basic hypotheses in Cognitive Load Theory (CLT) are: (1) the human brain's active memory capacity is limited; (2) the long-term memory capacity of human brain is unlimited; (3) knowledge is stored in the form of schema in long-term memory; (4) automation is a crucial process in the schematic structure (Sweller et al., 1998). Marcus, Cooper and Sweller (1996) mentioned in their study that prerequisite experiences and the essence/makeup of teaching materials are factors that affect a learners' cognitive load in an instructional process. Therefore we can define cognitive load as the load of working memory resulted from a given task assigned to the learner's cognitive system (Paas & Van Merriënboer, 1994; Sweller, Merriënboer & Paas, 1998). CLT effectively deals with the limitations that are induced by working memory by creating instructions that lower the intrinsic, extraneous and germane cognitive load on working memory (Sweller, Van Merriënboer & Paas, 1998; Schnotz & Kürschner, 2007; Van Merriënboer, Kirschner & Kester, 2003). All information processing irrelevant to the goals of instruction represents extraneous load (Mayer, 2008). According to the cognitive load theory, the imposed extraneous cognitive load should be as low as possible (Sweller, Van Merriënboer & Paas, 1998).

The primary purpose of instruction of color management and inspection is to ensure the students learn to deliver consistent results from the color calibration and image output equipment. Researchers believe that the viewpoints of designing 3D courseware derived from various learning theories, namely "cognitive psychology and information-processing theory" (which addresses the knowledge acquired from long-term memories) and the cognitive load theory (which suggest that the extraneous cognitive load imposed on a student should be as low as possible).

7. Dual-code theory and multimedia learning

Many studies showed that improper audio/visual stimulations distract learners and add to cognitive load (Craig, Gholson & Driscoll, 2002). Some scholars believe that, in a dual-code model that combines verbal and textual messages, verbal instructions do not improve the learning results of visual articles or images (Barron & Atkins, 1994; Beccue, Vila & Whitley, 2001). That prompted Kester, Lehnen, Van Gerven and Kirschner (2006) to integrate the content-related framework of text books with computer technologies in a research project based on schematic symbols. Findings from that project indicated a significantly lower cognitive load of the experimental group compared to the control group. To prevent verbal media from affecting the results and complexity of experimental instructions, verbal instructions were replaced by easy-listening music in the 3D courseware developed for this study. Certainly, instructional designers should develop these presentations to make efficient use of both visual and verbal modalities, involving dual-coding theory (Paivio, 1978) and allowing for multimedia learning (Mayer, 2001).

After studying related cognitive psychological literature, the researchers determined that the teaching of color management and inspection resulted in an awareness of improving teaching methodology and associated teaching materials but also identified the importance of avoiding an overload of students' mental effort according to cognitive load theory. The researchers would take into account the students' learning results and cognitive load when presented with color management and inspection materials.

DESIGNING AND IMPLEMENTING THE RESEARCH PROJECT

Sweller (1988) contended that instructional designers may reduce the learners' extraneous cognitive load by correcting the teaching materials and the way the teaching materials are presented, in order to bolster learning results. Therefore the study's authors gave experimental instructions using self-developed 3D courseware for color management and inspection, so as to build a multimedia platform with interactive and intuitive interface. By displaying simulations in a 3D setting, the authors explored learning results and cognitive load of color management and inspection students.

1. Research framework

Based on the literature regarding color management and inspection and learning theory, the authors designed some questions from the objectives number (2) and (3) to explore the learning results and cognitive load. For assuring the difference, the authors selected four different instruction groups and developed null hypotheses to compare and acquire the effectiveness and their learning results and cognitive load. The researchers conducted a process comprising analysis, design, development and verification. After seeking opinions of experts in such areas as digital learning, color management and education, the authors developed 3D courseware for color management and inspection. Quasi-experimental instructions using four different instructional methods were given to the students when the system was proved to be operating normally, in order to find out about what the system's instructional results actually are, and how heavy the learners' cognitive load is. Whenever system improvement was found necessary during the experiment, the courseware was immediately modified to ensure the system's good quality. Figure 2 shows the research framework in this study.

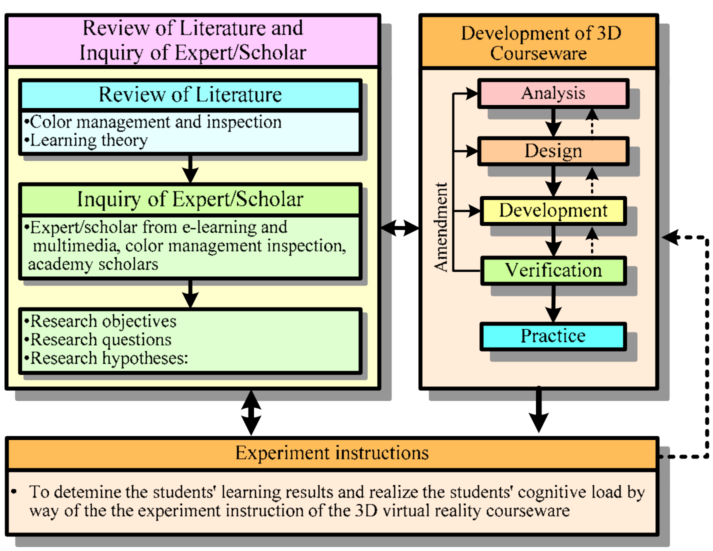


Figure 2. Research Framework

2. Designing the research project

The following passages explain both the development of courseware and experimental instructions. Since this study is focused on the learning results and cognitive load with regard to experimental instructions using 3D courseware (for color management and inspection) the appropriate 3D courseware was developed.

(1) Developing the courseware

The appropriate courseware was designed and developed into 3D environment associated with color management and inspection which included the following equipment and associated applications: SpectroEye III light booth, color checkers, monitors, scanners, plotters and EyeOne tester. Software included in the development process: Virtool, 3D Max, Java, Photoshop, Illustrator and Flash.

(2) Process of courseware development

Many problems were identified during the courseware development and research process that consisted of analysis, design, development and verification. For example, some students and experts involved in courseware testing said, "The curves in an image appeared rigid and not faithfully shown when I used the large-image output machine," "The courseware functioned terribly slow whenever a large-sized image file was processed by the color-finder, making me feel so clumsy," "The light booth gave an unrealistic effect, and the testing was performed without any sources of lighting." After a trial-and-error process combined with consultation with experts and corrections, the courseware was able to deliver images closely resembling the original with an easy-to-operate characteristic, as required in the theories of situational instruction and situational learning (Figure 3).

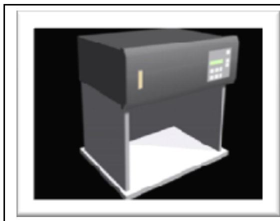
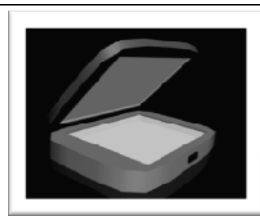
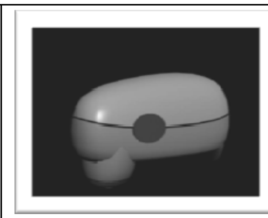
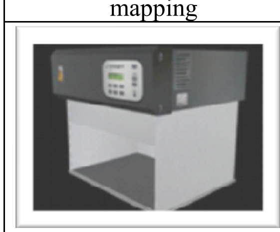
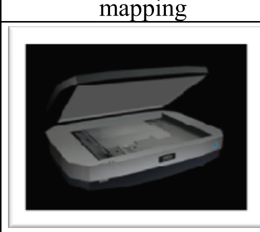
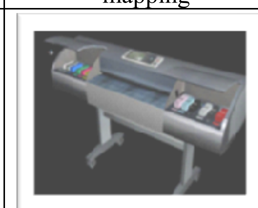
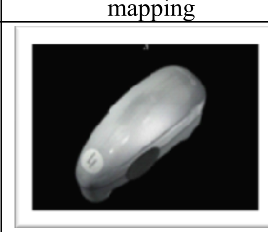
			
Light booth before UV mapping	Scanner before UV mapping	Plotter before UV mapping	EyeOne I/O before UV mapping
			
Light booth after using the software of UV mapping	Scanner after using the software of UV mapping	Plotter after using the software of UV mapping	EyeOne I/O after using the software of UV mapping

Figure 3. The comparison of typical equipment used in a color management laboratory (top) and 3D images (bottom)

3. Experimental instructions

Quasi-experiment instructions were given in this study, with the framework of experimental instructions shown in Figure 4.

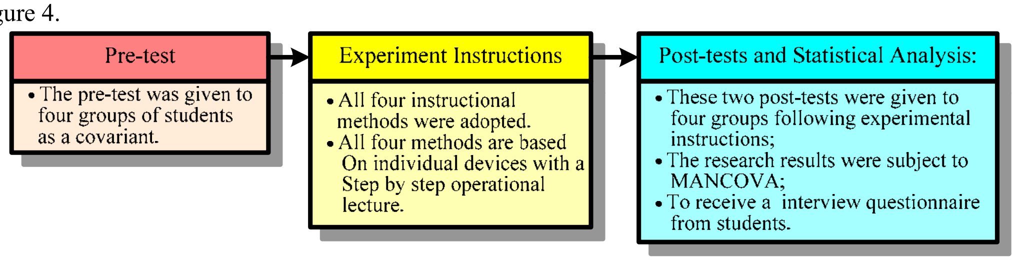


Figure 4. The program framework of experimental instructions

In many studies exploring the results of multimedia learning, experimental instructions were given to four groups of students who used texts, images, videos and animated cartoons, respectively, as the learning media. The research followed the principles set forth by Mok (1996), Kristof and Satran (1955), Assfalg and Pala (2000) on the interactive interface as the 3D design direction with standard operating procedures of color management. This study's author, therefore, decided to give the students experiment instructions in four groups with texts, 3D courseware, videos, images. The four groups, each containing 20 students, were given instruction using various methods to include A: lecture; B: lecture + 3D courseware-assisted instruction; C: lecture + video-aided instruction; D: lecture + image-assisted instruction. In a 10-week, 3-sessions-per-week experiment instructional program, up to eight students per week were allowed to practice operating the color management and inspection equipment in class after all groups had received instruction and demonstrations about the equipment usage. Approximately 24 students were allowed to make reservations for practice sessions on three evenings per week. Throughout the experimental program, students from all four groups were given lecturer and manual.

All these four methods are based on individual devices with a step-by-step operational procedure (See Appendix I), such as:

A. Operating plotter (6 steps/sequences: (1)Set up printer; (2)Select new-added print, (3)Added network print: (4)Choose network printer: (5)Set-up printer driver: (6)Set printer done.);
B. Calibrating operation (8 steps/sequences: (1)Turn-on Eye-One Match3; (2)Select printer model; (3)Output tested graphics; (4)Measure graphics; (5)Positioning graphics; (6)Save measure data; (7)Calculate ICC profile; (8)Save ICC profile);
C. Color approval (8 steps/sequences: (1)Select measure tool; (2)Select measure target; (3)Initialize measure tool; (4)Hang-up measure tool; (5)Save set-up; (6)Output test graphics; (7)Positioning output graphics; (8)Save measured data).

All these devices are allowed students to consult the user's manual after each instructional session.
Before the four groups of students received experiment instruction, they were given a pre-test using questions concerning color management and inspection from the "Test of Basic Perceptions of Image Processing and Color Management" in the archives of Adobe Certificate Associate testing program.

During the 10-week, 3-sessions-per-week program the four groups, each containing 20 students were given instruction using various methods to include A: lecture; B: lecture + 3D courseware-assisted instruction; C: lecture + video-aided instruction; D: lecture + image-assisted instruction.

After receiving appropriate operation procedure, students were given the first post-test with a focus on the operating skills of color management and inspection equipment. This hands-on post-test consisted of a 3-part, 22-step process (See Appendix I). The researchers assessed how a student performed each step which was scored, with 5 points given to those who succeeded on the first attempt; 3 points; the second attempt; 1 point, the third attempt; 0 point, the fourth attempt.

Following the first post-test, a second post-test was performed using a cognitive load questionnaire to grasp the students' cognitive load. Patterned after the one proposed in the Master's thesis of Kuo (2003) which is used to explore the cognitive load (shown in Appendix II), the questionnaire adopts a 7-point Likert Scale with 1 being "Very easy"; 2 being "Easy"; 3 being "Somewhat easy"; 4 being "Moderately difficult"; 5 being "Somewhat difficult"; 6 being "Difficult"; 7 being "Very difficult". The researchers developed the cognitive load scale of 3D color management and inspection based on the Kuo's scale of cognitive load (See Appendix III).

To explore issues underlying each group's learning process after experimental instructions, eight students were chosen (i.e., two students from each group) for a qualitative research that delves into problems facing each group. All of the eight students were asked to perform self-initiated learning with the help of 3D courseware, videos or images, followed by an interview.

RESEARCH RESULTS AND ANALYSES

1. The variance analysis for test results of color management and inspection equipment users

Analysis of covariance is to obviate the influence of the covariates and analyze the impact of the control variables on observed variables. Because there are two dependent variables in this research, the authors adopted MANCOVA. Based on the test scores obtained, a MANCOVA was conducted with the "Test of Basic Perceptions of Image Processing and Color Management" being the pre-test (covariant); the four instructional methods (A: lecture; B: lecture +3D courseware-assisted instruction; C: lecture + video-aided instruction; D: lecture + image-assisted instruction) as independent variables; the hands-on operations of color management and inspection equipment and learning/cognitive load being the post-tests (dependent variables). The MANCOVA was meant to grasp the difference among four instructional methods in learning results and cognitive load regarding color management and inspection.

Table 1 summarizes the learning results and cognitive load of different instructional methods regarding color management and inspection.

Table 1: Summary of the learning results and cognitive load of different instructional methods (means and standard deviations)

Dependent variables	Groups	N	M	SD
Learning results	Method A	20	66.75	5.857
	Method B	20	93.65	5.480
	Method C	20	77.45	13.000
	Method D	20	74.80	10.103
Cognitive load	Method A	20	8.45	2.544
	Method B	20	6.20	2.142
	Method C	20	7.05	2.762
	Method D	20	7.30	3.213

Source: This study's authors

Results of Levene's test of equality of error variances (Wilks'λ= .880, F=1.564, P=0.162 > .05) indicated the null hypothesis is accepted and the four groups share the same slope of regression line, which supports the hypothesis that covariant intra-group regression coefficients are homogeneous.

The instructional methods showed significantly different effects on the learning results of color management and inspection (Wilks'λ=.419, p <.001), as shown in Table 2. The ANCOVA results indicated a significant difference among instructional methods with regard to the students' learning results ($F_{(3, 72)}$=29.641, p=.000<.001) and cognitive load as well ($F_{(3, 72)}$=3.016, p=.016<.05).

Table 2: The summary of MANCOVA results of different instructional methods regarding color management and inspection

Source of variance	**df**	**SSCP Matrix**		**MANCOVA Wilks' λ**	**ANCOVA（F）**	
Inter-group (instructional methods)	3	308.170	11.50	.419***	Learning results	29.641***
		11.507	2.680		Cognitive load	3.016*
Intra-group	72	6007.516				
			-43.17			
		-4.77	343.66			

Note: * p<.05; *** p<.001. Source: this study's authors

Six findings are derived from Table 3. After having the posteriori comparison, it was found that: First, the learning results difference of Method B (lecture + 3D courseware-assisted instruction) (M=93.642) and Method A (lecture) (M=67.005) is reached significant. So we refused the "null hypothesis (1)" to indicate the learning results of Method B are superior to Method A. Second, the learning results difference between Method B (lecture + 3D courseware-assisted instruction) and Method D (lecture + image-assisted instruction) (M=74.652) is reached significant. So we refused the "null hypothesis (2)" to indicate the learning results of Method B are superior to Method D. Third, since the difference between Method B (lecture + 3D courseware-assisted instruction) and Method C (lecture + video-aided instruction) (M=78.338) is reached significant. So we refused the "null hypothesis (3)" to indicate the learning results of Method B are superior to Method C. Fourth, the cognitive load difference of Method B (M= 6.052) and Method A (M=8.258) is reached significant. So we refused the "null hypothesis (4)" to indicate the cognitive load of Method B is inferior to Method A. Fifth, the cognitive load difference between Method B and Method D (M=7.248) is not reached significant. So we accepted the "null hypothesis (5)" to indicate the cognitive load of Method B and Method D has no difference. Sixth, the cognitive load difference of Method B and Method C (M=7.747) is reached significant. So we refused the "null hypothesis (6)" to indicate the cognitive load of Method B is inferior to Method D.

In other words, First, students receiving instructions based on Method B (i.e., lecture + 3D courseware-assisted instruction) outperformed (M=93.642) all the other three groups (M=67.005, M=78.338, M=74.652); Second, students receiving instruction based on Methods B, C (i.e., lecture + video-aided instruction) and D (i.e., lecture + image-assisted instruction) outperformed (M=93.642, M=78.338, M=74.652) the "Method A" group in learning results (M= 67.005). Third, students receiving instruction based on Methods C and D differed only insignificantly in learning results (M=78.338, M=74.652). Fourth, students receiving instruction based on Methods A and C (M=8.258, M=7.747) significantly outscored the "Method B" group in cognitive load (M= 6.052). Fifth, students receiving instruction based on Methods A, C and D did not differ significantly in cognitive load scores. Sixth, students receiving instruction based on Methods B and D did not differ significantly in cognitive load scores.

Table 3: Comparing the the learning results and cognitive load of different instructional methods (posteriori comparisons)

Dependent variables	Groups	N	M	SD	Posteriori comparisons
Learning results	(1) Method A	20	67.005	2.057	2>1, 3, 4
	(2) Method B	20	93.642	2.057	2.3, 4>1
	(3) Method C	20	78.338	2.126	3, 4(n.s.)
	(4) Method D	20	74.652	2.048	
Cognitive load	(1) Method A	20	8.258	.492	1, 3>2
	(2) Method B	20	6.052	.492	1, 3, 4 (n.s.)
	(3) Method C	20	7.747	.509	2, 4 (n.s.)
	(4) Method D	20	7.248	.490	

n, s: no significance

2. Analyzing the results of interviews

The computer is already considered a highly valuable medium of instructions (Hannafin, 1987), but media indeed affect instruction, and the instructional capabilities vary among media types (Kozma, 1994). To better grasp learners' feelings toward the four instructional methods enabled by varied media (i.e., 3D courseware, videos and images), eight students, or two students selected from each group, were given interviews that generated the following findings:

(1) The attentiveness of learners receiving instruction based on Method A (i.e., lecture) were affected by the instructor's intonation and accent. With hands-on practice unavailable after each instructional session, students with poor comprehension or introverts dared not ask for replays of the video even when they were confused, because of the class-oriented instructions. Their doubts remained unsolved right before the tests, hence the considerable amount of stress.

(2) Most of the learners receiving instructions based on Method B (i.e., lecture + 3D courseware-assisted instructions) independently operated the courseware in class, a sign of growing interest. As the courseware developed for this study delivered images closely resembling the original equipment, it can be downloaded by learners after class via the Internet for a game-like learning experience enabled by 3D. Students in the Method B group noticeably outperformed the other groups in independency, interactivity and control over the courseware. They generally were confident in the learning process, although some of them mentioned that lags occurred when the computer equipment was in poor conditions.

(3) Although videos were played during instructional sessions using Method C (i.e., lecture + video-aided instruction), students with poor comprehension or introverts dared not ask for replays of the video even when they were confused, because the class-oriented instructions left them worried that asking questions would make them miss out on the highlights of lecture/videos. That in turn wasted the time of instructors as well as students, adding to the burden of course-based learning. The learners were allowed to replay the videos by themselves after class, but the video content was lecturer-centric and mostly leads to one-way learning. The video lacks speediness or fluency, and therefore may affect learning results as it gives varying impressions due to the individual differences of students. Some learners complained about the unsatisfying results despite the long time they spent watching the video.

(4) Following each instructional session based on Method D (i.e., lecture + image-assisted instruction), the operational steps were detailed in graphic forms for self-initiated learning, which allowed only for learning by rote. That is why learners in this group lacked confidence around the equipment. Among others, the hand-painted black-and-white images were lifeless and failed to interest the learners.

Conclusions and Suggestions

The 3D courseware developed for this study (for color management and inspection) was put through a process that involved repetitive testing, consultation with experts and corrections, in hopes that it will deliver images highly resembling the original with user-friendliness, as required in the theories of situational instruction/learning. Findings from the interviews were:

1. Students receiving instruction based on Method B (i.e., lecture + 3D courseware-assisted instructions) outperformed the other three groups in learning results.

This finding is reflected in the students' answers to interview questions. For example, they said the instructional method enabled by is the animated cartoons not only produced images closely resembling the original, but also ensured learners greater independency and user-friendliness (for repetitive learning), hence the better learning results compared to the other three groups. This finding supports the argument of Hiltz (1994) that virtual classrooms are meant for active learning, and that the pace of self-initiated learning is controllable. To facilitate significant learning, Shulman (1986) internalized virtual reality (3D), concept-based animated cartoons, symbols, image viewer, icons, and other factors of knowledge/teaching materials.

2. Students receiving instruction based on Method A (i.e., lecture) registered significantly worse learning results than the other three groups.

Judging from the students' opinions, the poor performance was due to the noticeably fewer interactions in lecture sessions compared to the other three instructional methods. The greatest flaw of the lecture approach, therefore, is that it tended to turn students into passive information-receivers who did not have to think (McKeachie & Svinicki, 2006), a proof that an interactive process affects the learning results considerably (Alavi et al., 1995; Webster & Hackle, 1997). This finding underscores the need for combining two or more media/materials in order to enhance learning results, as stated in the dual-code theory.

3. Students receiving instruction based on Method B (i.e., lecture + 3D courseware-assisted instructions) outperformed the other three groups in learning results.

It is known from the interviews that less intelligent students and introverts dared not ask questions even when they were confused by the lecture or video-aided instruction. Students complained that the images used in instruction looked unconvincing, and they lost interest in learning when colors of the images were not vibrant enough. The finding supports the argument of Biggs (1978) that an individual's perception style, personality and IQ are variables of learning that lead to varying learning results. Moreover, images in the color management and inspection 3D courseware helped learners effortlessly conduct self-initiated learning, especially in the case of repetitive learning (following graphic instruction). Students in the Method C group, nevertheless, had relatively less control over the repetitive learning process because it took them a long time to watch the video, and also because they found it difficult to memorize the detailed moves.

4. Students receiving instruction based on Method A (i.e., lecture) and Method C (i.e., lecture + video-aided instruction) apparently outperformed the Method B group (i.e., lecture + 3D courseware-assisted instruction) in cognitive load.

Judging from answers given by the students interviewed, an excessive amount of texts, teaching materials, and the instructors' verbal tones during lectures affected their interest in learning. To be specific, excessively long playing hours of videos, noises, and the video-playing process all distracted the learners. Mousavi, Low and Sweller (1995) mentioned a "split-attention effect" that is resulted from simultaneously using visual texts/descriptions and verbal instructions in an instructional session. In fact, a working memory zone in human brain packed with instructional content leads to an excessive cognitive load (Sweller, 1998).

5. Students receiving instruction based on Method B (i.e., lecture +3D courseware-assisted instructions) registered a noticeably lower cognitive load than the Method A (i.e., lecture) and Method C (i.e., lecture + video-aided instruction) groups.

The results of interviews with students indicate that, when class-oriented instruction were conducted using either Method A or C, less intelligent students and introverts dared not ask questions or replays of video even when they were confused, which in turn added to burdens on learners. Students in the Method B group, however, outperformed the other three groups because online instructions ensured speediness and highly accessible information (Kearsley, 1996). Without limitations of where and when the learning sessions should be conducted, Method B makes self-initiated learning easier and generates a comparatively low cognitive load for color management and inspection students. The finding supports the argument of Large, Beheshti, Breuleux and Renaud (1995) that animated cartoons are suitable for teaching procedural content.

6. Students receiving instruction based on Method A (i.e., lecture), Method C (i.e., lecture + video-aided instructions) and Method D (i.e., lecture + image-assisted instruction) differed only insignificantly in the cognitive load scores.

According to the results of interviews, students in the Method C group found it troublesome to replay the instructional video for repetitive viewing of the details. Students in the Method D group showed a considerable gap between learning results and the results of hands-on operations, although they were offered detailed graphic instruction. Students receiving instruction using Method A, C and D showed only insignificant difference in cognitive load scores, but Table 3 indicated that those in the Method D group reported a slightly lower cognitive load than the Method C group, which in turn registered a slightly lower cognitive load than the Method A group. While Large, Beheshti, Breuleux and Renaud (1995) said images are suitable for teaching descriptive articles, Najjar (1996) considered it more effective to use texts accompanied by image(s) than text-only content. As mentioned by Kalyuga (2000), the need to repetitively process the same information will impose extra cognitive load onto a reader. Apparently, a detailed guidance accompanied with images produces a slightly lower cognitive load compared to video-aided instructions.

7. Students receiving instruction based on Method B (i.e., lecture + 3D courseware-assisted instruction) and Method D (i.e., lecture + image-assisted instruction) differed only insignificantly in cognitive load scores.

It is known from the interviews that less intelligent students and introverts dared not ask questions even when they were confused about the lecturing or video-aided instructions. Students complained that the images used in instruction looked unconvincing, and they lost interest in learning when colors of the images were not vibrant enough. The finding supports the argument of Biggs (1978) that an individual's perception style, personality and IQ are variables of learning that lead to varying learning results. Moreover, images in the color management and inspection courseware help learners effortlessly conduct self-initiated learning, especially in the case of repetitive learning (following graphic instruction). Students in the Method C group, nevertheless, had relatively less control over the repetitive learning process because it took them a long time to watch the video, and also because they found it difficult to memorize the detailed moves.

Although instruction accompanied by images appear less convincing than those accompanied by 3D courseware, they enable people to effortlessly and repetitively learn, or memorize, the procedural steps of color management and inspection in a self-initiated process, hence the insignificant difference between Method B and D in cognitive load. The finding supports the argument of Large, Beheshti, Breuleux and Renaud (1995) that images are suitable for teaching descriptive articles. The Method B group outperformed Method D group because the virtual reality courseware allows for step-by-step operations, a finding that supports the argument of Collins, Brown and Newman (1989) that animated cartoons display each and every crucial move in the courseware-operating process, enabling a learners to imitate the moves in slow-motion mode or by breaking them down, which in turn helps achieve the learning goals.

Generally speaking, this study's authors believed that the 3D courseware (for color management and inspection) helped achieve better learning results than instructions offered either in the traditional style or assisted by images/videos. That is because the courseware enabled learners to fully benefit from multimedia learning and virtual reality, as stated in the dual-code theory. Not only does virtual reality offer simulated senses of sight, hearing and touch in a realistic setting, it also supported people of all learning styles (Strice, 1987) and consequently facilitated the development of superior spatial abilities (Fuys, Geddes & Tischler, 1988) as well as interactivity (Rogers, 1986). Not only did the 3D courseware for color management and inspection conserve knowledge well, as required in the situated instruction theory (Bredemeier & Greenblat, 1981), it also functioned in a realistic setting (Schank, 2002). The situational instructional method is known for employing iterative simulations (Alessi & Trollip, 2001) for repetitive learning in a trail-and-error process anytime (John & Scott, 1996). It resulted in an excellent, effortless learning environment that helped learners store the knowledge acquired in their long-term memories, and at the same time effectively improved the learning results with a reduced cognitive load.

This research can obtain several significant contributions: (1) 3D courseware developed by color management and inspection equipment that may be included in training programs in either colleges and industry; (2) 3D courseware can effectively solve the lack of instructional equipment for color management and inspection; (3) 3D courseware helped improve students' learning ability; (4) 3D courseware reduced the cognitive load of student learning color management and inspection skills.

There are three suggestions for courseware developers: (1) while Virtool is capable of high-fidelity modeling, it is too complicated and time-consuming. For fast and simple modeling, the 3D Max software is a good choice although it does not deliver images closely resembling the original, which however can be solved by means of Photoshop and/or UV Mapping (for a high-fidelity effect); (2) the graphics files should be moderately sized so they will not be difficult to download on a household computer, which usually has a narrow bandwidth; (3) the review of literature suggested that voice may distract learners, therefore easy-listening music replaced verbal messages in the 3D courseware developed for the study. However, it is advised that future researchers include verbal instructions in their courseware. As for the equipment, future researchers should adopt an upgraded CPU, along with increased capacity of main memory and an independent graphics card, so as to prevent lags from affecting students' results of, and interest in, learning.

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Appendix I. A post-test sample of 22 operational instruction steps in 3 individual devices

A. Operating Plotter (6 steps/sequences)						
STEP	**STEP NAME**	**1st completed**	**2nd completed**	**3rd completed**	**Failed**	**Total**
1	Set up printer	1				5
2	Select new-added print		1			3
3	Added network print		1			3
4	Choose network printer	1				5
5	Set-up printer driver			1		1
6	Set printer done	1				5
Sum A						22
B. Calibrating operation with Eye-One Match on Monitor/Printer (8 steps/sequences)						
STEP	**STEP NAME**	**1st completed**	**2nd completed**	**3rd completed**	**Failed**	**Total**
1	Turn on Eye-One Match3	1				5
2	Select printer model			1		1
3	Output tested graphics			1		1
4	Measure graphics		1			3
5	Positioning graphics		1			3
6	Save measure data		1			3
7	Calculate ICC profile			1		1
8	Save ICC profile			1		1
Sum B						18
C. Color approval (8 steps/sequences)						
STEP	**STEP NAME**	**1st completed**	**2nd completed**	**3rd completed**	**Failed**	**Total**
1	Select measure tool	1				5
2	Select measure target		1			3
3	Initialize measure tool		1			3
4	Hang-up measure tool		1			3
5	Save set-up			1		1
6	Output test graphics			1		1
7	Positioning output graphics		1			3
8	Save measured data	1				5
Sum C						24
T. Amount						**64**

Appendix II. Kuo's questionnaire of cognitive load scale

I. After reading the introduction of unit I "History of Stargazing", please try to recall your own learning process and answer the following two questions. **Reply description**: Please select one of the items at the option of the above right with your true feelings, and then circle the corresponding number.

The level of Cognitive load / The content of topics	Very easy	Easy	Fairly easy	Moderate difficult	Somewhat difficult	Difficult	Very difficult
1. I think that the content of unit I in learning is…….	1	2	3	4	5	6	7
2. I think I spent a lot of effort to remember the contents of unit I…..	1	2	3	4	5	6	7

Cognitive load scale

II. After reading the introduction of unit II "The birth of the solar system", please try to recall your own learning process and answer the following two questions. Reply description: Please select one of the items at the option of the above right with your true feelings, and then circle the corresponding number.

The level of Cognitive load / The content of topics	Very easy	Easy	Fairly easy	Moderate difficult	Somewhat difficult	Difficult	Very difficult
1. I think that the content of unit II in learning is…….	1	2	3	4	5	6	7
2. I think I spent a lot of effort to remember the contents of unit II…..	1	2	3	4	5	6	7

Appendix III. The cognitive load scale of this research

The Learning Cognitive Load Scale of 3D Color Management and Inspection

Grade： ID No.：

After reading the introduction of "Color Management and Inspections", please try to recall your own learning process and answer the following two questions. **Reply description**: Please select one of the items at the option of the above right with your true feelings, and then circle the corresponding number.

The level of Cognitive load / The content of topics	Very easy	Easy	Fairly easy	Moderate difficult	Somewhat difficult	Difficult	Very difficult
Sample: I think the teaching method of this unit is……..		✓					
1. I think the teaching method of "Color Management and Inspection" unit in helping learning knowledge is …….	1	2	3	4	5	6	7
2. I think the teaching method of "Color Management and Inspection" unit in helping operation is…….	1	2	3	4	5	6	7