Differentiated Instruction Efficiency of the Design Courses for Engineering Majors in a Smart Education Environment

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Abstract—The differentiated instructional strategy has been widely applied in countries around the world. However, the differentiated instruction of the design courses for engineering majors still has some barriers in term of learners, teachers, and attributes of the design courses in the smart education environment. To discuss the influences of the differentiated instructional strategy of the design courses for engineering majors on course achievement of learners in the smart education environment, a case study based on the course of "Architectural Interior Hand-painted Renderings" was conducted using two-group pre-test and post-test methods. The differentiated instructional strategy for this course in the smart education environment was designed to investigate its actual effect toward improving the learners' course achievement, as well as its staged efficiency in preview, classroom learning, and creating learning through the student's t-test from perspectives of its influence significance and staged efficiency. Results show that compared with traditional instructional strategy, differentiated instructional strategy can improve course achievement of learners significantly. During classroom learning, learners from the differentiated instruction class achieve significant improvements in term of "picture composition", "line drawing", "perspective drawing" and "color construction" compared with those during the preview. Learners further achieve significant improvements in terms of "picture composition," "line drawing," "perspective drawing," and "creativity" during creating learning compared with those during classroom learning. Differentiated instruction has significant influences on improvement of the learners' course achievement at different levels. This study provides method references to differentiated instruction design for engineering majors in smart education environment and offers a way to fulfill personalized needs of differential learners and improve teaching efficiency.

Keywords—smart education, engineering majors, design courses, differentiated instruction

1 Introduction

Education reform in universities around the world is currently accelerating and deepening. Differentiated instruction has been widely applied as an effective way to fulfill the individual needs of students with varying abilities who attend the design courses for engineering majors. With the rapid development of smart education environment around countries, the integrated growth of smart education and differentiated instruction system has achieved great progress. However, a series of problems have emerged in smart education and differentiated instruction field of the design courses in engineering universities, which may cause some barriers against the teaching objective. With respect to learners, a difference exists in knowledge accumulation of the design courses, and artistic qualities vary among students. With respect to teachers, they initially have not analyzed abilities of learners deeply and ignore individual difference among students. Second, the combination of information technology and course is not deep enough. The role in facilitating differentiated instruction implementation has not been reflected yet. Third, updating information-based instruction and intelligent instructional strategy is significantly insufficient. With respect to attributes of the design courses, the design courses cover abundant genres of art, thus resulting in obvious differences in learners' preferences. The demands for "teaching-learning-practicing" integrated instruction are higher and influences of differentiated instruction on teaching effect are stronger when compared with the non-design courses. With the rapid development of information technology, smart education environment has been formed, which provides conditions for creation and reformation of classroom instruction.

Compared with the traditional teaching method, various instructional strategies are optional for teachers in the smart education environment supported by abundant technologies, which comprise group collaboration, instruction method, guided-inquiry learning method, task-driven approach, and so on. Teachers can fully utilize resources and tools to construct teacher-student interaction links, conduct diversified evaluations, and fully stimulate learning enthusiasm and participation of students [1]. Based on the aforementioned analysis, this study constructed the differentiated instructional strategy of the design courses for engineering universities in the smart education environment, while its influences on course achievement of learners were analyzed by comparing with conventional instructional strategy. Finally, it provided beneficial references to the instruction of the design courses for engineering majors in the smart education environment from the perspective of teaching efficiency.

2 State of the art

2.1 Differentiated instructional strategy and teaching applications

The concept of differentiated instruction was first proposed by Carol Ann Tomlinson in 1995. She defined such instruction as "an instruction method that adjust teaching content and progress continuously in accordance to different preparation states, learning styles and interests of students. It requires teachers to make good teaching plans positively in advance, aiming to assure the most effective learning of each student to the maximum extent". Jiang and Hua [2] determined that differentiated instruction aims to implement differentiated instruction comprehensively in instruction guidance idea, objective, content, method, strategy, process, evaluation, and other aspects during classroom instruction activities according to the students' individual differences. It can fulfill their various learning needs and facilitate full development of each student on the original basis. Qiang [3] conducted differentiated instruction intervention practices based on the course of "Computer Network" for information technology major in M (university). According to the results, intervention strategies that are designed in accordance with the differentiated instruction intervention framework can improve learning performances of students significantly from the perspectives of cognition, behaviors, and abilities (collaborative learning and problem solving) Na et al. [4] demonstrated that dividing ability levels of students according to analysis on online and offline learning records of the course of "Program Development Foundation" and providing learning data and learning tasks for students with various ability levels and learning needs can improve the personalized abilities of each student.

The core concept and basic principle of differentiated instruction comprise the respect to differences of students, based on standard instruction, clear teaching object, flexible grouping, respectful participation, collaborative learning, based on learning data analysis, multiple evaluation, and so on. Using differentiated instructional strategy in classroom instruction for university students can improve the learning performances of learners significantly in term of cognition, behaviors, and abilities. Few studies on differentiated instructional strategy of the design courses for engineering universities exist. During classification of learners and differentiated instruction design, attention was paid to the course achievement of learners, but few attention was paid to interests, perception, and other subjective factors of students. How can one apply differentiated instruction philosophy to instruction design of the design courses in engineering universities? What are its achievements? All of these require systematic studies. Engineering university students were chosen as study objective and questionnaire survey was applied in this study. The subjective differences of students were included into references for student classification and differentiated instruction design to make the differentiated instruction practical and effective. Conclusions can provide theoretical references to differentiated instruction practices of the design courses in engineering universities.

2.2 Smart education and teaching applications

The concept of "smart education" comes from the "Smart Planet" program proposed by IBM in 2009. The "Smart Planet" program interprets each great field of human society under the concept of smart planet and the concept of "smart education" is officially proposed. Ke [5] believed that the vision of smart education aims to reform the present school education of "instruction factory" type in the industrial era by using the new generation of information technology, improve efficiency and intelligence degree of education system, and train intelligent people to adapt to the development of times for the information society. Zhu [6] divided the research framework of smart education into five parts, including smart education philosophy, smart environment, smart instruction method, smart assessment, and smart talents (smart learners in school context). Huang [7] believed that a smart education environment has numerous functions, such as optimizing teaching content displays, convenient acquisition of learning resources, promoting classroom interaction, instruction context awareness and instruction environmental management. Mehdi et al. [8] believed that intelligent education environment based on cloud storage and artificial intelligence (AI) can realize the automatic acquisition, coding, and analysis of learning process data and learning environment data to support real-time, dynamic diagnosis and evaluation for teachers. Liu [9] demonstrated that teacher-student interactions are more flexible and diversified under the smart education environment in the age of "Internet+". In addition to real-time interaction in classrooms, teachers and students can also communicate after class based on the cloud platform. Al-Qirim et al. [10] reported that teachers can guide students toward independent learning, provide timely feedback, and stimulate them to participate in instruction activities positively by using various classroom interaction tools, thus realizing high-efficiency deep interaction between teachers and students. Smart education environments can increase the teacher-student interaction level effectively and promote improvements in learning interest, learning motivation, engagement, and learning achievement of students [11–12]. Korozi et al. [13] argued that a smart education environment provides convenience for teaching innovation of teachers. They can master learning conditions of students timely and adopt effective teaching intervention to promote classroom learning under a smart education environment. Xu et al. [14] has also proven that smart classrooms can provide strong technical support to group cooperative learning and facilitate the students' understanding and comprehension of basic knowledge, thus realizing transition from low-cognition training goal to high-cognition training goal. Based on mobile devices and wireless communication technology, Hwang et al. [15] increased learning interest, attitude, and course achievement effectively by designing the mobile learning environment based on formative evaluation.

The smart education environment provides strong support to increase learning interest, learning motivation, teacher-student interaction, and course achievement of students. Nevertheless, teachers usually design classroom instruction by focusing on technical means in existing study and teaching practices, and pay attention to informative classroom instruction forms, but ignore student-centered core philosophy of smart education. In teaching design, key attention is paid to teaching means, but the implementation of smart education throughout the teaching is ignored. There are few studies on differentiated instruction in the smart education environment, especially the staged efficiency of differentiated instruction. Discussing the construction of the differentiated instructional strategy in the smart education environment and further improving course achievement of learners are effective ways to improve teaching and learning effects. This study constructed the differentiated instructional strategy of the design courses for engineering majors based on the teaching assistance provided by smart education environment. It discussed the significance of the influences of differentiated instructional strategy on improvement of course achievement through an experimental approach, as well as the staged practical effect of differentiated instructional strategy. This study is expected to provide method references to differentiated instructional design for engineering majors in the smart education environment and offer ways to improve teaching efficiency.

3 Differentiated instructional strategy design in the smart education environment—An example based on the course of "Architectural Interior Hand-painted Renderings"

Guided by smart education and research framework, this study aims to facilitate online and offline teacher-student interaction by combining specific conditions of a smart education environment in Chongqing Open University, Chongqing Technology and Business Institute, and characteristics of the course. The differentiated instructional strategy of "Architectural Interior Hand-painted Renderings" was designed from the perspectives of pre-class, in-class, and after-class by targeting at improving the learners' learning achievement (Figure 1).

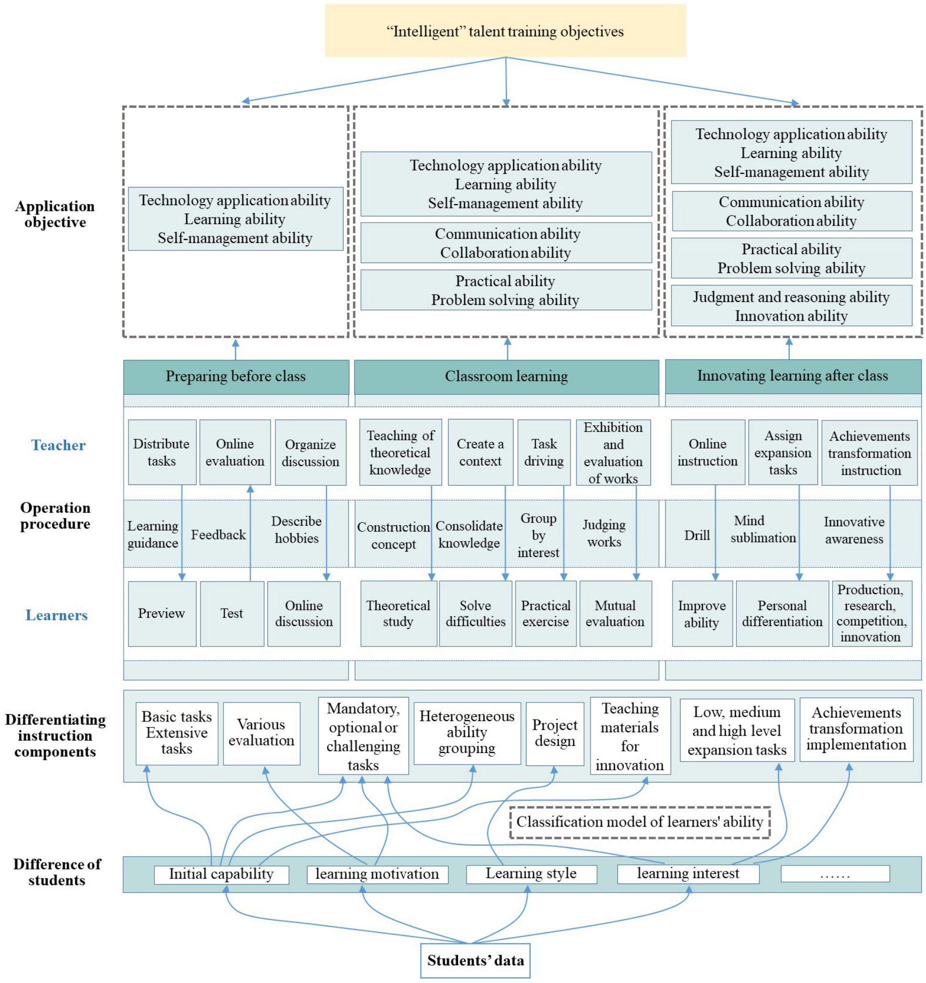

Fig. 1. Structure drawing of differentiated instructional strategy

Figure 1 shows that the structure of differentiated instructional strategy for the course of "Architectural Interior Hand-painted Renderings" includes the following five levels.

Students' data. It usually includes learning records (stored in the learning platform), interactive exercises, observation data, survey data, standard test, project tasks, self-report data of students, and so on. The students' data can generally be divided into two types. First, a series of variables are gained by discussing with senior experts of the industry and front-line teachers. These variables cover all knowledge and operations in the design courses and can reflect teaching requirement of the design courses well.

These variables were sent to learners in the form of questionnaire survey and online test. Corresponding scores were formulated to each variable and the final scores were used as the Type-1 learning data. Second, big data analysis was conducted by preceding courses, thus gaining the original knowledge level of students. The original knowledge level of students is used as another type of learning data.

Difference of students. Differences of students which are reflected by data of students in this study mainly include initial learning ability difference, learning motivation difference, learning style difference, learning interest difference, and so on. Ability classification models of learners of the design courses were constructed by analyzing the requirement of actual posts and teaching objectives of the design courses in engineering universities. They were divided into the "basic type," "improvement type," and "expansion type" according to differences of students. These are beneficial for teachers to fully understand individual differences of students. Based on differences, it seeks communication and cooperation, and reflects the students' dominant role. This is beneficial to promote equity of education, help teachers to establish the teaching philosophy of respecting differences, and provide references to smart education in term of target, effectiveness and operability of learner training.

Differentiated instruction components. Teaching content, teaching process (activities), teaching outcome, and teaching environment are differentiated appropriately to adapt to the differences of learners in experiences, ability, interest, and style. The operation procedure of differentiated instructional strategy is divided into three stages, namely, the preview, classroom learning, and creating learning.

Operation procedure. The operation procedure refers to specific teaching activity procedures or logic steps. It is the core of instructional strategy. In this study, operation procedure learns the instructional strategy of flipped classroom, observes the general cognitive law of "from simple to complicated and from easy to difficult", and exhibits the complete learning process and learning experiences. A complete teaching process can be divided into two stages: knowledge teaching and knowledge internalization. A flipped classroom aims to transfer knowledge teaching from the form of micro-video media in traditional classrooms to a pre-class stage, and transfer the knowledge internalization to the in-class stage. Knowledge teaching and internalization in flipped classrooms are completed through student-student and teacher-student negotiations. Because the flipped classroom is conducive to learners with various abilities, realizing the real differentiated instruction is possible [16]. Almost all flipped classroom modes emphasize on importance of micro-video and targeted tests in the independent learning stage of individuals. Such stages are mapped as the "preview" stage. The operational procedure of the designed differentiated instructional strategy can generally be described by "three stages and 3-4-3 links" in the horizontal direction by combining field observations of the teaching process, frontline teaching experiences, and teaching context of schools. The three stages refer to preview stage (before class), classroom learning stage (in-class) and creating learning stage (after class). The three stages can be divided into three, four, and three links, respectively. The operation procedure reflects dynamics of instructional strategy on the time axis. Although the operation procedure has some stability, it is not fixed, but is flexible according to practical teaching context.

Application objective. The application objective of the designed differentiated instructional strategy is mainly to improve course achievement of learners. It emphasizes on the development of various intelligence abilities of students in preview stage, classroom learning stage and creating learning stage of the differentiated instructional strategy, respectively. Good experiences run through the whole learning process.

4 Experimental study on differentiated instruction efficiency in smart education environment

4.1 Study objective

This study discussed the efficiency of differentiated instruction in improving course achievement of learners and its staged efficiencies in the learning process under a smart education environment.

4.2 Study hypothesis

This study supposed that the differentiated instructional strategy is superior to the traditional instructional strategy in improving course achievement of learners.

4.3 Study objects and process

A pre-test of existing course achievements of five original classes in Chongqing Open University, Chongqing Technology and Business Institute was conducted. Class 4 and Class 5, which have equivalent course achievements in the pre-test stage, were chosen as the study objects. Class 4 had 48 students, comprising 20 males and 28 females. Class 5 had 48 students, comprising 21 males and 27 females.

The same teacher fully utilized the smart education environment to instruct the course of "Architectural Interior Hand-painted Renderings" for one semester. Before the implementation of differentiated instruction, the two classes had a pre-test of the learned content. After finishing differentiated instruction, the course achievements of two classes were tested (post-test).

4.4 Measuring tools

A questionnaire survey method and interview method were applied in this study to collect subjective data, which comprises software usage, learning style, learning experiences and self-satisfaction, thus enabling to fulfill the needs of analyzing teaching and learning effects of differentiated instructional strategy and traditional instructional strategy. The measuring tools used in this study include the "online pre-test survey scale of previous knowledge, experiences and learning interest," as well as the "self-rating scale of intelligent ability training effect".

Online pre-test survey scale of previous knowledge, experiences and learning interest. This questionnaire mainly includes three questions: (1) What do I already know? It is used to reflect previous experiences, knowledge, and skills directly that students have been developed. (2) What do I want to know? It is used to reflect the points of interests, points of focus and even specific opinions and doubts of students to the teaching topic. (3) What did I learn? Questions can be proposed by combining specific core concepts and key operations to comprehend the depth of the concept and proficiency of the operation that students reached.

The analysis of previous knowledge and experience data can help teachers in placing the difficulty and complexity of teaching content into the latest development zone of learners, embed new knowledge and new skills into hot tasks that students are interested in, and design differentiated instructional strategies.

Self-rating scale of intelligent ability training effect. This scale is for evaluation before and after the implementation of a differentiated instructional strategy in the smart education environment, aiming to measure changes of learners in nine intelligence abilities and one value experience. The scale was designed from 10 dimensions of learning ability, technical application ability, self-management ability, collaboration ability, communication ability, problem solving ability, practical ability, innovation ability, judgment and reasoning ability, and value experience. It comprised 28 choice questions and each used a four-point Likert scale, namely, "Totally agree," "Agree," "Disagree," and "Completely disagree".

4.5 Data analysis method

The students' performances of each class were "pre-tested" before the differentiated instruction implementation to the "Architectural Interior Hand-painted Renderings" for the major of architectural interior design. The experimental and control classes were chosen. The calculation formulas of the mean and standard deviation are shown as follows:

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{1}$$

$$S = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \overline{x})^2}{n-1}} \tag{2}$$

where $\overline{x}$ is the mean number of samples. x_i is the course achievement of the ith learner. n refers to the number of learners. S refers to the standard deviation of samples.

The significances of the course achievement improvement of the experimental class and control class were analyzed through a paired sample t-test before and after the differentiated instruction implementation. The formulae of t-values for the paired sample t-test of course achievements before and after the differentiated instruction implementation (pre-test and post-test) are shown as follows:

$$t = \frac{\overline{x} - 0}{S_{\overline{x}}}, S_{\overline{x}} = \frac{S}{\sqrt{n}} \tag{3}$$

where x is the difference variable and $\overline{x}$ is the mean of the difference variable. n refers to the number of sample observations and S is the standard deviation of difference variable, wherein $S_{\overline{x}}$ is the standard error of mean of the difference variable.

The significance of course achievement improvement of the experimental class and control class after the differentiated instruction implementation was analyzed through an independent sample t-test. The calculation formulae of the t-value are shown as follows:

$$\left.\begin{aligned} t &= \frac{\overline{x_1} - \overline{x_2}}{\sqrt{S_p^2/n_1 + S_p^2/n_2}} \sim t(n_1 + n_2 - 2) \\ S_p^2 &= \frac{(n_1 - 1)\, S_1^2 + (n_2 - 1)\, S_2^2}{n_1 + n_2 - 2} \end{aligned}\right\} \tag{4}$$

$$\left.\begin{aligned} t &= \frac{\overline{x_1} - \overline{x_2}}{\sqrt{S_1^2/n_1 + S_2^2/n_2}} \sim t(n) \\ n &= \frac{(S_1^2/n_1 + S_2^2/n_2)^2}{(S_1^2/n_1)^2/n_1 + (S_2^2/n_2)^2/n_2} \end{aligned}\right\} \tag{5}$$

where n_1 and n_2 are numbers of two types of independent samples, respectively. $\overline{x_1}$ and $\overline{x_2}$ are mean of sample, respectively. S_p^2 is the sample variance at equal variance of two samples. S_1^2 and S_2^2 are variances of two samples at an unequal variance, respectively. n refers to the degree of freedom (DOF).

Multiple comparisons of the significant differences in scores on five ability dimensions of course achievement in various stages were conducted through a one-way analysis of variance (ANOVA). The formula of the F-value of one-way ANOVA is as follows:

$$F = \frac{(n-k)S_A^2}{(k-1)S_E^2} \sim F(k-1, n-k) \tag{6}$$

where k is the level of influencing factors, which refer to learners of 3 levels (denoted as L1, L2 and L3). n refers to the number of tests under various levels of influencing factors. In this study, five ability dimensions (A1, A2, A3, A4 and A5) of "picture composition," "line drawing," "perspective drawing," "color construction," and "creativity" of learners at three levels were tested. S_E^2 expresses the error sum of squares and S_A^2 is the effect sum of squares.

4.6 Experimental data analysis

A total of 96 "online pre-test survey scales of previous knowledge, experiences and learning interest" as well as the "self-rating scales of intelligent ability training effect" were sent, respectively. All questionnaires were effective and collected, thus exhibiting an effective recovery rate of 100%. Information about the course achievement, questionnaire data, survey data, and important learning process (e.g., process information in guidance on learning, learning records in the learning platform and scores of three stages) was input, reviewed, and analyzed using the SPSS16.0 statistical analysis tool.

Effects of differentiated instructional strategy on course achievement. The post-test scores of the experimental class and the control class were compared horizontally to deduce the differences in influences of the traditional instructional strategy and differentiated instructional strategy on course achievement. The paired sample statistics of pre-test and post-test course achievements of two classes are shown in Table 1.

Table 1. Paired sample statistics of pre-test and post-test course achievements

		Mean	Number of Cases	Standard Deviation	Standard Error of Mean
Experimental class	Pre-test	74.01	48	14.498	2.093
	Post-test	83.94	48	6.241	0.901
Control class	Pre-test	73.96	48	12.372	1.786
	Post-test	75.06	48	8.938	1.290

The course achievement of the experimental class is improved significantly. The mean of post-test scores (83.94) of learners are increased by 9.93, compared with that of the pre-test scores (74.01). The mean score of the control class is increased by 1.10 from 73.96 of the pre-test scores to 75.06 of the post-test scores. The mean score of the experimental class is 83.94, which is 8.86 higher compared with that of the control class (75.06).

Significance analysis of the effects of the differentiated instructional strategy on course achievement of learners. To analyze the significance of the course achievement improvement of the experimental and control classes, paired sample t-tests before and after the differentiated instruction implementation were conducted. Results are shown in Table 2.

Table 2. Results of paired sample t-tests before and after the differentiated instruction implementation

	Paired Differences					t	sig
	Mean	Standard Deviation	Standard Error of Mean	95% Confidence Interval of the Difference			
				Lower	Upper		
Experimental class	–9.929	10.437	1.506	–12.960	–6.899	–6.591	0.000
Control class	–1.104	8.125	1.173	–3.463	1.255	–0.942	0.351

Table 2 shows that because $sig=0.000<0.05$, the course achievement of experimental class is improved significantly after implementation of differentiated instructional strategy. For the control class, $sig=0.351>0.05$, which indicates that the course achievement of the control class has not improved significantly under the traditional instructional strategy.

Significance analysis of course achievement improvement of the experimental class after differentiated instruction implementation compared to that of the control class. To analyze the significance of the course achievement improvement of the experimental class and control class after the differentiated instruction implementation, an independent sample t-test was conducted to the significance of course achievement improvement of the experimental class compared with that of the control class. Results are shown in Table 3.

Table 3 shows that, in Levene's test for equality of variances, the significance level of test for homogeneity of variance is 0.031<0.05, indicating that no assumption exists of equal variance of two classes. In the t-test for equality of means, t=5.640 and sig=0.000<0.05. This reflects that under 95% confidence interval of the difference, the post-test scores of the experimental and the control classes may differ significantly. The differentiated instructional strategy can influence course achievement significantly compared with the traditional instructional strategy.

Table 3. Results of independent sample t-test for the experimental class and control class

Post-Test for Course Achievement	Levene's Test for Equality of Variances		T-Test for Equality of Means						
	F	sig	t	Degree of Freedom	sig	Mean Difference	Standard Error of Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	4.785	0.031	5.640	94	0.000	8.875	1.574	5.751	11.999
Equal variance not assumed			5.640	84.030	0.000	8.875	1.574	5.746	12.004

After the two-month differentiated instruction implementation, the mean course achievements of both the experimental class and the control class are improved to some extent. The course achievement of the experimental class is improved significantly. This revealed that the differentiated instructional strategy can improve course achievement significantly. This proves the following research hypothesis: the differentiated instructional strategy is superior to the traditional instructional strategy in improving course achievement of students.

Staged influences of differentiated instruction on ability dimensions. Hand-painted works, the course assignment of "Architectural Interior Hand-painted Renderings", mainly investigate five ability dimensions of "picture composition", "line drawing", "perspective drawing", "color construction" and "creativity". Three stages of the differentiated instructional strategy (preview, classroom learning and creating learning) were denoted as S1, S2, and S3. Scores on each term of five ability dimensions of the students' hand-painted works can disclose the influences of the differentiated instructional strategy on staged learning. The comparison of scores in five ability dimensions (A1~A5) in stages S1~S3 was conducted. Results are listed in Table 4.

Table 4. Difference comparison of scores in stages S1~S3

Ability Dimensions	(S2−S1) Standard Deviation	(S3−S2) Standard Deviation	(S2−S1) Standard Error of Mean	(S3−S2) Standard Error of Mean	(S2−S1) sig	(S3−S2) sig
A1	2.119	1.589	0.306	0.229	0.000	0.000
A2	2.376	1.686	0.343	0.243	0.022	0.000
A3	3.328	3.347	0.480	0.483	0.000	0.000
A4	1.331	1.952	0.192	0.282	0.000	0.379
A5	3.517	5.031	0.508	0.726	0.224	0.000

Table 4 shows that compared with S1, sig values of A1~A4 during S2 are lower than 0.05, indicating that hand-painted works in S2 and S1 differ significantly in terms of A1~A4. With respect to A5, sig=0.224>0.05, indicating that differentiated instructional strategy has insignificant influences on A5 in S2 compared with that in S1.

Compared to S2, sig values of A1, A2, A3 and A5 during S3 are lower than 0.05, indicating significant differences between these two stages in above four ability dimensions. For A4, sig=0.379>0.05, indicating that differentiated instruction has insignificant influences on A4 in S3 compared to that in S2.

Effects of differentiated instruction on course achievement of learners at different levels. Because the homogeneous grouping form was applied in the classroom learning stage, the experimental class was divided into three ability levels according to the 27% rule in psychometrics: ordinary level (13 students, L1), improvement level (22 students, L2), and expansion level (13 students, L3). Multiple comparisons of significant differences in scores of five ability dimensions of hand-painted works among students at various levels were conducted through a one-way ANOVA. Results are listed in Table 5.

Table 5. Post Hoc test output

Control Variable	Layer I Variable	Layer II Variable	Mean Difference (I−II)	Standard Error	sig
A1	L3	L2	–0.333	0.813	0.684
		L1	–0.286	0.895	0.751
	L2	L3	0.333	0.813	0.684
		L1	0.048	0.727	0.948
	L1	L3	0.286	0.895	0.751
		L2	–0.048	0.727	0.948
A2	L3	L2	0.692	0.906	0.449
		L1	0.829	0.997	0.410
	L2	L3	–0.692	0.906	0.449
		L1	0.137	0.810	0.866
	L1	L3	–0.829	0.997	0.410
		L2	–0.137	0.810	0.866

(Continued)

Table 5. Post Hoc test output *(Continued)*

Control Variable	Layer I Variable	Layer II Variable	Mean Difference (I−II)	Standard Error	sig
A3	L3	L2	–1.358	1.220	0.271
		L1	–2.829	1.342	0.041
	L2	L3	1.358	1.220	0.271
		L1	–1.470	1.090	0.184
	L1	L3	2.829	1.342	0.041
		L2	1.470	1.090	0.184
A4	L3	L2	0.075	1.321	0.955
		L1	–1.586	1.454	0.281
	L2	L3	–0.075	1.321	0.955
		L1	–1.661	1.181	0.166
	L1	L3	1.586	1.454	0.281
		L2	1.661	1.181	0.166
A5	L3	L2	0.050	0.508	0.922
		L1	–0.343	0.558	0.542
	L2	L3	–0.050	0.508	0.922
		L1	–0.393	0.453	0.391
	L1	L3	0.343	0.558	0.542
		L2	0.393	0.453	0.391

Table 5 shows that the associated probability (sig value) of all students on all ability dimensions is higher than 0.05, except that the sig values of L3 and L1 on A3 is lower than 0.05. This reflects that under five ability dimensions of A1 to A5, no significant difference in course achievement improvement among L1, L2 and L3 exists in most cases. The increased scores of L1, L2, and L3 on A1 to A5 are relatively balanced. Only a significant difference between L3 and L1 on A3 exists ($sig=0.041<0.05$) and the scores of L3 are increased. However, the increased scores of L3 and L1 on A3 are relatively balanced. Homogeneous grouping and collaborative learning are generally applied in the classroom learning stage, which facilitates the common progress of all students evenly.

5 Conclusion

Compared with traditional teaching environment, the design courses for engineering majors in the smart education environment are conducive to realize learner-centered education philosophy. To discuss the influences of differentiated instructional design in the smart education environment on course achievement of university students from engineering majors further, the differentiated instructional strategy of the design courses for engineering majors is designed. The significance of course achievement improvement after the differentiated instruction implementation and staged effect of differentiated instructional strategy are analyzed through a questionnaire survey and experimental study. Some major conclusions could be drawn:

The course achievement of the class that adopts differentiated instruction in the smart education environment is improved significantly more than that of the class without using differentiated instruction.

The influences of differentiated instruction on course achievement of learners in stages of previews, classroom learning, and creating learning may differ.

Differentiated instruction has significant influences on improvement of the learners' course achievement at different levels.

This study still has some shortages. The instruction of the design courses for engineering majors was chosen as the study objective, but differences exist in courses, teachers, and learning situations in teaching practices. Comparing the effects of differentiated instruction designs of various courses on the students' learning outcomes in the smart education environment and proposing the differentiated instructional strategy with better guidance can be the study directions in the future.

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7 References

[1] Zhang, Y., Hao, Q., Chen, B. L., Yu, H. E., Fan, F. L., Chen, Z. (2019). Research on college students' classroom engagement and its influencing factors in smart classroom environment—using educational technology research method course as an example. China Educational Technology, 384(1), pp. 106–115. http://doi.org/10.3969/j.issn.1006-9860.2019.01.016

[2] Jiang, Z., Hua, G. D. (2002). Preliminary comments on the essence of differentiated teaching conducted in the light of the aptitudes of individual students. Journal of the Chinese Society of Education, 4, pp. 52–55. http://doi.org/10.3969/j.issn.1002-4808.2004.04.015

[3] Qiang, F. (2020). Research on the differentiating instruction intervention of college students based on learning analysis. Xi'an, China: Shanxi Normal University. http://doi.org/10.27292/d.cnki.gsxfu.2020.002674

[4] Na, J., Xu, B., Li, D. C. (2020). Differentiating instruction design to meet the learning needs of students with different ability dimensions. Computer Education, 9, pp. 5–9. http://doi.org/10.16512/j.cnki.jsjjy.2020.09.002

[5] Ke, Q. C. (2012). Technology-driven educational reform and innovation. China Educational Technology, 4, pp. 9–13. http://doi.org/10.3969/j.issn.1006-9860.2012.04.002

[6] Zhu, Z. T. (2016). New developments of smarter education: From flipped classroom to smart classroom and smart learning space. Open Education Research, 1, pp. 18–26. http://doi.org/10.13966/j.cnki.kfjyyj.2016.01.002

[7] Huang, R. H., Hu, Y. B., Yang, J. F., et al. (2012). The functions of smart classroom in smart learning age. Open Education Research, 18(2), pp. 22–27. http://doi.org/10.3969/j.issn.1007-2179.2012.02.004

[8] Pirahandeh, M., Kim, D. H. (2017). Energy-aware and intelligent storage features for multimedia devices in smart classroom. Multimedia Tools & Applications, 76(1), pp. 1139–1157. https://doi.org/10.1007/s11042-015-3019-1
[9] Liu, B. Q. (2016). Research on design and implementation strategy of smart class teaching in the age of "Internet +". China Educational Technology, 10, pp. 51–56. http://doi.org/10.3969/j.issn.1006-9860.2016.10.009
[10] Al-Qirim, N. (2016). Smart board technology success in tertiary institutions: The case of the UAE University. Education & Information Technologies, 21(2), pp. 1–17. https://doi.org/10.1007/s10639-014-9319-7
[11] Jena, P. C. (2013). Effect of smart classroom learning environment on academic achievement of rural high achievers and low achievers in science. International Letters of Social & Humanistic Sciences, 3(3), pp. 1–9. https://doi.org/10.18052/www.scipress.com/ILSHS.3.1
[12] Cao, P. J. (2014). Investigation on primary and middle school students' learning experience in teaching with ICT. China Educational Technology, 9, pp. 24–28. http://doi.org/10.3969/j.issn.1006-9860.2014.09.005
[13] Korozi, M., Leonidis, A., Antona, M., et al. (2017). LECTOR: Towards reengaging students in the educational process inside smart classrooms. International Conference on Intelligent Human Computer Interaction. Springer, Cham, pp. 137–149. https://doi.org/10.1007/978-3-319-72038-8_11
[14] Xu, X. L., Wang, X. H., Gu, X. Q. (2017). Design and effectiveness of group collaborative learning in smart classroom. Open Education Research, 23(4), pp. 112–120. http://doi.org/10.13966/j.cnki.kfjyyj.2017.04.011
[15] Hwang, G. J., Chang, H. F. (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. Computers & Education, 56(4), pp. 1023–1031. https://doi.org/10.1016/j.compedu.2010.12.002
[16] Bergmann, J., Sams, A. (2012). Flip your classroom: Reach every student in every class every day. Reston, US: International Society for Technology in Education. https://doi.org/10.1111/teth.12165

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