Computers & Education 55 (2010) 858–867

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Construction safety training via e-Learning: Learning effectiveness and user satisfaction

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ARTICLE INFO

Article history:
Received 22 January 2010
Received in revised form
20 March 2010
Accepted 26 March 2010

Keywords:
Adult learning
Media in education
Multimedia/hypermedia systems
Applications in subject areas
Improving classroom teaching

ABSTRACT

In Taiwan, promoting knowledge of "Labor Safety" which relates to life and work right is very important. Safety training and learning effectiveness become essential issues of adult learning. To reduce the costs of educational training, enterprises have also started to aggressively introduce e-learning education training. Unlike the construction industry, few studies have investigated the effectiveness of e-learning and conventional learning. This study tested the effectiveness of the safety education to prevent falls by different learning modes used to assess safety behavior and learning effectiveness during the education training period. According to the average pass rate, satisfaction degree of course and total number of unsafe behavior, the e-learning mode improves learning effectiveness. Additionally, when the e-learning mode is introduced in the construction safety education training, the labor can use the teaching material more independently and multimedia system, such as animated teaching materials, case teaching, and repeated course learning, to reduce the error rate of operation, property loss rate, and light (heavy) injury. Under this condition, the e-learning mode is positively associated with the learning effectiveness of construction safety education training. High learning effectiveness promotes safe behavior during construction operations.

1. Introduction

Constant technological improvement and innovation have increased the incidence of occupational injury from using new technologies and chemicals. Domestic safety health education helps to protect labor occupational safety health and prevent business disaster by avoiding property loss caused by occupational disasters, carry out related occupation education and training to enhance labor skill and advance operation safety. Knowledge of "Labor Safety" is essential. Labor safety related to life and work right. In order not to cause the loss of human resources and maintain the economic development, labor safety education training and learning effectiveness become important issues. According to 2007 statistics reported by the Council of Labor Affairs, Executive Yuan, 29 317 workers died in occupational disasters. Three worker injuries or deaths occurred every hour. The direct and indirect economic losses are difficult to estimate. Hence, avoiding occupational disasters requires intensive study and effort.

In addition to the "Labor Safety and Health Act" and its sub-act, "Administration of Labor Safety and Health Act", labor safety-related legislation in Taiwan includes the "Labor Safety and Health Facility Rule", "Labor Check Method" and "Occupational Accident Labor Protection Act". This legislation is intended to reduce occupational injuries by requiring workers to undergo safety education and training. According to statistical data released by the Council of Labor Affairs, Executive Yuan, safety education training was instrumental in reducing the rate of accidents per thousand workers from 4.12 in 2001–3.61 in 2008, a reduction of 14.568%. During the same period, the rate of injuries per thousand workers dropped from 3.76 to 3.18. These data confirm the effectiveness of labor safety education and training.

Developed countries, including US, EU, Japan, and Taiwan have recently begun promoting e-learning. To reduce the costs of educational training, enterprises have also started to aggressively introduce on-line education training via Internet. Given the huge demand for e-learning programs, domestic academic units and large enterprises have begun establishing e-learning platforms and are gradually

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doi:10.1016/j.compedu.2010.03.017

Table 1
Background value of project.

	Project A	Project B	Project C
Project attribute	Steel building for dwelling	High-rise building for factory	General buildings for office
Work duration	15 months	9 months	17 months
Education training mode	Traditional training	E-Learning	e-learning + Traditional training
Teaching type	Lecturer teaching	Digital materials	Lecturer teaching and digital materials
Course mode	3 h per month, total of 3 stages	3 h per month, total of 3 stages	3 h per month, total of 3 stages
Learning evaluation way	Paper testing	On line testing	On line testing
Observation time	6 months	3.5 months	6 months

acquiring related expertise (Levy, 2007). Unlike the construction industry, some enterprises have attempted to deliver safety education training via e-learning mode. However, few studies have investigated learning effectiveness or have performed cost analyses of e-learning environments and be focused on how to promote safety knowledge and implement it (Jackson & Loomis, 2002; Suraji & Stephen, 2001). Thus, there are few researches about safety education and e-learning in construction industry. This study investigates the effectiveness of e-learning and conventional learning in delivering construction safety education training. The objective of the study was to test the efficacy of digitizing safety education training programs in construction operations. The satisfaction and effectiveness evaluation during e-learning were investigated via the current conditions of e-learning and questionnaires. Moreover, references investigated to construct the research architectures and problems. The methods in this study (*i.e.*, descriptive statistics, factor analysis, reliability analysis, canonical correlation analysis and multiple regression analysis) can be used to investigate e-learning effectiveness and to upgrade learning applications in order to improve the effectiveness of safety education training. Thus, the specific goals of the study were as follows:

(1) Analyze the current conditions of construction safety education training, and to identify factors that may affect e-learning effectiveness.
(2) Investigate the impact of "Teaching Material Design" and "Platform Function" on e-learning effectiveness.
(3) To concretely analyze and verify learning effectiveness via questionnaires for reference when developing e-learning courses in construction safety education.

2. Literature review

2.1. Construction occupational safety

According to 2006 statistical data from the Council of Labor Affairs, Executive Yuan, the three major causes of occupational disasters are climate factors (including earthquakes, storms and typhoons), safety environment and behavior. The data indicated that 67.82% of all workers who are injured each year do not receive labor safety education training. Labor safety education training substantially improves safety and reduces loss of life. Construction laborers tend to suffer the most serious occupational injuries and the injury rate is consistent. This study explores the possible reasons.

The labor environment in the construction industry differs from that in other industries. The safety of the working environment also depends on whether the specific construction project is a plant, reservoir, bridge, building, tunnel sap and so on. Safety and education training must be provided onsite because construction machines and tools differ. Therefore, the construction industry shares the most parts

Table 2
Training course records.

Stage	Content	Project A	Project B	Project C
The first stage	Course execution time	The 3hrs courses on the 3rd day of 1st week by traditional training	The 3hrs courses in the 1st week by e-learning training.	The 2 h courses on the 1st day of 1st week by traditional training; 1hr by e-learning in the week.
	Number of participants	18 persons	15 persons	27 persons
	Test after course	80% pass	90% pass	92% pass
	Satisfaction degree[a]	32.85 points	45.65 points	42.15 points
The second stage	Course execution time	The 3hrs courses in the 2nd day of 7th week by traditional training.	The 3hrs courses in the 5th week by e-learning training.	The 2 h courses in the 1st day of 7th week by traditional training; 1hr by e-learning in the week.
	Number of participants	20 persons	15 persons	27 persons
	Test after course	86% pass	92% pass	87% pass
	Satisfaction degree[a]	37.23 points	42.16 points	41.28 points
The third stage	Course execution time	The 3hrs courses in the 3rd day of 17th week by traditional training.	The 3hrs courses in the 9th week by e-learning training..	The 2 h courses in the 1st day of 18th week by traditional training; 1hr by e-learning in the week.
	Number of participants	18 persons	12 persons	25 persons
	Test after course	85% pass	93% pass	87% pass
	Satisfaction degree[a]	35.85 points	43.63 points	45.10 points
Average pass rate		83.67%	91.67%	88.67%
Average satisfaction degree		35.31 points	43.81 points	42.51 points

[a] The satisfaction degree is the average score of questionnaire after course. The 5-point Likert-Type Scale is adopted by the questionnaire. The expression is from very dissatisfaction (1 point) to very satisfaction (5 points). There are 10 selection problems, and the full score is 50 points.

Table 3
The assessment for the safety behavior after education training (unit: times).

Stage	Parameter	Project A	Project B	Project C
Audit on the first stage[a]	Error rate	17	12	10
	Property loss rate	3	2	2
	Light injury rate	1	0	1
	Heavy injury rate	0	0	0
Average times of each person		1.17	0.93	0.48
Audit on the second stage[a]	Error rate	9	5	7
	Property loss rate	1	1	1
	Light injury rate	0	1	1
	Heavy injury rate	0	0	0
Average times of each person		0.50	0.26	0.33
Audit on the third stage[a]	Error rate	5	2	1
	Property loss rate	1	1	1
	Light injury rate	0	0	1
	Heavy injury rate	0	0	0
Average times of each person		0.33	0.25	0.12
Total times of unsafe behavior		37	24	25

[a] The audit is the safety assessment for the construction behavior of operator.

of occupational disasters according to the statistics, which are related to the unsafe behavior of labor construction. However, the so-called "Unsafe Behavior" means safe facility, operation behavior and professional knowledge without following the requirements of construction environment, which the operation results include "Error", "Property Loss", "Minor Injury" and "Major Injury". The unsafe behaviors are common because of the numerous laborers needed for project properties with large mobility or constructor environment such as subcontract projects to have the small work range and large mobility; or constructors are type B construction industry to have the smaller contracting amount, and safety education and training cannot be implemented. Therefore, the risk of occupational accidents is high.

Labor safety education training in most of industries is delivered via on-the-job training and classroom instruction. Implementing current labor safety and health education for the construction industry differs according to the construction environment. Some construction types require onsite training whereas others allow classroom instruction. Factors such as geographic conditions, time and cost determine whether constructors adopt simpler methods such as video teaching, to achieve a declaration of education training. Providing complete knowledge of safety education is apparently insufficient and may even be negligent. The e-learning mode can often minimize training time and cost by delivering teaching materials and platform functions via Internet at any time and place. The learning schedule, repeated learning, and learning achievement test of education training can be regulated to reach the substantial training result. The cost of education training can be reduced greatly. Therefore, the introduction of e-learning in labor safety education training is a new learning mode. For example, an e-network of all labor education created by the Council of Labor Affairs, Executive Yuan provides substantial labor information and knowledge to be used and learned by the users. It employs the e-learning mode to provide continuous training. Therefore, e-learning has already proven feasible for labor safety education training. Besides, enabling laborers to study the safe knowledge of operation in advance, it can strengthen the labor to understand the knowledge and importance of labor safety during the working period in accordance with the environment of facilities and the required course type of demand.

2.2. e-learning

The purpose of labor safety education is to prevent the occurrence of occupational disasters. The learning courses are often used to train and strengthen the professional knowledge of safety behavior. The new education mode can cooperate with the network and technological tool to achieve immediate learning environment at any time and any place. Thus, the learning can be divided into four categories: the computer-aided learning, e-learning, remote learning and on-line learning. The former three ones are the learning ways conducted through electronic media, such as CD, auxiliary software, interactive TV etc. The online learning is conducted through the Internet or Intranet to achieve the interaction among learner, course, and teacher. E-learning indeed is a form of online learning. Therefore, the online learning is called e-learning or web-based learning at present. The International Data Corporation (IDC) also proposes that the e-learning can be divided into the synchronous learning and asynchronous learning. The synchronous learning means the students and teachers are on line at the same time. On the contrary, the asynchronous learning is at different time. No matter the synchronous or asynchronous learning, the characteristics include interface, learning resource, and remote learning. David (2000) mentioned that the e-learning not only transmits the content through the internet, but also applies it to various management procedures, including the collection of training content and the management of learning information etc. It can increase the personal technical ability and raise the whole ability of organization.

2.3. Learning effectiveness

Learners must continually assess their learning effectiveness in an e-learning environment. Bostrom, Olfman, and Sein (1990) argued that assessment of e-learning effectiveness must consider not only actual effectiveness in learning content, but also the attitude of the learner in the network learning environment. Gorman (1995) proposed that e-learning is technology-based training that can increase learning effectiveness. Its significant effects include increased learning opportunities, support blending learning (both synchronous and asynchronous learning), satisfaction of individual learner needs, and highly diversified learning. Alavi, Wheeler, and Valacich (1995) developed an index for assessing learning effectiveness, which measured satisfaction degree of learning, learning achievement and classroom assessment. Binnerr, Dean, and Millinger (1994) proposed that degree of satisfaction with learning is a useful measure of the efficiency of on-line courses.

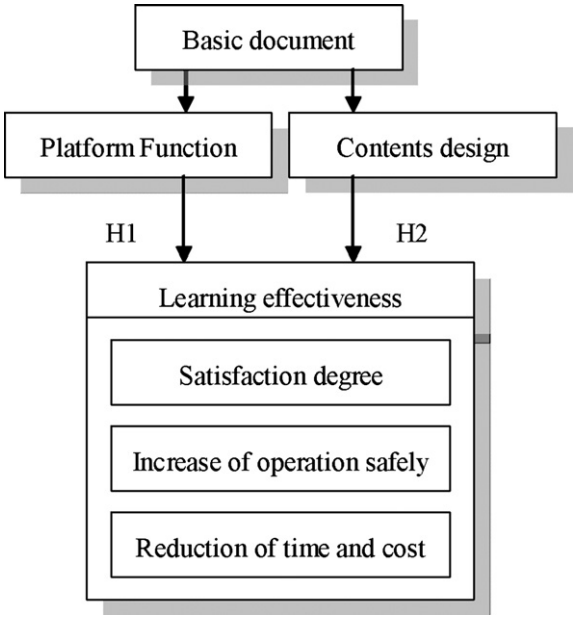

Fig. 1. Positive effect framework of the questionnaire.

Maki, Maki, Patterson, and Whittaker (2000) proposed that the satisfaction degree of learning and learning achievement are important factors influencing learning effectiveness. To summarize the above, learning effectiveness can be influenced by the learning satisfaction, learning achievement and classroom assessment. Thus learning satisfaction is a useful index. The procedure for introducing e-learning in enterprise education training can usually be divided into three parts: content design, platform function and course lead. Regarding overall learning achievement, each element may affect learning effectiveness. Therefore, this paper considers the background of construction safety education. The impact of "Content Design" and "Platform Function" on e-learning effectiveness is discussed. Learning effectiveness is determined by three major factors: learning satisfaction, increase in operation safety and reduction of time and cost.

3. Research methods and design

This study tested the effectiveness of e-learning for delivering construction safety education training and how to assess its effectiveness. Holcomb (1993) proposed seven methods of assessing learning effectiveness, including interview, test, questionnaire, observation, document analysis, scenario analysis and action plan etc. Therefore, this paper employed interview, test, questionnaire, observation, and document analysis to investigate learning effectiveness. A two-stage materials analysis was performed in this study. At the first stage, different learning and training results generated from different education training mode of Project A, Project B, Project C were investigated. According to the analysis results of the first stage, a questionnaire survey was performed the second stage. The labor safety education training of e-learning mode was tested for e-learning effectiveness through questionnaire for two construction projects with similar attributes. As noted in 4.1, the first stage of the analysis was the preliminary materials assessment. As noted in 4.2, the second stage of the questionnaire survey was the e-learning effectiveness assessment.

Table 4
Statistics of questionnaire.

Sex		Male	Female	Total
Number of people		72(87%)	11(13%)	83(100%)
Actual age	20–30 years old	12%	0%	12%
	30–40 years old	45%	5%	50%
	Over 40 years old	30%	8%	38%
Education degree	Under junior high school	28%	8%	36%
	Senior high school (occupational)	52%	5%	57%
	Above college	7%	0%	7%
Information accomplishment	Never use internet in the past	0%	0%	0%
	Ever use internet but not familiar with words processing operation	74%	13%	87%
	Familiar with words processing operation	13%	0%	13%
Learning state	3 h per week	39%	4%	0%
	3 h–6 h per week	22%	9%	0%
	Above 6 h per week	26%	0%	0%

Table 5
The result of item analysis.

No.	Content of question	*F*	*P* (*F*-value significance)	*t*	*P* (*t*-value significance)
1	The platform provides self learning function to improve my learning effectiveness.	1.223	0.635	7.964	0.000***
2	The quality of network will influence my learning effectiveness.	2.186	0.428	8.011	0.000***
3	The platform provides group discussion function to improve my learning effectiveness.	0.902	0.517	7.126	0.000***
4	The platform provides learning guide function to improve my learning effectiveness.	0.437	0.179	8.627	0.000***
5	The platform provides test tracing function after course to influence my learning effectiveness.	1.926	0.445	10.586	0.000***
6	The suitability for the operation of platform will influence my learning effectiveness.	0.979	0.015*	8.427	0.000***
7	The convenience of internet learning will influence my learning effectiveness.	0.901	0.389	6.401	0.000***
8	Good design of user interface (system interface) will promote my learning effectiveness.	0.628	0.523	9.345	0.000***
9	The course leading of on-line lecturer will promote my learning effectiveness.	0.429	0.475	7.929	0.000***
10	The whole efficiency provided by the platform will promote my learning effectiveness.	1.296	0.761	10.586	0.000***
11	The suitability of designed teaching materials will influence my learning effectiveness.	2.118	0.504	8.066	0.000***
12	The enrichment and pluralism of multimedia teaching materials will influence my learning effectiveness.	3.902	0.820	11.218	0.000***
13	The structural sequence for the design of teaching materials will influence my learning effectiveness.	0.923	0.306	7.315	0.000***
14	The expression method of the teaching materials will influence my learning effectiveness.	1.867	0.219	10.025	0.000***
15	The suitability for the learning time of course unit will influence my learning effectiveness.	0.457	0.426	10.590	0.000***
16	The actual case explanation for the introduction of teaching materials will help my learning effectiveness.	3.577	0.003**	12.390	0.000***
17	The design for the teaching materials practiced after class will help my learning effectiveness.	1.011	0.551	7.0.521	0.000***
18	The on-line simulation test and review design of teaching materials will influence my learning effectiveness.	2.190	0.408	9.549	0.000***
19	The integrality for the contents design of teaching materials will influence my learning effectiveness.	5.026	0.396	10.078	0.000***
20	Compared to traditional mode the e-learning will promote my learning effectiveness.	0.729	0.577	7.873	0.000***
21	I am satisfied about the design of on-line teaching materials.	3.017	0.684	9.523	0.000***
22	I am satisfied about the guiding mode of course activity.	0.882	0.314	7.011	0.000***
23	I am satisfied about the efficacy for interactive discussion of course.	1.763	0.273	8.302	0.000***
24	I am satisfied about the function of platform (including the network quality).	1.562	0.016*	10.117	0.000***
25	I am satisfied about whole learning management of teaching activity.	0.807	0.569	10.060	0.000***
26	The e-learning can promote personal learning effectiveness.	3.663	0.632	11.790	0.000***
27	The e-learning course can increase the interest of learning.	2.181	0.001**	10.561	0.000***
28	The e-learning course can increase the safety knowledge of operation.	3.975	0.359	10.903	0.000***
29	The arrangement of repeated learning course can reduce the wrong operation.	0.458	0.518	8.651	0.000***
30	The flexibility of learning time can improve the learning effectiveness.	2.093	0.227	11.230	0.000***
31	Self learning management can improve the management performance of time.	1.352	0.000***	12.372	0.000***
32	Compared to the traditional labor safety education training, the e-learning can save time and cost.	0.986	0.573	10.968	0.000***

Note: $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

4. Result

4.1. Preliminary materials assessment

The content analysis method has numerous applications. Numerous materials can be analyzed and explained systematically and statistically. Kerlinger (1985) described content analysis as a systematic, objective, and quantitative research method, its purpose is to measure examine the parameters upon propagating. Weber and Specht, (1997) also argued that "the content analysis method is a research methodology, namely a group of procedure to make effective inference for document content." The content analysis method is one qualitative research method. Although contact with research subjects is still needed, the Hawthorne Effect is avoided due to the presence of the

Table 6
Reliability test.

Aspect	Characteristic item	Factor Factor loading	Eigenvalue	Explained variance	Cronbach'α
Platform Function	The quality of network will influence my learning effectiveness. 0.821	Network quality	3.815	12.573%	0.8926
	The suitability for the operation of platform will influence my learning effectiveness. 0.819	Platform operation			
	Good design of user interface (system interface) will promote my learning effectiveness. 0.792	User interface			
	The platform provides test tracing function after course to influence my learning effectiveness. 0.836	Test after course			
Contents Design	The enrichment and pluralism of multimedia teaching materials will influence my learning effectiveness. 0.852	Animation design	3.276	13.421%	0.8142
	The actual case explanation for the introduction of teaching materials will help my learning effectiveness. 0.783	Case teaching			
	The on-line simulation test and review design of teaching materials will influence my learning effectiveness. 0.715	Simulation test			
	The integrality for the contents design of teaching materials will influence my learning effectiveness. 0.674	Materials capacity			
Learning effectiveness	I am satisfied about the design of on-line teaching materials. 0.729	Learning satisfaction	2.965	15.953%	0.8752
	The arrangement of repeated learning course can reduce the wrong operation. 0.667	Operation safety	2.781	13.247%	0.8367
	Self learning management can improve the management performance of time. 0.834	Time cost	3.012	16.517%	0.8219

researcher or by the arrangement of research scenario. Thus, the content analysis method has the "objective", "systematical" and "quantitative" feature. It is a pure quantizing type analysis employed after converting qualitative materials into quantitative materials and to analyze or explain as this phenomenon.

At the preliminary materials assessment course of first stage, the research objects included three projects (Project A, Project B, Project C) in a high-rise building operation. The content analysis method is adopted, and the safety education to prevent falls. Table 1 shows the different learning modes used to assess safety behavior and learning effectiveness during the education training period. Project attributes, work duration, education training mode, teaching type, course mode, learning evaluation way and observation time are measured to determine the overall value of safety education training.

Learning effectiveness is essential in labor safety education training. Error occurrence and injury rate during project execution are the typical measures of the effectiveness of safety training. Therefore, the acceptance of achievement is divided into three stages (learning by stages in accordance with the course content). Table 2 shows the materials collected during the project, which include course execution time, number of participants, test after course and satisfaction degree. The average pass rate and average satisfaction degree shown in Table 2, indicates e-learning is most effective in Project B. The second most effective is blended learning mode.

A positive association between good training results and safety behavior in actual operations is expected in all projects regardless of the safety education and training program adopted. As for the labor safety education training, the "error rate", "property loss rate", "light injury rate", and "heavy injury rate" are used as the parameters to assess and explain the training achievement. Therefore, Projects A, B, and C were audited by 3-stage training. Table 3 shows the assessment for the safety behavior after education training.

Table 3 shows that safety education training reduces the number of unsafe behaviors. The gradual induction and review of phased course can increase the safety behavior of actual operation greatly, and reduce the error rate and property loss rate. Thus, after summarizing the preliminary materials assessment content of first stage, the following result can be obtained under different training modes:

1) Good education training can minimize server injury.
2) According to the average pass rate, satisfaction degree of course and total number of unsafe behavior shown in Table 2 and Table 3, the e-learning mode improves learning effectiveness.
3) Repeated education training can significantly reduce the injury rate. Therefore, safety education training can prevent the injury of labor operation, and it is also the key point of this research.

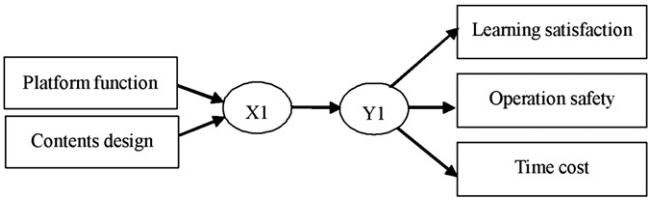

Fig. 2. The framework of canonical correlation analysis.

Table 7
The influence of platform function to learning effectiveness.

Independent variables (X)	Correlation factor ($X1$)	Dependent variables (Y)	Correlation factor ($Y1$)
Network quality	−0.85	Learning satisfaction	−0.87
Platform operation	−0.92	Operation safety	−0.91
User interface	−0.76	Time cost	−0.83
Test after course	−0.68		
Variance extracted (%)	85.32	Variance extracted (%)	81.67
Overlay	69.18	Overlay	67.89
		P^2	0.67
		Canonical correlation coefficients (P)	0.82

Note: $^{**}p < 0.001$.

4.2. e-learning effectiveness assessment

According to conclusion of first stage from the preliminary materials assessment, the "e-learning" with the highest satisfaction degree is used to investigate the learning effectiveness. The SPSS for Windows 12.0 is used to analyze and very the basic information of questionnaire and relevant information of every question as shown in Fig. 1. This research defines the following research hypotheses:

H1: "Platform Function" has a positive effect on learning effectiveness.
H2: " Contents Design" has a positive effect on learning effectiveness.

Regarding overall learning achievement (increase in operation safety and reduction of time and cost), the impact of "Platform Function" and "Content Design" on e-learning effectiveness is discussed. H1 and H2 hypotheses are supported on platform function and Content Design that positively affects learning effectiveness. Therefore, How to prove them is the research question of the study.

To test the validity of the sample size, Projects D and E were used as different construction projects in the questionnaire. The fall safety education training was the primary training program. The participants were thirty-eight workers in Project D and forty-five workers in Project E, respectively. Eighty-three participants completed the e-learning program and questionnaire survey. The on-line questionnaire was designed to prevent invalid answers, so eighty-three effective samples were actually obtained. Table 4 shows the statistics of questionnaire.

As for the validity of questionnaire, the validity of content and item analysis method are adopted. Among them, the content of questionnaire is built in accordance with the preliminary materials, the interview of labors and professional lecturers. In the item analysis, the F-value is used to test each question. If it is significant ($p < 0.05$) and t-value is also significant ($p < 0.05$), then this question has the distinguished degree. From the item analysis result shown in Table 5, it is found that every question is significant ($p < 0.001$). Therefore, all questions are reserved to build the validity of questionnaire.

Before analyzing the reliability, to confirm the construction validity of questionnaire first and applying the exploratory factor analysis to extract the common factors. It means that to determine the original variable with larger variation amount by using the characteristic value larger than 1.0. According to the viewpoint proposed by Kaiser (1974), larger Kaiser-Meyer-Olkin (KMO) value is more suitable for the factor analysis, which shows there are more common factors among variables. On the contrary, if the KMO value < 0.5, it will be not suitable for analyzing. Table 6 shows the KMO $= 0.871$, the accumulated variation amount $= 71.711$, and $P < 0.001$, which is significant. Thus, the measurement of questionnaire is suitable for factor analysis. "Platform Function" is divided into four factors in this paper, such as the network quality, platform operation, user interface, and test after course. "Contents Design" is divided into four factors, such as the animation design, case teaching, simulation test, and materials capacity. "Learning Effectiveness" is divided into three factors, such as the learning satisfaction, operation safety, and time cost.

As for the reliability, Cronbach's α factor is used to show the same characteristics of item. If α value is greater, the consistency is higher and the stability of questionnaire is higher. Generally speaking, when α value is above 0.7, it means high reliability. When it lies between 0.7 and 0.4, it means the moderate state. When it is lower than 0.4, it means low reliability. All reliability values of questionnaire are greater than 0.7, it shows that the content of questionnaire has the consistent level.

The content of e-learning effectiveness assessment at second stage is mainly to discuss the influence of "platform function" and "contents design" on the "learning effectiveness". Thus, the "platform function" and "contents design" are used as the independent variables, and the "learning effectiveness" is used as the dependent variable to conduct canonical correlation analysis, as shown in Fig. 2. The multiple

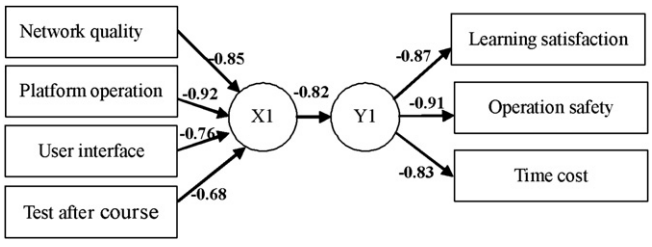

Fig. 3. The path of canonical correlation analysis on platform function and learning effectiveness.

Table 8
The influence of contents design to learning effectiveness.

Independent variables (X)	Correlation factor ($X1$)	Dependent variables (Y)	Correlation factor ($Y1$)
Animation design	−0.93	Learning satisfaction	−0.91
Case teaching	−0.87	Operation safety	−0.75
Simulation test	−0.72	Time cost	−0.82
Materials capacity	−0.76		
Variance extracted (%)	56.17	Variance extracted (%)	79.68
Overlay	83.51	Overlay	57.93
		P^2	0.58
		Canonical correlation coefficients (P)	0.76

Note: $^*p < 0.05$.

regression analysis is used to discuss the relation of these three items. The purpose is to check whether it is consistent between the results of canonical correlation analysis and multiple regression analysis.

In Table 7, four influence factors of function platform are the network quality, platform operation, user interface, and test after course. With respect to the assessment indexes of "learning satisfaction", "operation safety", and "time cost" of learning effectiveness as shown in Fig. 3, their relations can be summarized as follows:

1) Correlation coefficient $P = 0.82$, and it is significant if the coefficient correlation is more than 0.001. It shows that there is positive relation between two variables, and it supports H1 research hypothesis.
2) The overlap of independent variable and dependent variable is 67.89%. Thus, it shows four independent variables (network quality, platform operation, user interface, and test after course) can influence the dependent variables (learning satisfaction, operation safety, and time cost) through canonical correlations.
3) Among the factors influencing the effectiveness of education training, the "platform operation" has the biggest contribution to independent variable ($X1$). Among the assessment indexes of "learning satisfaction", "operation safety", and "time cost" of learning effectiveness, the "operation safety" has the biggest contribution to dependent variable ($Y1$).
4) As for the influence of platform function on the learning effectiveness, the platform operation has the biggest influence to the learning effectiveness, and the next one is the network quality.

In Table 8, four influence factors of contents design are the "animation design", "case teaching", "simulation test", and "materials capacity". With respect to three assessment indexes of learning effectiveness as shown in Fig. 4, their relations can be summarized as follows:

1) Correlation coefficient $P = 0.76$, and it is significant if the coefficient correlation is more than 0.05. It shows that there is positive relation between two variables, and it supports H2 research hypothesis.
2) The overlap of independent variable and dependent variable is 57.93%.
3) Among the factors of contents design, the "animation design" has the biggest contribution to independent variable ($X1$). Among three factors of learning effectiveness, the "learning satisfaction" has the biggest contribution to dependent variable ($Y1$).
4) As for correlation coefficient, animation design of contents design has the biggest influence on the learning satisfaction of learning effectiveness.

The above data indicate that platform function and content design positively affect learning effectiveness. An effective learning platform enables learners to use the teaching materials effectively an a reliable environment. The pluralism and vividness of content design induces learning interest, increases learning satisfaction, and positively influence learning effectiveness. Therefore, the more perfect of platform function is, the more significant learning effectiveness is. It can deeply influence the acquisition of operation safety knowledge and actual work effectiveness. In order to confirm the positive relation for the influence of learning effectiveness, this research employs multiple regression analysis to check the consistency of analysis. It is expressed by multiple regression analysis of platform function on learning effectiveness and multiple regression analysis of content design on learning effectiveness.

The platform function is used as independent variable and the learning effectiveness is used as dependent variable to conduct multiple regression analysis, and the result is shown in Table 9. It is found that the significant level of the "learning satisfaction", "operation safety",

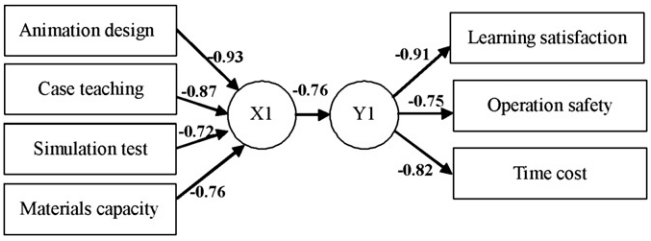

Fig. 4. The path of canonical correlation analysis on contents design and learning effectiveness.

Table 9
Multiple regression analysis of platform function to learning effectiveness.

Standard regression coefficient (β)		Learning effectiveness		
		Learning satisfaction	Operation safety	Time cost
Platform Function	Network quality	0.10**	0.12	0.06*
	Platform operation	0.23**	0.10	0.15
	User interface	0.14*	0.07	0.09
	Test after course	0.25**	0.17*	0.26
F-value		16.03	12.27	10.19
P value		0.000***	0.000***	0.000***
R Square		0.22	0.08	0.16
Adjusted *R*2		0.21	0.06	0.14

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

and "time cost" is ($F = 16.03$, $p < 0.001$), ($F = 12.27$, $p < 0.001$), and ($F = 10.19$, $p < 0.001$), respectively, and the explanation ability of "learning satisfaction" is up to 21% ($R2 = 0.21$). In addition, from the standard regression coefficient β and significance ($p < 0.05$, **$p < 0.01$, ***$p < 0.001$), the following three results are found:

1) "Network quality" of the independent variable has significant influence on the "learning satisfaction", "operation safety", and "time cost" of learning effectiveness. It shows that good network quality can improve the learning effectiveness.
2) "Platform operation" and "user interface" have significant influence on the "learning satisfaction" of learning effectiveness.
3) "Test after course" has significant influence on the "learning satisfaction" and "operation safety" of learning effectiveness. It shows the test after course could enforce the operation safety and the learning satisfaction.

Content design and learning effectiveness were used as independent and dependent variables, respectively in multiple regression analysis. Table 10 shows the regression analysis results. The effects of "learning satisfaction", "operation safety", and "time cost" were statistically significant, and "learning satisfaction" had the highest explanatory power. Additionally, standard regression coefficient β and significance revealed the following:

1) The "animation design" and "simulation test" of content design significantly affected "learning satisfaction" and "time cost" of learning effectiveness, which indicates that pluralism and vividness of content design increase] learning satisfaction and reduce the time cost.
2) Use of the "case teaching" method significantly affects "learning satisfaction" and "operation safety", which indicates that selecting an effective case study can help the learner to absorb knowledge and improve satisfaction degree and operation safety.
3) "Materials capacity" is not significantly related to any of the three indexes of learning effectiveness.

5. Discussion

This study employed canonical correlation analysis and multiple regression analysis to verify the mutual relationships among platform function, content design and learning effectiveness. Factor analysis of the platform function and content design aspects of the questionnaire indicated that the key factors in learning effectiveness are network quality, platform operation, user interface, and test after course of platform function; animation design, case teaching, simulation test, and materials capacity of content design. The data also revealed that learning satisfaction, operation safety, and time cost are three important indices of learning effectiveness. Therefore, the verification results supported H1 and H2 as follows:

(1) Test of H1 and H2 Hypotheses
   (a) The H1 hypothesis is that platform function positively affects learning effectiveness. Canonical correlation analysis and multiple regression analysis revealed that the platform function positively affects learning effectiveness. An e-learning environment is effective if it motivates the learner, provides the content needed for learning, and creates a learning context. The platform function plays an important role on the motivation and context. Analysis of the four factors of network quality, platform operation, user

Table 10
Multiple regression analysis of contents design to learning effectiveness.

Standard regression coefficient (β)		Learning effectiveness		
		Learning satisfaction	Operation safety	Time cost
Contents design	Animation design	0.25***	0.26	0.19*
	Case teaching	0.03**	0.09*	0.21
	Simulation test	0.13*	0.07	0.18*
	Materials capacity	0.04	0.11	0.06
F-value		15.71	5.90	8.69
P value		0.000***	0.000***	0.000***
R Square		0.19	0.06	0.05

Note:*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

interface, and test after course of platform function found that the smoothness of network, easy operation of platform, affinity of user interface and the test assessment of learning ability are the impressions of learner. Learning satisfaction first produces direct influences and then raises operational safety. As for the learner, the concept of time is cost, and the independence of self learning is a major factor. Therefore, H1 hypothesis was fully supported.

(b) The H2 hypothesis is that content design positively influences learning effectiveness. The analytical results found that "learning satisfaction" is an essential index of learning effectiveness. Regardless of the animation design, case teaching, and the results of simulation testing of content design, good content design must include multimedia animation, actual case introduction, self-achievement simulation, and suitability of teaching materials unit, which will influence the learning satisfaction of learning effectiveness and raise the operation safely directly. Therefore, H2 hypothesis is established in canonical correlation analysis. However, multiple regression analysis revealed that the "materials capacity" of content design is not significantly related to any index. Thus, H2 hypothesis was partially supported.

(2) Mutual relation between the introduction of e-learning in construction safety education training and its learning effectiveness

An effective e-learning platform must provide the learning mode preferred by the learners, such as independence, flexibility, community etc. Because it possesses the functions instead of traditional learning, when the e-learning mode is introduced in the construction safety education training, the labor can use the teaching material more independently. The labor can also use the functions provided by platform, such as animated teaching materials, case teaching, and repeated course learning, to reduce the error rate of operation, property loss rate, and light (heavy) injury.

(3) Mutual relation between the safe behavior of construction operation and e-learning effectiveness

The purpose of construction safety education training is to reduce the occurrence opportunity of unsafe behavior. A good training mode can reduce unsafe behavior and increase the overall safety of construction operations. Among them, the e-learning mode is a subject worthy to be discussed studied. The overall analysis revealed that the key indexes of learning effectiveness are learning satisfaction, operation safety, and time cost. Regarding construction labor, learning satisfaction increases occupational safety. Additionally, because the working time of laborers is often arranged tightly, time is needed for independent learning, so the time cost an important factor influencing the learning satisfaction. Under this condition, the e-learning mode is positively associated with the learning effectiveness of construction safety education training. High learning effectiveness promotes safe behavior during construction operations.

6. Conclusions

The purpose of this research is mainly to discuss the e-learning effectiveness for the introduction of construction safety education. Analysis of the questionnaire results indicated that suitable education training mode and suitable training course content can reinforce the safe behavior of labor operation, no matter the age, education degree and information accomplishment of labor. Given the current technological environment and the time and cost of construction safety education and training, this research investigates the effectiveness for introduction of e-learning in construction safety education training. Increasing occupational safety via the e-learning mode proved to be highly feasible. Further study is needed to clarify the mutual relationship on cost and effectiveness via e-learning and whether e-learning is an effective substitute for traditional education and training.

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