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Exploring the relationship between students' interaction in smart learning environments and various variables through the structural equation model

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Abstract

For the functions of enhancing students' learning performance by integrating advanced technologies and equipment, the smart classroom has become a worldwide research issue recently. This study aims to produce a model to determine what variables affect students' interaction in a smart learning environment. Participants consist of 254 undergraduate students and master students who have experience of learning in a smart classroom for more than one semester. Two scales were adopted in this study as a data instrument. The first one is the "Smart Classroom Inventory". The second one is "Interaction and Student Satisfaction Scales". The Structural Equation Model (SEM) was used in this study for data analysis. A model is built to explain the relations between students' interaction and variables related to the smart classroom. According to the research results, we find that students' interaction can be positively affected by variables of Spatial physical design, Learning data, Differentiation, and Cooperation related to the smart classroom.

1. Introduction

The rapid development of technology has provided more possibilities to establish more social, interactive, flexible, and student-centered learning environments and the smart classroom is one of these learning environments (Macleod, Yang, Zhu, & Li, 2018). According to previous researches, the smart classroom is a technology-enhanced classroom, which intelligently monitors and manages students' learning (Huang, Yongbin, Yang, & Xiao, 2012; Macleod et al., 2018; Shen, Wu, & Lee, 2014). Thus, instructional designers and educators have unique opportunities to foster interaction and collaboration among students, when they study in a smart learning environment (Beldarrain, 2006).

Interaction is considered a necessary ingredient for a successful learning experience, especially in a smart learning environment (Moore, 1989; Beldarrain, 2006). Compared with the traditional classroom, a smart classroom supports richer forms of interaction (Bao, Kong, & Chen, 2015; Huang et al., 2012; Zhang, Zhang, & Han, 2014). Some of the technical tools are frequently used in a smart classroom, such as wiki and whiteboards. Some researches have proven the function of these tools to promote students' interaction. The instant interaction happening in the smart classroom has caught the attention of some researchers. Hwang et al. (2012) proposed the "SMART" model to characterize the smart classroom, where "R" represents "Real-time interaction". Similarly, Li et al. (2014) divided the smart learning environment into six parts, one of which is the user interaction, including five kinds of interaction activities, which are 'interaction with intelligent learning system', 'peer interaction', 'interaction with teacher', 'interaction with virtual role' and 'social interaction'. In other researches, more technical equipment such as interactive demonstration systems of distance education (Chen, Zhao, & Xu, 2008) was developed and used to construct a more flexible environment and support the interaction in class. Although the motivational power of smart classrooms has been well demonstrated (Tibúrcio & Finch, 2005; Wang, Hwang, Wang, & Lu, 2016), research into elements of the smart classroom that lead to effective interaction is not as extensive. To better construct an intelligent learning environment, it is important to understand how a smart classroom promotes students' interactive behaviors. Following the aforementioned literature, this research is aimed to determine what variables affect students' interaction in a smart learning environment.

2 Literature Review

2.1 Smart classroom

Coined by Rescigno (1988), the term 'smart classroom' was defined as a teaching site embedded with personal computers, interactive CD-ROMs, video programs, closed-circuit television, VHS programs, satellite links, local area networks, and telephone modems on the basis of the traditional classroom. In recent years, the U.S. 'Daily Forum' pointed out that the smart classroom is a learning environment that uses innovative educational activities to improve the use of technology from classroom management to teaching, making educators and learners part of a superior learning environment (Molnar, 2007). According to Hwang et al. (2012), a smart classroom is a multimedia-enhanced classroom, which provides learning support for students by perceiving their emotions and behaviors. Chen, Ye, and Xu (2012) defined the smart classroom as an environment embedded with audio, lights, and electric equipment such as computers, projectors, and interactive whiteboards, which offers teachers and students access to resources and make them engage in various learning activities, including distance learning. Zhang et al. (2014) referred to the concept of the smart classroom as a smart learning space that is built using ubiquitous computing, IoT technology, cloud computing technology and intelligent technology to promote students' knowledge building. In summary, the smart classroom has the following functions: integrating emerging technologies with traditional teaching environments through advanced technical equipment, effectively monitoring and managing the classroom, and providing technical assistance.

2.2 Interaction

There are many types of interaction defined according to different perspectives. Contreras-Castillo, Favela, Perez-Fragoso, and Santamaria-Del-Angel (2004) divided courses into two categories: formal/structured interaction and informal interaction. When scholars use 'formal' interaction or 'structured' interaction, they mean that students have to follow a protocol defined by teachers, while 'informal interaction' means that the events are not planned. Moore (1989) mentioned that there are three types of interaction according to the interaction objects: learner-learner interaction, learner-instructor interaction and learner-content interaction. Learner-learner interaction is an interaction between one learner and other learners. Learner-instructor interaction is an interaction between the learner and the expert who conducts a class. Learner-content interaction is an interaction between the learner and the content or subject of study. Hillman, Willis, and Gunawardena (1994) considered the interaction occurs between learners and technologies that are used to deliver instruction and presented the concept of learner-interface interaction. To distinguish the interaction occurring in teaching from the interaction occurring outside teaching, the concept of teaching interaction is presented, which include learner-learner interaction, learner-instructor interaction and leaner-content interaction (Gilbert & Moore, 1998; Chen, 2004). Based on previous researches, we regard interaction in a class as all actions of exchanging information among different subjects.

2.3 Interaction in smart classroom

Several studies found that a smart classroom improves learners' interactive behavior more effectively, compared with the normal learning environment (Tibúrcio & Finch, 2005). Yu, You, and Tsai (2012) conducted a comparative study and the study result shows that the social feedback system in a smart classroom can promote interactive feedback and students' learning satisfaction. Wang, Jiang, and Huang (2015) developed the classroom interaction observation tool (CIOSM) and used it to observe 54 lectures of 18 smart classrooms in 12 primary and middle schools in Hong Kong, Beijing, and Shenzhen. The study results indicated that the smart classroom environment with rich technology can effectively support the development of classroom interaction (Wang et al., 2016).

Moreover, some researchers focus on the factors that may have an influence on students' interactions in the smart learning space. Li et al. (2014) assessed the characteristics of the smart classroom and construct the Smart Classroom Scale which focused on the physical appearance, teaching and learning activities, and ecology of the smart classroom. The physical appearance of the smart classroom was categorized into four dimensions (Spatial design, Flexibility, Technology usage, and Learning data), as shown in Table 1. The teaching and learning activities of the smart classroom include different strategies teachers use in class, such as Differentiation and Cooperation (see Table1). Several studies provide clues to reveal the effects of these characteristics on student interaction. According to Li (2015), a flexible designed physical environment will affect the interaction between teachers and students. In addition, the technology application of the smart classroom and data management can promote the level of feedback between teachers and students. Ting (2013) pointed out that mobile technologies coordinate and synchronize three types of learning interactions (learner-learner, learner-instructor, and learner-content interaction) to achieve better and more effective learning. With the help of technology, students participate in explorative learning and synchronize their social interactions around their physical world with the instructional illustration of the subject content. Based on the above studies, we can put forward the hypothesis that the physical appearance of the smart classroom will directly affect student interaction and indirectly affect student interaction through teaching and learning activities. Because the effects of smart classroom vary according to the type of interactions, this study categorizes the students' interaction into three dimensions (Online interaction with others, Offline interaction with others, and Learner-content interaction), as shown in Table 2.

3 Method

3.1 Research model and hypotheses

The research model is created based on the research hypothesis in accordance with the literature. This study uses six variables to describe the physical appearance and instructional activities of the smart classroom, and three variables to describe students' interactions. The descriptions of these variables are shown in Table 1 and Table 2. The model is shown in Figure 1, and every research hypothesis is represented by a single arrow between two variables.

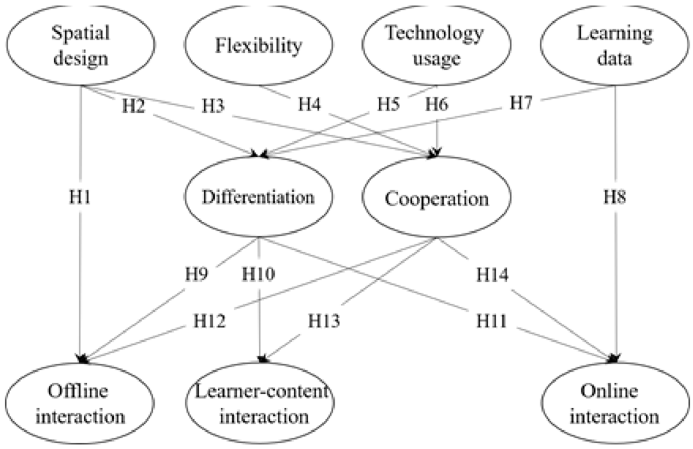

Figure 1: Research Model.

The research hypotheses are as follows:

H1 Spatial design of the smart classroom has a positive effect on students' online interaction with others.
H2 Spatial design of the smart classroom has a positive effect on Differentiation.
H3 Spatial design of the smart classroom has a positive effect on Cooperation.
H4 Flexibility of the smart classroom has a positive effect on Cooperation.
H5 Technology usage of the smart classroom has a positive effect on Differentiation.
H6 Technology usage of the smart classroom has a positive effect on Cooperation.
H7 Learning data of the smart classroom has a positive effect on Differentiation.
H8 Learning data of the smart classroom has a positive effect on students' online interaction with others.
H9 Differentiation has a positive effect on students' offline interaction with others.
H10 Differentiation has a positive effect on learner-content interaction.
H11 Differentiation has a positive effect on students' online interaction with others.
H12 Cooperation has a positive effect on students' offline interaction with others.
H13 Cooperation has a positive effect on learner-content.
H14 Cooperation has a positive effect on students' online interaction with others.

Variables	Description
Spatial design	The extent to which the spatial area, furniture equipment, and information technology infrastructure of smart classrooms.
Flexibility	The extent to which the flexible support for users by classroom environment
Technology usage	The extent to which learners use information technology as a tool to learn and to access information.
Learning data	The extent to which the information technology was used to acquire and compute the learn data of the users.
Differentiation	The extent to which teachers cater for learners differently based on ability, rates of learning and interests.
Cooperation	The extent to which learners cooperate on learning tasks.

Table 1: Description of the physical appearance and instructional activities of smart classroom (Li et al., 2014).

Variables	Description
Online interaction with others	The extent to which learners communicated with peers and teachers through online learning platform.
Offline interaction with others	The extent to which learners communicated face to face with peers and teachers in classroom.
Learner-content interaction	The extent to which students acquire learning content, including the time they took and the difficulty of learning materials.

Table 2: Description of the students' interaction (Kuo et al., 2014).

3.2 Participants

Participants of the research consist of 254 undergraduate students and master students in a university in Beijing. All these students aged from 18 to 24 have experience of learning in the smart classroom for more than one semester. The questionnaire uses a 5-point Likert-type scale with anchors from strongly disagree (scored as 1) to strongly agree (scored as 5). Students who filled out the questionnaire came from various majors.

3.3 Data collection instrument

Two different scales are adopted in this research as data instruments. The first one is the "Smart Classroom Inventory". This scale is developed by Li et al. (2014). The original form of this scale aims at describing the features of a smart classroom and consists of 36 items and 10 factors. In this adapted scale, the factors are reduced to 6: Spatial design, Flexibility, Technology usage, Learning data, Differentiation, and Cooperation. The second scale is "Interaction and Student Satisfaction Scales". This scale is developed by Kuo, Belland, Schroder, and Walker (2014). The original form of this scale aims at measuring interaction and student satisfaction in a blended learning environment and consists of 32 items and 4 factors. In this study, the factors are reduced to 3: Online interaction with others, Offline interaction with others, Learner-content interaction.

The instrument of this research consists of 9 factors and 31 items. "Spatial design" sub-dimension consists of 4 items, "Flexibility" sub-dimension consists of 2 items, "Technology usage" sub-dimension consists of 2 items, "Learning data" sub-dimension consists of 3 items, "Differentiation" sub-dimension consists of 2 items, "Cooperation" sub-dimension consists of 3 items, "Online interaction with others" sub-dimension consists of 7 items, "Offline interaction with others" sub-dimension consists of 5 items, "Learner-content interaction" sub-dimension consists of 3 items. Cronbach alpha consistency coefficient calculated in this research is 0.924.

3.4 Data collection

The data collection instrument was applied to the study group employing the online and paper questionnaire published in the school. Participants who volunteered in the study were not asked to provide any personal information such as name, student ID, etc. A total of 300 questionnaires were distributed and 282 questionnaires were collected, with a recovery rate of 94%. 28 invalid questionnaires were removed, and 254 valid questionnaires were left.

4 Results

The Structural Equation Model (SEM) is used in this study for data analysis to explain the relations between the characteristics of the smart classroom and students' interaction. A model is created using the AMOS 22.0 Graphic program. The compatibility level of relation patterns in the recommended model is determined by several fit indexes (Durak & Saritepeci, 2018). 1) χ^2 (chi-square value), RMSEA (root-mean-square error of approximation), GFI (goodness-of-fit-index), CFI (comparative fit index), AGFI (adjusted goodness-of-fit index).

The model in this research is verified by data after several modifications. Table 3 displays the fit ranges of the goodness of fit criteria and the test result of the fit indexes.

Fit Values	Acceptable Fit Values	Values Reached
χ^2	P>0.05	303.378 P=0.000
χ^2/df	<3	1.744
RMSEA	<0.08	0.054
GFI	>0.9	0.901
CFI	>0.9	0.954
AGFI	>0.9	0.869

Table 3: Values of Goodness of Fit Index in Structural Equation Model.

According to Table 3, the χ^2 (chi-square value) of the model is 303.378. The P-value is 0.000, but this value can be ignored because of the large sample size of this research. The GFI value (.901), CFI value (.954) and RMSEA value (.054) fall in the fit ranges. The AGFI value (.869) is less than, but close to, the ideal value (0.9), so it is acceptable. The covariance matrix of the conceptual model is close to the covariance matrix obtained from the data, which indicates that the conceptual model is more consistent with the actual data. On the whole, the modified structural model fits well.

Table 4 shows the Hypothesis Acceptance table after model modifications. According to table 3, 10 hypotheses (H1, H2, H3, H7, H8, H9, H10, H11, H12, H13) are accepted (β-coefficient=0.381; p<0.05).

	β- coefficient	P	Acceptance/Rejection
Spatial design - Offline interaction with others	.539	0.000	Acceptance
Spatial design- Differentiation	.196	0.001	Acceptance
Spatial design -Cooperation	.633	0.000	Acceptance
Technology usage –Differentiation	.748	0.000	Acceptance
Technology usage - Online interaction with others	.246	0.009	Acceptance
Differentiation - Offline interaction with others	.181	0.000	Acceptance
Differentiation - Learner-content interaction	.616	0.000	Acceptance
Differentiation - Online interaction with others	.566	0.000	Acceptance
Cooperation - Offline interaction with others	.483	0.000	Acceptance
Cooperation - Learner-content interaction	.336	0.000	Acceptance

Table 4: Hypothesis Acceptance/Rejection Table.

Figure 2 displays coefficients of the modified structural equation model and Table 5 displays the direct effect, indirect effect and overall effect among each variable. The coefficient represents the strength of the relationship between variables. The direct effect refers to the direct influence of causal variables on outcome variables, the indirect effect refers to the indirect influence of causal variables on outcome variables through one or more mediators, and the total effect is the sum of direct effect and indirect effect.

5 Conclusions

In this research, we produce a model and determine that students' interaction can be positively affected by variables of Spatial design, Learning data, Differentiation, and Cooperation related to the smart classroom.

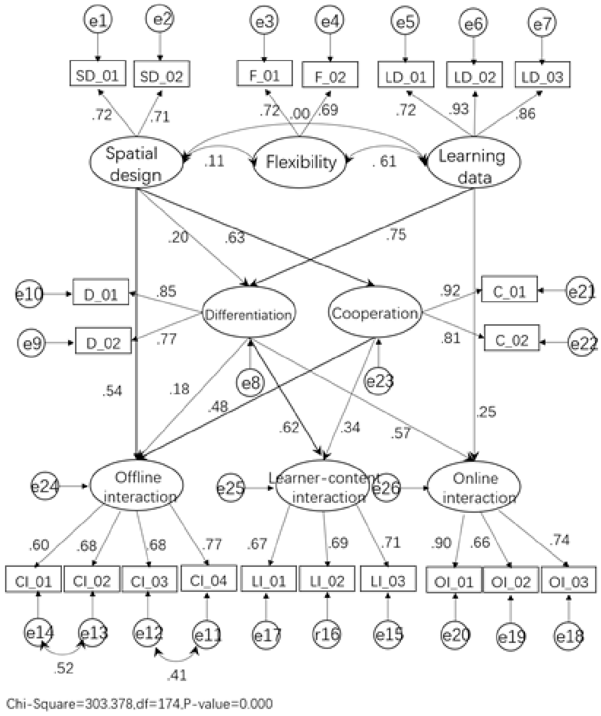

Figure 2: Modified structural equation model diagram.

		Spatial design	Learning data	Differentiation	Cooperation
Differentiation	Total effect	.196	.748		
	Direct effect	.196	.748		
	Indirect effect				
Cooperation	Total effect	.633			
	Direct effect	.633			
	Indirect effect				
Offline interaction with others	Total effect	.881	.136	.181	.483
	Direct effect	.539		.181	.483
	Indirect effect	.341	.136		
Learner-content interaction	Total effect	.334	.461	.616	.336
	Direct effect			.616	.336
	Indirect effect	.334	.461		
Online interaction with others	Total effect	.111	.669	.566	
	Direct effect		.246	.566	
	Indirect effect	.111	.424		

Table 5: The direct effect, indirect effect and overall effect.

Four main conclusions of this research are drawn. The first conclusion is that the spatial design of the smart classroom affects students' offline interaction with others directly and positively (0.54).

This finding is consistent with the viewpoint of Wang et al. (2016) that learning environments with technology equipment such as interactive learning desktop could enhance the frequency of interaction between students in a class. The second conclusion indicates that learning data management of the smart classroom affects students' online interaction with others directly and positively (0.25), which means that an intelligent learning space can promote the interaction in distance education. This finding may prove the point of Dekdouk (2012) that reliable data storage and management are part of the assessment of smart classroom learning. The third conclusion is that spatial design (0.2) and learning data (0.75) of the smart classroom have a direct effect on differentiation. Moreover, differentiation affects students' offline interaction with others (0.18), online interaction with others (0.57), and learner-content interaction (0.62), which means that spatial design and learning data management of smart classrooms can help teachers to better satisfy students' personalized learning requirements so as to promote students' learning efficiency. The fourth conclusion is that the spatial design of the smart classroom has a direct and positive effect on cooperation (0.63). Moreover, cooperation affects students' offline interaction with others (0.48) and learner-content interaction (0.34). These two findings are consistent with the research result of Wang et al. (2016) that classroom types and teaching activities have a significant cross-effect on the quality of classroom interaction.

The shortcoming of the study is that although the participants have the experience of learning in the smart classroom, their learning processes were not very 'smart' because teachers may not be able to make good use of the potential of a smart classroom. As a result, the quality of the data may not be good. For future researches, we will consider the learning experience of participants more carefully. For future construction of a smart learning environment, we suggest that teachers use appropriate facilities to organize learning activities.

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