An Evaluation of the Visual Presentation e-Learning on Engineering Drawing by Using the S-P Chart Analysis

David W. S. Tai, Ren-Cheng Zhang, and Jia-Ling Chen

Abstract—**This study was aimed to apply the S-P chart analysis to evaluate vocational high school students' learning achievement in the subject of the engineering drawing course by using visual presentation e-learning. The S-P chart analysis could provide the instructors two caution indices - the caution index for students and the caution index for problems. In addition, the paired-sample t test was used to verify the students' learning achievement. After 8 weeks experimental teaching, this study found that the most of the students' learning type was effective, however, some students' learning condition were still insufficient. The findings could help understanding the learning conditions and learning types before and after the experimental teaching in visual presentation e-learning.**

Index Terms—**S-P chart analysis, engineering drawing, visual presentation, learning achievement, caution index.**

I. Introduction

The teaching of engineering drawing in technical careers has undergone a great evolution in recent years, and the new technology has been conditioning the teaching learning process in engineering drawing [1] However, researchers found it hard for students to visualize the 3D object given the 2D representations of the same object [2]. Under this point of view, the new technology brought a new way of learning, but also caused new learning problems in learning. In addition, spatial ability influences academic performance in engineering. In particular, 3D spatial perception influenced level of academic performance in engineering graphics. Therefore, teaching intervention to train spatial ability is necessary [3]. Technology can enhance lecturing style and presentation, thus, multimedia technology allows students to extend their comprehension, reasoning, and problem solving skills and application of complex 3D object problems more easily [4]. For the sake of learning, students are expected to possess high expectations for success and engage in academic activities ideally [5]. As the results, diagnosis is an important part of the learning process, and it helps instructors to analyze the abnormal performance of learners, understand the suitableness of given test items for test-takers, evaluate their responses to each test item and pinpoint misconceptions of learners with respect to a given test subjects [6]. Therefore, the aim of this paper is to apply the S-P chart analysis to diagnose students' abnormal performances in engineering drawing, moreover, through experimental design to investigate the differences in students' learning condition types before and after the experiment.

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II. Literature Review

A. Engineering Drawing

Engineering drawings communicate the requirements for the manufacture in the end product. Generally, engineering drawings contain multiple orthographic projections, and these are useful for determining the outer shape. In addition, it may contain section views. In the educational disciplines, engineering drawing is one of the common subjects, and it is a practical course and also played the role of technology foundation. Moreover, it carries controls and maintains the product definition traditionally. Today engineering drawing is based on 3-D CAD models designed by engineers [7] since the computers have entered the automation technology in the early 1980s.

B. Visual Presentation

Presentations that combine visual and verbal information are widely used for displaying instructional material [8], and in the educational practice, they are a common tool to support the learning process. In addition, students have the opportunity to work easily with representations of complex systems in the computer-based multimedia learning environments [9]. The utilization of interactive, multimedia based tools and delivery mechanisms in teaching and learning environments is becoming an important aspect of the implementation of a more innovative approach to teaching in engineering [10]. However, in research on visualization, dimensionality as factor is often confounded [7].

C. S-P Chart

In 1970s, Japanese educator Takahiro Sato proposed Student-Problem chart analysis (S-P chart analysis) to help teachers diagnose the abnormal performances held by students or problems [11]. The S-P Chart provides caution indexes for diagnosing the abnormal performance of examinees, and a disparity coefficient for diagnosing test item sheets [6]. Moreover, it is a test analytical method, and this analysis could generate two indices for items and task-takers separately [12], and using charts to illustrate the data additionally.

Traditionally, the test measurement only analyzed the item

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difficulty index and the discrimination index, but the response data were not considered, therefore, the S-P Chart uses disparity coefficient, homogeneity coefficient, item caution index and student caution index to help instructors diagnose student learning performance, test quality, and learning conditions [13].

The S-P Chart is according to caution index for students and caution index for problems to diagnose students' abnormal performances. The data matrix of dichotomous scoring is assumed that there are N (i=1, 2, 3, …, n) test-takers and M (j=1, 2, 3, …, m) items, and $Y=(y_{ij})_{n\times m}$ displays the data matrix. After sorting by sequence is applied, total score is defined as $y_i = \sum_{j=1}^{M} y_{ij}$ for each test-taker. On the other hand, $y_{\bullet j} = \sum_{i=1}^{n} y_{ij}$ is defined as the ratio of correct responses. In the same time, the caution index for student i (CSi) is defined as follows [14; 12]:

$$CS_i = 1 - \frac{\sum_{j=1}^{M} (y_{ij})(y_{\bullet j}) - (y_{i\bullet})(u')}{\sum_{j=1}^{y_{i\bullet}} (y_{\bullet j}) - (y_{i\bullet})(u')} \quad (1)$$

where

$$u' = \frac{1}{m}\sum_{j=1}^{M} y_{\bullet j} \quad (2)$$

Particularly, the S-P chart analyze is one of the analytical method that enables researchers to use in small sample sizes [15]. According to students' caution index and correct ratio on items, all test-takers could be classified into 6 learning condition types, as illustrated in Fig. 1:

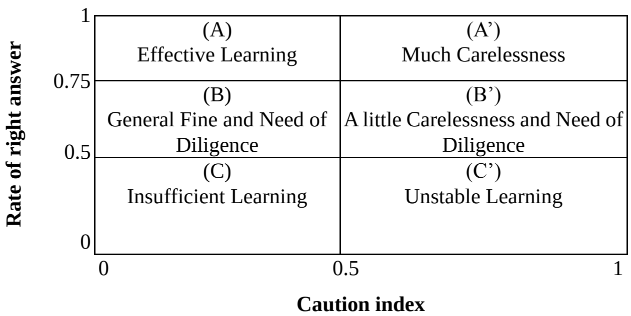

Fig. 1. Classification of learning styles for students [16].

According to the data matrix, the caution index for item j (CP_j) is defined as follows:

$$CP_j = 1 - \frac{\sum_{i=1}^{N} (y_{ij})(y_{i\bullet}) - (y_{\bullet j})(u)}{\sum_{i=1}^{y_{\bullet j}} (y_{i\bullet}) - (y_{\bullet j})(u)} \quad (3)$$

where

$$u = \frac{1}{n}\sum_{i=1}^{N} y_{i\bullet} \quad (4)$$

The caution index for problems and correct ratio of test-takers, all items could be classified into 4 types, as shown in Fig. 2.

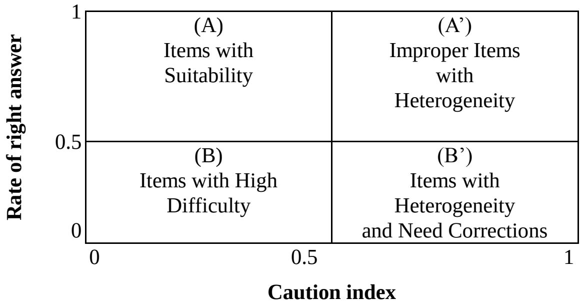

Fig. 2. Classification of learning styles for items [16].

III. Method

A. Research Design and Participants

The aim of this study is to investigate students' learning condition types. The participants of this study consisted of 41 students selected from engineering drawing course in a national vocational high school in Taiwan. In order to obtain their learning achievement, the pretest and posttest were given to all participants before and after the 8-week (3 hours per week) experimental teaching.

B. Instrument

The engineering drawing e-learning course was designed under the new standard curriculum of vocational high school. The learning achievement test was comprised of 40 multiple-choices questions originally. After tested in a pilot test, and results from the pilot tests were analyzed by expert panel to explore the reliability, conceptual validity and content validity for understanding the appropriateness, feasibility, content validity, and reliability. The formal test was comprised of 25 items, and the KR_{20} reliability coefficient of this test was calculated as 0.7347, therefore, this learning achievement test was considered as having good difficulty and discrimination indices respectively.

C. Data Analysis

By using the test item analysis and S-P chart analysis under the classical test theory. The quantitative analysis of the tests was conducted by using the TESTER for Windows 2.0.

IV. Research Findings

A. Evaluations on Items

The test summary shows a summary of the test results, the average ratio of correct responses was 61.75%. Generally, the appropriate questions have a difficulty of 0.50 [17], therefore, this test was considered moderate in its difficulty. In average, the participants answered 15.44 questions correctly. The range of the correct responses was 18 (the minimum was 4 questions and the maximum was 22 questions), variance was 16.05, and the standard deviation was 4.01.

The disparity index D^* is .491, it means that the result of this test had no heterogeneity, and the D^* value approaches a normal condition. Generally, the standard D^* value is 0.5 for a combination test. If this value is greater than 0.6, means the heterogeneity exists in this test, and this test should be modified properly.

According to the classification method of items, the results are depicted in Table I. The number of items which belong to A, A', B, B' are 11, 7, 4, 3 respectively. The items of type A' and B' need advanced corrections.

TABLE I: RESULTS OF ITEMS EVALUATION

Item ID	CP	correct ratio	Item Types
1	0.058	0.9	A
10	0.288	0.93	A
12	0.41	0.76	A
15	0.372	0.8	A
17	0.071	0.78	A
6	0.205	0.9	A
20	0.324	0.56	A
3	0.284	0.61	A
7	0.403	0.61	A
8	0.337	0.66	A
9	0.213	0.73	A
2	0.87	0.76	A'
24	0.725	0.8	A'
25	1.035	0.88	A'
13	0.619	0.56	A'
16	0.616	0.51	A'
4	1.033	0.73	A'
5	0.768	0.68	A'
11	0.439	0.37	B
14	0.38	0.2	B
21	0.262	0.49	B
22	0.305	0.29	B
18	0.891	0.22	B'
19	0.907	0.32	B'
23	0.546	0.39	B'

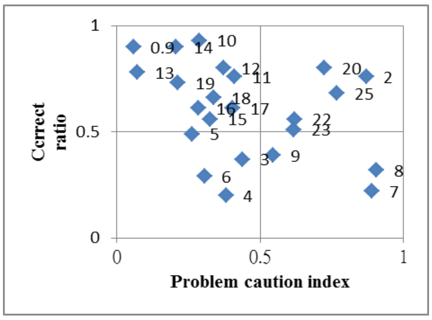

Fig. 3. The scatter diagram for item quality diagnosis.

By using MS Excel to illustrate the scatter diagram for item quality diagnosis, the longitudinal axis is the ratio of correct responses, and the horizontal axis is the caution index for items, as shown in Fig. 3.

B. Evaluations on Students

Fig. 4 and Fig. 5 are the scatter diagrams for students' before and after learning types, the longitudinal axis is the ratio of correct responses, and the horizontal axis is the students' caution index. The scatter diagrams are used to illustrate students' learning types and learning conditions, furthermore, the differences between pretest and posttest is obvious to see in these figures.

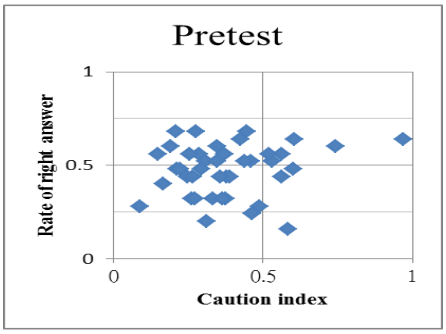

Fig. 4. The scatter diagrams for students' learning type (pretest).

Fig. 5. The scatter diagrams for students' learning type (posttest).

According to students' caution index and the ratio of correct responses, students learning types are divided into 6 kinds. The diagnosis of the pretest and the posttest is showed in Table II. This study found that the most of the participants were B type (general fine and need of diligence, 14 participants) and C (insufficient learning, 18 participants) type before the experiment. However, after the experimental design, the participants distributed evenly, and the most of the students could reach to A type and B type. Still, some of the students are C or C', but the learning condition were raised generally by viewing the scatter diagrams. Some of the students learning conditions were not well-prepared or positive enough, therefore. The result of the paired-samples t-test shows a significant difference in the learning achievement, as shown in Table III.

TABLE II: STUDENTS' LEARNING TYPE DIAGNOSIS

Tests	Students' learning type					
	A	A'	B	B'	C	C'
Pretest			14	6	18	3
Posttest	5	5	18	5	5	3

TABLE III: THE RESULT OF PAIRED-SAMPLES T-TEST ANALYSIS

Variables	Tests	n	Mean	SD	95% CI	r	t
Learning achievement	pretest	4	.47	.136	[-.193, .093]	.450	-5.803***
	posttest	1	.61	.162			

*** $p < .001$

V. Conclusions and Suggestions

In order to investigate the participants' improvement on orthographic projections and applied geometry by using visual presentation e-learning, this study used paired-sample t test to verify the students' learning achievement. The results of this study showed that there is a significant difference between the pretest and the posttest. In addition, the posttest was significantly better than the pretest. Moreover, the students' ability on orthographic projections and applied geometry were improved after the visual presentation e-learning. The most of the students' learning conditions were stable especially, and some students reached the type of effective learning. However, some students' learning achievement did not reach the level by viewing the S-P Chart, therefore, the students' learning conditions should further investigate. The S-P chart analysis belongs to classical test theory, and it is an efficient method to help teachers diagnose the abnormal performances. More specifically, the S-P Chart can help teachers to understand students' learning conditions and learning types before and after teaching. Therefore, the S-P Chart is suitable for the pretest and posttest experimental design.

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