An Empirical Study of the Critical Factors Influencing Learner Satisfaction and Effectiveness: A 3D CAD System's Perspective

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Abstract—**This study proposed a multicriteria methodology from the perspective of perceived learner satisfaction on the basis of the fields of human–computer interaction, information systems, and educational theory. The published critical success factors of the information system were surveyed and grouped into four categories: user-interface design, quality of technology, learners' interactive collaboration capabilities, and instructors' technical competence. Each category included several measures. A survey was conducted to investigate these critical success factors affecting learning satisfaction in 3D environment. The sampling consisted of students at both undergraduate and graduate levels who were users of a three-dimensional computer-aided design (3D CAD) system. The analytical results revealed that user-interface design, learners' interactive collaboration capabilities, and instructors' technical competence are the critical factors affecting perceived learner satisfaction. The findings of this study teach academics and practitioners of 3D CAD systems how to enhance learner satisfaction and further strengthen the implementation of their learning programs.**

Index Terms—**3D CAD System, Multicriteria Methodology, Learner Satisfaction**

I. Introduction

3D CAD is an integral part of the curriculum setting for art and design majors, and represents a significant digital artistic design tool used throughout the curriculum from basic art to professional artistic design. As Such, training in the use of this integral tool itself serves as a fundamental part of the course curriculum.

Some commonly used CAD software, such as 3DS Max, Maya, and SketchUp, provide good software compatibility and visual workflow, and are widely adapted to the fields such as industrial design, animation design, and costume design. The 3D CAD users can not only effectively present design concepts, but also explore and observe physical properties, such as space, shape, texture, and lighting in a 3D environment, which plays an important role in the training of professional skills and establishment of expertise. However, compared to 2D CAD software, painstaking efforts are required from beginners to master 3D CAD software and their relevant operational skills, which involve a comparatively complicated human–computer interaction process. Therefore, studies into the factors affecting learner satisfaction in the application of teaching 3D CAD software are expected to significantly enhance the teaching quality of relevant courses and the ability of students to fully apply the inherent benefits of 3D CAD software.

Previous studies, from perspectives such as psychology and information systems (ISs), have confirmed certain factors that impact learner satisfaction in ISs. Some of these studies have discussed the factors influencing learner satisfaction from a single dimension, such as from teachers', learners', or technical perspectives, while others have conducted comprehensive analyses from a multidimensional viewpoint. However, most of these studies have focused on the assessment of a web-based learning environment. With respect to the specific application of 3D CAD software to the artistic design curriculum, researchers in this field require specialized investigations that address both teaching and learning in real situations.

Therefore, on the basis of previous studies' results, this study will build an assessment model for the factors influencing learner satisfaction by combining the aspects of the application of technology and art education. Besides, the significant factors influencing the learning satisfaction of 3D CAD software will be assessed from

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learners' perspectives by using questionnaires and data analysis. This study provides teachers with an improved understanding of learner acceptance of 3D CAD technology and the relevant factors affecting into help educators enhance their teaching methods and procedures, as well as to improve the efficiency of both educators and learners.

II. Literature Review

In the field of ISs, the concept of user satisfaction typically represents the degree to which users believe that the IS they are using conforms to their requirements. This representation is an important factor toward assessing the successful application of the system. According to the results of e-learning studies, the main factors affecting user satisfaction include six dimensions: students, teachers, curriculum, technology, system design, and environment. On the basis of these results, in combination with the actual process of art and design majors learning 3D CAD software, this study considers four key factors that impact learning satisfaction: user-interface design, quality of technology, learners' interactive collaboration capabilities, and instructors' technical competence. The following is a detailed analysis of these four factors.

The quality of technology, an important factor affecting learner satisfaction, includes two elements: software and hardware. Software quality refers to its stability, security, reliability, speed of response, ease of use, and user-friendliness. Several studies have pointed out that learner satisfaction in an e-learning environment is significantly affected by the quality of technology. A software tool that incorporates friendly human–computer interaction is more likely to be adopted and can enhance user satisfaction. Therefore, the higher the quality and reliability of information technology (IT) is, the higher the learner satisfaction will be.

A significant model for explaining and predicting the behavior of IT adoption is the technology acceptance model, which consists of three important variables: perceived usefulness, perceived ease of use, and attitude toward use of IT. Some studies have confirmed the significant effect of perceived usefulness and ease of use on learner satisfaction. During continuous development and application, other internal and external variables, including perceived functionality, perceived user-interface design, and perceived system support, have been added to this model to explain acceptance behaviors of the different technical backgrounds. For instance, user-interface design can facilitate user control and interaction with the interface. Cho et al. (2009) [1] pointed out that the interactivity between the student and the interface is considered as the most important aspect toward improving the quality of education through e-learning. Related literatures have also pointed out that the enhancement of interface design can help stimulate learners' motivation and thereby increase their e-learning course completion rates.

ISs are open systems, which mean that user characteristics affect their application effectiveness. Teachers, as organizers and instructors, play an important role in classroom-based 3D CAD teaching environments. Selim (2007) [2] suggested that instructors should adopt interactive teaching style and encourage student–student interaction. It is also important that instructors have good control over IT and are capable of performing basic troubleshooting tasks. On the other hand, within learning environments, instructors should have enough time to interact with students in their learning process (2005) [3]. Piccoli et al. (2001) [4] pointed out that interaction allows individuals to share information, to receive feedback, and to more readily evaluate progress, which are significant to the learning outcomes affecting information systems.

In summary, on the basis of the scale provided by student evaluations of learning effectiveness and satisfaction, we conducted an exploratory study directed at 3D CAD system learners. This study divides the factors affecting learning satisfaction of 3D CAD into four categories: user-interface design, quality of technology, learners' interactive collaboration capabilities, and instructors' technical competence. The specific categories and the 18 criteria are shown in Table I.

TABLE I.
RELATED REFERENCES REGARDING THE CRITICAL FACTORS AND CRITERIA THAT AFFECT LEARNER SATISFACTION

Categories	Criteria	Pertinent Literature
A. User-interface design	A1. Ease of use	D. Y. Shee et al. [5]
	A2. User-friendliness	
	A3. Ease of understanding	
	A4. Information presentation	T. C. Reeves et al. [6]
	A5. Screen design	
B. Quality of technology	B1. Presence of many useful functions	P. C. Sun et al. [7]
	B2. Presence of good flexibility	
	B3. Operational stability	C. W. Holsapple et al. [8]
	B4. Responsiveness	
	B5. Speed	
C. Learners' interactive collaboration capabilities	C1. Interaction with other learners	R. D. Johnson et al. [9]
	C2. Interaction with teachers	
	C3. Exchange of learning with others	D. Y. Shee et al. [5]
	C4. Active participation in discussion	H. M. Selim [2]
D. Instructors' technical competence	D1. Instructors' technical competence with the 3D CAD technology	T. Volery et al. [10]
	D2. Instructors' encouragement of student interaction	
	D3. Instructor enthusiasm	
	D4. Quality of instructor explanation regarding use of 3D CAD	

III. METHODOLOGY

A. Research Model and Hypotheses

This study investigates the learner satisfaction of 3D CAD software from a multidimensional perspective by combining considerations involving the application of IT and education theory. The research model employed is shown in Figure 1, and the hypothesized relationships among the variables are summarized in Table II.

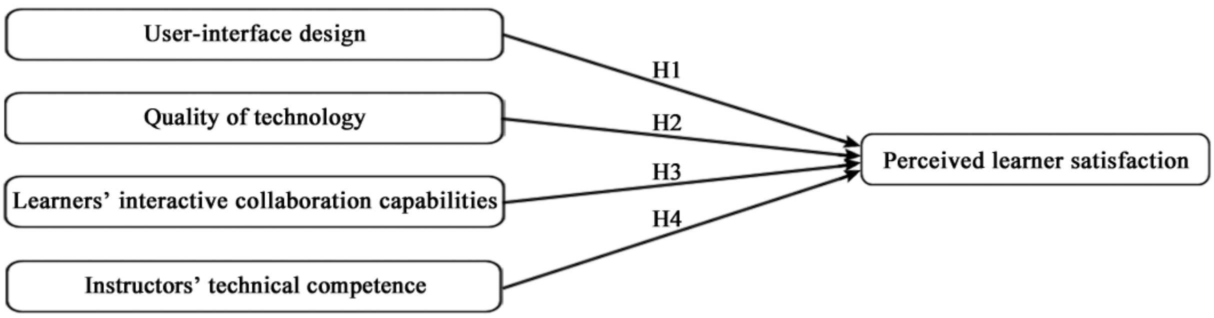

Figure 1. Framework of the study

TABLE II.
RESEARCH HYPOTHESES

Research Hypotheses
H1: User-interface design will positively influence perceived satisfaction.
H2: Quality of technology will positively influence perceived satisfaction.
H3: Learners' interactive collaboration capabilities will positively influence perceived satisfaction.
H4: Instructors' technical competence will positively influence perceived satisfaction.

B. Measurement Development

We conducted a series of in-depth interviews with experienced 3D CAD software learners to examine the validity of the research model described above. Next, we developed questionnaire items on the basis of considerations elaborated in previous literature.

The questionnaire includes questions related to basic personal information and the 18 criteria listed in Table I. The respondents were required to rate the questions on a 5-point Likert scale in order to express their attitude. The answers were marked from 1 to 5, in correspondence to "strongly disagree", "disagree", "uncertain", "agree", and "strongly agree" respectively. We distributed 50 questionnaires and retrieved 41. The response rate was 82% and the usable rate was 78%.

C. Participants

To ensure the reliability of the result, we selected senior students having experience in 3D CAD software from a university in Zhejiang Province, China, as the participants. This study used the statistical package for the social sciences (SPSS) 19.0 Windows software program for the statistical analysis. A descriptive analysis of the questionnaires used in the study shows balanced gender ratios, with male students accounting for 51.3% and female 48.7%. Fifty percent of the respondents were industrial design majors, while the remaining were majors in urban planning, landscape design, visual communication, digital media, etc. In addition, 76.9% of the respondents ranged from 21 to 25 years old, indicating that most of them were sophomore to second-year graduate students.

IV. DATA ANALYSIS

A. Reliability and Validity Analysis

Reliability and validity of the questionnaire data were tested. Reliability refers to the quality of a measurement, indicating the degree to which the measurement is consistent, i.e., repeated measurements would give the same result. In order to investigate the internal consistency of the survey's subscales, Cronbach's alpha and the corrected item-total correlation (CITC) were applied to some of the criteria given in Table I. Table III indicates that the value for Cronbach's alpha exceeds 0.7 for the criteria set considered. Table IV indicates that the CICT exceeds 0.35 for all criteria considered, and thus, the data are reliable. Besides demonstrating reliability, the application of Cronbach's alpha can be used to indicate whether an item should be deleted, so as to improve the overall reliability. In this manner, it was determined that items B4, B5, and D3, from Table I, should be deleted and the remaining 15 variables should be confirmed. The results meet the reliability requirements, as shown in Tables III and IV.

TABLE III.
RELIABILITIES OF THE SURVEY

Cronbach's Alpha Value	No. of Items
.872	15

TABLE IV.
CORRECTED ITEM-TOTAL CORRELATION FOR THE 15 CONFIRMED CRITERIA

Item	CITC
A1. Ease of use	.426
A2. User-friendliness	.376
A3. Ease of understanding	.611
A4. Information presentation	.606
A5. Screen design	.526
B1. Presence of many useful functions	.465
B2. Presence of good flexibility	.642
B3. Operational stability	.494
C1. Interaction with other learners	.490
C2. Interaction with teachers	.597
C3. Exchange of learning with others	.667
C4. Active participation in discussion	.362
D1. Instructors' technical competence with 3D CAD technology	.648
D2. Instructors' encouragement of student interaction	.485
D4. Quality of instructors' explanation regarding use of 3D CAD	.494

An important quality of a measurement, reflecting validity, is the extent to which the measurement reflects the underlying construct, that is, whether it measures what it purports to measure. Reference to the variable scale of the previous studies provides the present research with considerable content validity. This fact transfers the emphasis onto the question of structure validity. The structure validity of the questionnaires was tested through factor analysis, the results being shown in Table V. Bartlett's Test of Sphericity was used to test whether the original correlation matrix is an identity matrix, and the Kasier–Meyer–Olkin (KMO) Measure of Sampling Adequacy was applied to measure the adequacy of the sampling applied to the questionnaire study and the appropriateness of the factor analysis. As shown in Table V, the KMO Measure of the Sampling Adequacy index exceeds 0.7, which indicates that the significance of the criteria measured is sufficient and the studied data are suitable for factor analysis. The fact that Bartlett's significance value is 0.000 proves the validity of the research data for factor analysis and the research as a whole.

TABLE V.
RESULTS OF KMO AND BARTLETT'S TEST

KMO Measure of Sampling Adequacy		.738
Bartlett's Test of Sphericity	Approx. Chi-Square	301.443
	df	105
	Sig.	.000

B. *Factor Analysis*

Factor analysis was used to measure the data structure of the sample and to test the validity of the initially designed data structure. The Eigen value of a factor greater than 1 indicates that the factor is suitable. A varimax orthogonal rotation was performed to determine the factors, and rotated factor loadings greater than 0.5 were confirmed. Table VI demonstrates the results of factor analysis for the 15 variables, whose Eigen values are ranked from high to low. The results show that the Eigen values of the first four factors are greater than 1. After a varimax rotation, the total variance identified by these four factors is 21.413%, 18.315%, 15.747%, and 15.059% respectively, and the four identified factors represent 70.534% of the total variance. Therefore, the information contained in the originally observed data can be well explained by these four factors. Moreover, the first factor is the most significant, and accounts for more than 21% of the total variance of the 15 original variables.

The rotated factor loadings after a varimax rotation are shown in Table VII. The rotation indicates that factors with relatively large loadings are distributed among several particular variables, and that the loadings show a simple structure. The analysis results clarify the structure design of the abovementioned data.

TABLE VI.
DETAILED DESCRIPTION OF TOTAL VARIANCE

Initial Eigen Values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
5.587	37.250	37.250	5.587	37.250	37.250	3.212	21.413	21.413
2.277	15.182	52.432	2.277	15.182	52.432	2.747	18.315	39.728
1.561	10.407	62.839	1.561	10.407	62.839	2.362	15.747	55.475
1.154	7.695	70.534	1.154	7.695	70.534	2.259	15.059	70.534
.833	5.554	76.088						
.786	5.239	81.327						
.673	4.485	85.811						
.476	3.175	88.986						
.437	2.912	91.897						
.376	2.504	94.402						
.252	1.680	96.082						
.192	1.283	97.365						
.149	.992	98.357						
.138	.923	99.280						
.108	.720	100.000						

TABLE VII.
ROTATED COMPONENT MATRIX

Items in Questionnaire	Component			
	1	2	3	4
A2. User-friendliness	.864	.082	.187	-.223
A1. Ease of use	.808	.061	.052	.390
A4. Information presentation	.798	-.117	-.049	.181
A3. Ease of understanding	.754	.361	.194	.028
A5. Screen design	.656	.196	.180	.307
C1. Interaction with other learners	.096	.895	.090	.025
C4. Active participation in the discussion	.141	.821	.134	.335
C2. Interaction with teachers	.145	.703	.250	.398
C3. Exchange of learning with others	-.035	.535	.503	.186
B3. Operational stability	.121	.026	.918	.121
B1. Presence of many useful functions	.182	.201	.832	-.025
B2. Presence of good flexibility	.120	.331	.546	.402
D2. Instructors' encouragement of student interaction	.192	.090	.264	.714
D1. Instructors' technical competence with the 3D CAD technology	.038	.132	.064	.687
D4. Quality of instructors' explanation regarding use of 3D CAD	.159	.349	-.059	.682

C. *Hypotheses Testing*

A stepwise multiple regression analysis was conducted to test the hypotheses. The 15 influential variables derived from the previous research were applied as independent variables, while perceived learner satisfaction was used as the dependent variable. Tables VIII, IX, and X present the results of the regression analysis.

In Table VIII, the Durbin–Watson (DW) values lie between 1.5 and 2.5, which indicates that the model suffers from no autocorrelation problems. The adjusted value for R^2 is 0.422, indicating that 42.2% of the variance of the perceived learner satisfaction can be explained by those three critical variables.

TABLE VIII.
MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin–Watson
1	.474	.225	.204	1.136	
2	.629	.395	.362	1.017	
3	.684	.468	.422	.968	2.477

Table IX shows the F-value of the variance analysis being 10.263, and a significance value of 0.000, reflecting the significance of the regression.

TABLE IX.
ANOVA RESULTS

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	13.832	1	13.832	10.716	.002
Residual	47.758	37	1.291		
Total	61.590	38			
Regression	24.335	2	12.167	11.758	.000
Residual	37.255	36	1.035		
Total	61.590	38			
Regression	28.824	3	9.608	10.263	.000
Residual	32.766	35	.936		
Total	61.590	38			

In Table X, the variance inflation factor (VIF) values lie between 0 and 10, this means that the model suffers from no multi-collinearity problem.

TABLE X.
STEPWISE REGRESSION ANALYSIS COEFFICIENTS

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	β			Tolerance	VIF
Constant	3.564	.182		19.591	.000		
UID	.603	.184	.474	3.274	.002	1.000	1.000
Constant	3.564	.163		21.880	.000		
UID	.603	.165	.474	3.656	.001	1.000	1.000
ITC	.526	.165	.413	3.186	.003	1.000	1.000
Constant	3.564	.155		23.004	.000		
UID	.603	.157	.474	3.844	.000	1.000	1.000
ITC	.526	.157	.413	3.350	.002	1.000	1.000
LICC	.344	.157	.270	2.190	.035	1.000	1.000

From the above three-step regression analysis, three factors are considered to have critical relationships with learner satisfaction, owing to the significance values of less than 0.05. These factors include user-interface design, instructors' technical competence, and learners' interactive collaboration capabilities. Therefore, Hypotheses 1, 3, and 4 are supported. Hypothesis 2 is not supported because of a significance value greater than 0.05. This shows that the quality of technology does not significantly influence learner satisfaction. The final regression formula of the model can be presented as follows:

LS = 3.564 + 0.603 (UID) + 0.526 (ITC) + 0.344 (LICC)

In the formula, LS indicates learner satisfaction, UID indicates user-interface design, ITC indicates instructors' technical competence, and LICC indicates learners' interactive collaboration capabilities.

V. CONCLUSIONS

In summary, this study developed a framework with four dimensions—user-interface design, quality of technology, learners' interactive collaboration capabilities, and instructors' technical competence, which reflect the degree of learner satisfaction. Factor analysis and stepwise multiple regression analysis were conducted to verify the proposed model, and to clarify the factors influencing learner satisfaction of 3D CAD software in the present educational context. The results showed that three dimensions of the proposed model had a significant effect on the learners' perceived satisfaction. According to this study, learners regard the system interface as the most significant dimension. Many IS-related studies have pointed out that a well-designed and user-friendly interface becomes a critical factor in determining whether learners will enjoy using a 3D CAD system. Therefore, the result given here corresponds to previous research findings. Besides, instructors play key roles in students' learning processes in face-to-face teaching environments. Moreover, the effects of learning activities and student satisfaction are influenced by instructors' technical competence in handling learning activities and explaining how to use the 3D CAD system. Therefore, school administrators must be very careful in selecting instructors for 3D CAD courses. Specialized instructor training might be very helpful for this purpose. Finally, learners' interactive collaboration capabilities, such as asking questions, practicing, and interacting with multiple stakeholders, is a significant factor in learner satisfaction. Through increased information sharing and processing, learners are likely to experience enhanced learning and performance.

However, the factor involving the quality of technology failed to be supported. The main reason for this may be that the commonly-used 3D CAD software products are uniformly functioning and operationally stable. Furthermore, software developers optimize and update 3D CAD software functions continuously, and a large number of models and plug-ins are provided to meet user needs.

In future studies, other dimensions or criteria will be added to the existing research model on the basis of the latest progress in 3D technology and changes in 3D CAD software pedagogy. It is hoped that the model presented will cover most of the main factors affecting education in the use of 3D CAD software, so as to enhance the teaching and learning processes.

REFERENCES

[1] V. Cho, T. C. Edwin Cheng, W. M. Jennifer Lai, "The Role of Perceived User-interface Design in Continued Usage Intention of Self-paced E-learning Tools", *Computers and Education*, vol. 53, pp. 216–227, 2009.

[2] H. M. Selim, "Critical Success Factors for E-learning Acceptance: Confirmatory Factor Models", *Computers and Education*, vol. 49, pp. 396–413, 2007.

[3] B. Khan, *Managing E-learning Strategies: Design, Delivery, Implementation and Evaluation*, Information Science Publishing, USA, 2005.

[4] G. Piccoli, R. Ahmad, B. Ives, "Web-based Virtual

Learning Environments: A Research Framework and a Preliminary Assessment of Effectiveness in Basic IT Skill Training", *MIS Quarterly*, vol. 25, no. 4, pp. 401–426, 2001.
[5] D. Y. Shee, Y. S. Wang, "Multi-criteria Evaluation of the Web-based E-learning System: A Methodology Based on Learner Satisfaction and Its Applications", *Computers and Education*, vol. 50, pp. 894–905, 2008.
[6] T. C. Reeves, S. W. Harmon, "Systematic Evaluation Procedures for Instructional Hypermedia/ Multimedia", *In Proceedings of the Annual Meeting of the American Educational Research Association*, 1993.
[7] P. C. Sun, R. J. Tsai, G. Finger, Y. Y. Chen, "What Drives a Successful E-learning? An Empirical Investigation of the Critical Factors Influencing Learner Satisfaction", *Computers and Education*, vol. 50, no. 4, pp. 1183–1202, 2008.
[8] C. W. Holsapple, Anita Lee-Post, "Defining, Assessing, and Promoting E-learning Success: An Information Systems Perspective", *Decision Sciences Journal of Innovative Education*, vol. 4, no. 1, pp. 67-85, 2006.
[9] R. D. Johnson, S. Hornik, E. Salas, "An Empirical Examination of Factors Contributing to the Creation of Successful E-learning Environment", *International Journal of Human–Computer Studies*, vol. 66, no. 5, pp. 356–369, 2008.
[10] T. Volery, D. Lord, "Critical Success Factors in Online Education", *The International Journal of Educational Management*, vol. 14, no. 5, pp. 216-223, 2000.

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