Impact of Pedagogical Space Design on Collaborative Learning in Tertiary Education

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Abstract. The integration of communication and information technologies has induced pedagogical changes. Teaching methods have shifted from "passing expertise knowledge to students" to "active and collaborative learning", which has brought about changes in learning space design. Facilities should be able to encourage learner participation through provisions, such as IT/AV enhancements. Learning space configuration should also allow flexibility in adapting to different uses. Modular furniture can facilitate quick reconfiguration to enhance group activities. The Hong Kong Polytechnic University has carried out refurbishment work on traditional classrooms and lecture theatres aiming at improving the learning environment. Conventional classrooms and lecture theatres were renovated into modern and technology-enhanced teaching rooms to facilitate active learning. Questionnaire surveys were conducted to review the performance of the renovated learning spaces. This paper summarizes the survey findings and draws conclusions on how space and furniture design can facilitate collaborative learning in tertiary education.

Keywords: Modern technologies; collaborative learning; learning space design, flexible furniture.

1. Introduction

Learning is the central activity of tertiary education and includes formal learning in classrooms/lecture theatres, and informal learning involving interaction among individuals (Oblinger, 2006). Traditional teaching is based on teacher-centered method that is primarily concerned with the one-way delivery of information to students (Jamieson, Fischer, Gilding, Taylor, & Trevitt, 2001). Learning space design in

traditional pedagogy is focused on the delivery of information from teachers to students. The teaching lectern is the focal point of the teaching space, and students are oriented towards it. Comfort and ergonomics are the main considerations in furniture design.

Modern technologies have induced pedagogical changes (Cornell, 2002). Information and telecommunication technologies have become an effective tool for access to graphics, sound, presentations, and real-time interactive communications that provide a vast array of teaching opportunities for teachers (Colace, De Santo, & Vento, 2003; Fruchter, 1999). The increasing ownership of digital devices like computer notebooks has enriched learning methods (Brown & Long, 2006). The integration of communication and information technologies shift teaching from teacher-centered practices with primarily one-way delivery of knowledge to student-centered and flexible learning approaches (Jamieson, 2003). Learning becomes an active constructive process in which students become more responsible for their learning (Jamieson, 2003). Students' active participation and interactivity, particularly in group activities, are playing important roles in university education (Brown & Long, 2006). Built pedagogy is the ability of space to define the teaching method (Oblinger, 2006). Well-designed learning space can facilitate and enhance active/collaborative learning, provide an environment to students for academic and social purposes, and promote the use of modern facilities (Lippincott, 2006). The design should be user-centered taking into consideration (a) functionality (flexibility and adaptability), (b) user-friendliness, (c) comfort, and (d) aesthetics (Cornell, 2002; Lippincott, 2006; Chism & Bickford, 2002). Classrooms should be equipped with a variety of technologies to support computer activities-and designed to allow flexibility and support the multifunctionality of the learning spaces to facilitate groups of different sizes (Lippincott, 2006). Ubiquitous power sockets should be provided to support a variety of modern technologies including computers, projectors, smartboards, video editing equipment and video conferencing tools (Fruchter, 1999; Brown & Long, 2006; Lippincott, 2006). Teachers should be able to move close to students and walk freely around the classroom to engage individual students without physical obstacles (Chiu, 2016).

Modular furniture should be provided to enhance group activities in different sizes (Chiu, 2016; Ceppi & Zini, 1998). Modular tables can facilitate speedy reconfiguration (Fruchter, 1999; Chism & Bickford, 2002; Chiu, 2016; Taylor, 2009). Chairs are preferred to be designed on mobile wheels to facilitate grouping, have a flexible back, adjustable seat height, and adequate foam support for personal comfort (Cornell, 2002). Ambient lighting, good sound insulation and adjustable interior temperature can provide a comfortable environment for learning. The use of lively colors, interesting textures and patterns can further motivate learning (Lippincott, 2006; Taylor, 2009).

2. The Strategic Plan 2012-18 of The Hong Kong Polytechnic University

In view of the current developments in teaching pedagogy, The Hong Kong Polytechnic University (PolyU) has carried out a series of refurbishment work to conventional classrooms and lecture theatres under the Strategic Plan 2012-18 (The Plan). The work includes updating, upgrading and creating innovative learning spaces and facilities at

PolyU with the aim of improving the learning environment. Upgrading, refitting and revamping work on some classrooms and lecture theatres has been carried out since summer 2014. Most of the renovation work was completed in 2017. Two questionnaire surveys were conducted to collect feedback from students and teachers who had the experience of using the renovated classrooms and lecture theatres as learning spaces. The questionnaire surveys aimed to review the effectiveness of the renovations.

Traditional teaching rooms were transformed into modern and technology-enhanced teaching rooms with upgraded IT/AV facilities. Classrooms N001, 002 and 003 were combined into a large learning space. Movable glass partitions were installed to support different sizes of teaching groups (Fig. 1). Flexible furniture was provided to enhance grouping (Fig. 2). Vibrant colours, like patterned flooring (Fig. 3) were introduced to promote learning incentive. The renovation works are expected to enhance both active and conventional teaching.

Fig. 1. Movable glass partitions in N001, 002 and 003

Fig. 2. Flexible furniture

Fig. 3. Vibrant floor patterns

3. Questionnaire Survey

A questionnaire survey was conducted to collect student comments on the performance of the refurbished classrooms and lecture theatres as students are the major stakeholders of the learning spaces. Based on literature review and the scope of The Plan, the survey questionnaire was compiled from categorizing the renovation works of learning spaces into the four design principles: (a) application of modern technologies to facilitate collaborative learning, (b) flexibility in space design, (c) creating comfort in the learning environment, and (d) aesthetic in the learning environment. Students were asked to rate their level of agreement that the provisions have achieved their design purposes (1= strongly agree; 2 = agree; 3 = no comment; 4 = disagree; 5 = strongly disagree). They were also asked to rank the importance of continuous assessment on the performance of learning spaces. Four rounds of the questionnaire survey were conducted in November 2017. Five hundred copies of questionnaire were distributed, and 402 completed copies were collected and scrutinized with a response rate of 80%.

4. Analysis of Questionnaire Survey

The data collected from the questionnaire survey was tabulated with the use of the Microsoft Excel 2016 software and exported into the database in the SPSS statistical software. The data was analyzed by Factor Analysis in order to reduce a set of large data into smaller sets of components for better analysis (Pallant, 2000; Pallant, 2007; Chan, Cheung, & Wong, 2015a). The relative importance of the identified impacts was analyzed with the "mean score method". The mean scores (MS) for each variable of perceived effects were ranked in ascending order according to their relative importance from calculation based on-the five-point Likert scale, where 1 = "strongly agree" to 5 = "strongly disagree". Effect variables with a value below 3 are important. The MS were computed from formula 1 below (Chan, Cheung, & Wong, 2015b):

$$MS = \sum(f \times s)/N; (1 \leq M \leq 5) \quad \textbf{(1)}$$

The 15 variables of design requirements/elements were examined by Factor Analysis using the extraction method of Principal Component Analysis and the rotation method of Oblimin with Kaiser Normalization converged in 10 iterations with–the number of components to be extracted set to '6'. With reference to Table 1, the values of KMO and Sig. are 0.926 and 0.000, respectively, which support that applying Factor Analysis as the analytical tool is appropriate.

Table 1. *KMO and Bartlett's Test*

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.926
Bartlett's Test of Sphericity	Approx. Chi-Square	3648.743
	Df	120
	Sig.	.000

5. Findings of Analysis

Six components were identified after rotation as listed in Table 2. The rotation solution presented the pattern of loadings in a manner that was easier to interpret (Pallant, 2007). Table 3 summarized the results after factor extraction and rotation. The six components are categorized into 6 underlying factors which are (i) Modern Technologies, (ii) Facilitation for Group Discussion, (iii) Multifunction, (iv) User-friendliness, (v) Comfortability and (vi) Manageable and Pleasant Environment.

5.1. Modern technologies

Rapid developments of information technologies have a large impact on classroom design and induced pedagogical changes (Graetz & Goliber, 2002). The learning method has shifted from "passive" to "active" student-centered and flexible learning approaches (Brown & Long, 2006; Jamieson, 2003). Higher education has become reactive (Fruchter, 1999). Classrooms should be equipped with a variety of modern technologies (including computers, projectors, smartboards, video editing equipment and video conferencing tools) and flexible furniture (Brown & Long, 2006; Lippincott, 2006). Factor (i) reviews that modern and technology-enhanced teaching rooms can facilitate interactive and student-centered learning.

5.2. Facilitation for Group Discussion

Learning space design has shifted from "information commons" to "learning commons", or from design based on resources to human-centered basis (Brown & Long, 2006). Facilities that encourage learner participation are increasingly important in learning space design (Jamieson, et al., 2001). Brown and Long (2006) suggested that space layout and furniture design should enable easy reconfiguration to facilitate constructivism learning. Lam et al. (2016) identified that learning activities such as

debate, discussion and teamwork are conducive to active learning principles, which can best be carried out in small discussion groups. Flexible furniture, such as movable chairs and modular table, can allow speedy re-grouping of students into different group sizes to facilitate group discussion.

5.3. Multifunction

The size and form of a lecture theatre govern-much of the teaching that happens within it. New learning environments need to allow for multi-functionality (Jamieson, et al., 2001). The learning space should be able to reconfigure on an as-needed basis to support computer, activities, teamwork, presentations and interaction in the geographically distributed setting (Fruchter, 1999; Lippincott, 2006). The design of multifunctional classrooms should allow for the speedy reconfiguration of the learning space. Movable partitions such as glazing panels in N001/002/003 enable flexibility in the learning space.

5.4. User-friendlessness

Maximizing user-control of facilities by teachers and students is important in interactive learning (Jamieson, et al., 2001). Usability implies clarity, ease of use, access and control of the provisions. Users need to understand the operation of the facilities and feel empowered to use them (Cornell, 2002). The upgraded IT/AV tools such as multiple monitors, touch-sensitive monitors, projector screen and writing glass panels should be user-friendly and simple in operation.

5.5. Comfortability

The intent of addressing comfort is to promote well-being and minimize distraction (Cornell, 2002). Interior design, furniture design and microclimatic condition of the classroom/lecture theatre are contributing factors to comfortability. Teachers should be able to move close to students and walk freely around the classroom to engage individual students without physical obstacles (Chiu, 2016). Furniture should be flexible and facilitate grouping (Chiu, 2016; Ceppi & Zini, 1998). Mobile chairs with flexible backs, adjustable seat height and adequate foam support for personal comfort are preferred to facilitate grouping (Cornell, 2002). Ambient lighting, good sound insulation and adjustable interior temperature can provide a comfortable environment for learning. Lively colour, interesting textures and patterns can further motivate learning (Lippincott, 2006; Chism & Bickford, 2002).

5.6. Manageable and Pleasant Environment

The right environment can create a more relaxing and sociable setting (Cornell, 2002). It is doubtless that a pleasant, comfortable and appealing environment can motivate learning. The feeling of comfort may vary under different climatic conditions. For instance, a higher lighting level and warmer interior temperature are preferred in the cold winter season. The ability of users to adjust the interior condition of learning

spaces according to their needs at different times can ensure a comfortable and pleasant environment that promotes learning.

Table 2. *Pattern Matrix*

	Component					
	1	2	3	4	5	6
1.1	.165				-.608	-.148
1.2	.155			.142	-.717	
1.3		-.193		.168	-.585	
2.1		-.818	.108		-.104	
2.2		-.865				-.155
2.3		-.885		.117		.116
3.1				.915		
3.2				.722	-.148	-.141
3.3					-.112	-.782
3.4		-.101			-.138	-.789
3.5	.287			.278	.329	-.481
3.6	.513	-.192				-.150
4.1	.554	-.210		.135		-.129
4.2	.906			-.103		
4.3	.904					.129

Note: Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
Rotation converged in 10 iterations.

Legend

1.1 The equipped technologies (e.g. computers, projectors, smartboards, video auditing equipment, video conferencing tools, 3D visualization, etc.) enhance learning
1.2 The provision of plug-n-play (access to technology, ubiquitous power and data connection) is useful
1.3 Say-n-see: You can easily present, modify, record and retrieve information by using the provided facilities
2.1 Versatility: The learning space is designed for multiple uses
2.2 Relate-n-reflect: The space design facilitates group discussion
2.3 Fold-n-go: the furniture can be easily reconfigured to facilitate grouping in different sizes
3.1 Chairs with flexible backs and adjustable seat heights are comfortable and enhance concentration in learning
3.2 The acoustics of the room are satisfactory and improve concentration
3.3 Lighting is ambient
3.4 Adjustable lighting level can enhance learning
3.5 The interior temperature is comfortable
3.6 The ability to adjust interior temperature is important to learning comfort

4.1 Inspire-n-invite: the environment is comfortable and enjoyable
4.1 The use of color can motivate learning
4.3 The textures, patterns and finishing are interesting which can motivate learning

Table 3. *Summary of Factor Analysis*

Components	**Factors**	**Underlying Factors**
1	1.1 Technologies enhance learning 1.2 Technology-associated provision is useful	*Modern Technologies*
2	2.2 Space design facilitates group discussion 2.3 Furniture design facilitates different groupings	*Facilitation for Group Discussion*
3	2.1 Learning space designed for multiple uses	*Multifunction*
4	1.3 Ease of use of facilities i.e. user-friendly	*User-Friendliness*
5	3.2 Good acoustic provision can improve concentration in learning 3.3 Ambient lighting is important 3.4 Adjustable lighting enhances learning	*Comfortability*
6	3.6 Adjustable room temperature provides learning comfort 4.1 Comfortable and enjoyable environment is important	*Manageable and Pleasant Environment*

6. Discussion and Conclusion

The data collected from the 402 completed questionnaires were analyzed by Factor Analysis processed by SPSS. After factor reduction, six components were identified. The six components can be categorized into six underlying factors relating to Modern Technologies, Facilitation for Group Discussion, Multifunctionality, User-friendliness, Comfortability, and a Manageable and Pleasant Environment. The development of applying IT/AV technologies is rapid, which induces pedagogical changes. Modern technologies such as computers, projectors, smartboards, video auditing equipment, video conferencing tools and 3D visualization have become common teaching media. Ubiquitous power and data connections should be provided in classrooms and lecture rooms for access to IT/AV technologies. In interactive and collaborative learning, students are encouraged to participate in group discussion. The design of the learning spaces and furniture should facilitate grouping. The design of the teaching room is preferred to be multifunctional for effective use of space and adaptability to different methods of teaching/learning. Movable partitions can easily divide a large teaching space into smaller rooms for different class sizes and for carrying out different activities.

Modular furniture can be easily reconfigured into different group sizes. The provided technologies should be user-friendly and simple in operation, allowing students and teachers to operate them with little to no technical support enhancing efficient collaborative learning. A comfortable environment can promote student concentration in learning. Good acoustic provision, ambient lighting and thermal comfort contribute to learning comfort. User-manageable interior conditions are important in providing a comfortable learning environment. Users should be able to adjust the interior temperature of classrooms and lecture theatres according to different weather and climatic conditions. Lively interior design can motivate learning. Careful selection of colour, texture and pattern of finishing can create a vibrant atmosphere.

Conclusively, pedagogical space design is important to facilitate interactive learning and collaboration among teachers and students. The design of the learning space should be student-oriented, which facilitates the application of modern technologies in teaching and learning. Flexibility in the use of learning and teaching spaces should be allowed to maximize the functionality of the room. Furniture design should facilitate group discussion which should create a comfortable and pleasant interior learning environment as vital design considerations.

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