Who shapes the network of a pedagogical space?
Clues from the movements in the physical places

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Abstract. Researchers who study pedagogical space mostly look at physical space, such as the density of space usage and education-related material designs. The interaction of objects and the resulting network in the physical space, referred to as a secondary pedagogical spatiality, have received less attention. In a classroom setting, objects may refer to the lecturers and students. This study examines the representations of their body movements corresponding with concurrent verbal language, seat layout, and instructional equipment. We further examine the objects' movements and how they relate to the physical spaces and understand the process of interactions in the physical spaces. The findings, which support the Actor-Network Theory concerning the connectedness and fluidity of objects in physical places, help move toward a theory of pedagogical network.

Keywords: Network in physical spaces, Pedagogy, Actor-network theory, Multimodality, Bodily movement.

1 Introduction

Several studies have shown that spaces (e.g., conventional classrooms, digital educational platforms, workshops, outdoor) affect the formation of the social consciousness of lecturers and students and prevent them from effective education-related activities[3,4,9,12]. Researchers mainly focused on investigating the density of space usage[23] and education-related material design[11,15]. In contrast, the physical interactions within pedagogical spaces are underexplored. Essentially, educational activities are dynamic assemblies of social actions, reactions, and interactions among lecturers, students, instructional equipment, and the sites[8]. Lecturers typically take the lead in educational activities and stand as the focal point in the spaces, and students sit around them during lectures. Thus, making sense of the physical interactions within pedagogical spaces and the relationship between lecturers and educational activities is essential.

Pedagogical space can be understood as Euclidean space, the common understanding of physical space. However, a second spatiality level also exists, formed by a network connected by *objects*[21]. This second level of spatiality is commonly known as *a fluid form of space*[21], which consists of 1) objects, including lecturers, students,

and instructional equipment[19,20], and 2) The objects' movement [20]. From a linguistic point of view, the objects are multimodal carriers in pedagogical discourse[18,32]. Kress indicated that humans' verbal expression serves as one of the primary multimodality in teaching discourse, gesture, gaze, bodily movement, and instructional equipment reveal unspoken information[17]. However, the impacts of using instructional equipment in educational activities have been relatively understudied. Thus, we propose that the formation of pedagogical space is related to the movements of objects, particularly instructional equipment use. The study is undertaken from Law's network space theory (NST) [21], Latour's Actor-network theory[20], and multimodal discourse[18] for examining the representations of instructional equipment, lecturers' gestures, and body movements corresponding with concurrent verbal language, and the seat layout of students. We further identify the objects through their movements and their correlations with the physical spaces. In this article, we will answer two questions:

- What are the representations of the objects' movements in physical spaces?
- How do the objects shape the pedagogical network in physical spaces?

2 Related work

2.1 Pedagogical space

Objects' Movements. The pedagogical space is revealed through the objects' educational events and their movements performed. Thus, the representations of objects' movements and the relations between objects are essential for understanding the pedagogical space. Their representations conform to *a syntax of consistent functionality*[21] and *move only within Euclidean space, remaining immobile within network space* [21]. Lecturers' and students' bodied movements (e.g., gestures, postures, mental states-related behaviors) and instructional equipment used (e.g., computers, projection screens, desks, chairs) are tagged. We defined two types of object movements, 1) *Active movement*. Lecturers' and students' bodied movements[6,7] and bodily interactions[2] have been evaluated through their independent modalities—body movements and gestures. However, few studies analyze the movements of lecturers' and students' social actions. Lim speculated a social-related classification of gestures[24] according to Martinec's types of actions[25–27]. In a classroom context, he believes gestures are separated into communicative gestures (i.e., representing action and indexical action), which feature self-representation and linguistic correlation, and performative gestures (i.e., presenting action), which reflect people's states and behaviors[24]. Lecturers' and students' social actions are recognized by verbal content, gaze, gestures, postures, and body orientation, according to Lim's multimodal taxonomy in classroom discourse[22]. In addition to the preceding, the lecturers' movements and gestures scales are supposed to sketch the pedagogical network space. 2) *Passive movement.* The physical instructional equipment is typically set aside for easy accessibility, allowing for relative movement. Hence, the

instructional equipment's movements are derived from bodily interactions with lecturers.

Objects' relative distance. Lecturers situating themselves in a teaching environment has been studied through physical space level [1,5,22,30]. Yet, the relationship between lecturers' movements and physical spaces is rarely explored. Humans perceive space by measuring the distance between objects according to the framework of the interpersonal distance of man [13,14]. However, applying Hall's interpersonal space set to evaluate the representations of lecturers' interpersonal space perception cannot interpret the lecturers' space use. Previc proposed the behavioural systems involved in 3-D spatial interactions [28] that humans perceive easy manipulation and their somatosensory and motor system are active in peripersonal space. This is similar to Hall's intimate space. In focal extrapersonal space referring to Hall's personal space, humans primarily use eye movement for object recognition. Humans' movement is target-orientated, and they tend to have more head movement in action extrapersonal space which is identical to Hall's social space. Consequently, their somatosensory perception is reduced but remains visual and auditory perception actively. Bodily movement is adopted in ambient extrapersonal space resembling Hall's public space, and the humans' intention approaches spatial orientation.

2.2 Multimodality in pedagogical spaces

Lecturers, as the center of educational activities, are mainly in charge of transmitting structured knowledge and directing the mobility of turn-taking. Students, the prominent participants in educational activities, are expected to comprehend novel knowledge and interact in educational communication[16]. Instructional equipment aids and facilitates effective communication between lecturers and students. As a result, lecturers are the primary objects in educational activities, while students and instructional equipment collaborate to carry out educational activities.

Lecturers' multimodality: Lecturers' gaze, gestures, postures, and mental state-related behaviors as kinetics forms of multimodality carry unspoken and context-related information[32]. In the interim, lecturers' verbal language functions for narrating educational content and highlighting important information, reflecting their social and mental state[30]. The orchestration of those lecturers' multimodalities composes a dynamic system of teaching discourse. Analyzing those multimodalities and their composition is critical to comprehending lecturers' social actions and distinguishing the relationships with students, equipment, and physical space.

Students' and instructional equipment's multimodality: Students and equipment primarily produce unspoken and passive multimodality. In a lecture setting, students usually play the roles of the audience, and their bodied movements are not particularly large. However, students bring lecturers unspoken information through their gaze and slight body movements. Lecturers widely reported that they perceive a sense of social presence while teaching in front of students[10,28]. Instructional equipment, including

computers, projection screens, desks, and chairs, are other types of unspoken multimodality. They support lecturers in presenting visualized and deconstructed information as semiotic resources. They demonstrate images, text, and videos, but lecturers are required to access and manipulate them actively. Hence, instructional equipment also obtains semiotic modality. In a later stage, we will examine the instructional equipment that has been identified and evaluate their relations with lecturers and students.

3 Methods

Given the theoretical propositions in the preceding sections, this paper applies the proposed conceptions of pedagogical spaces' formulation through the lecturers' and students' movements together with verb language and instructional equipment in three real-life teaching settings. Through the movements and correlations of the objects, the case study approach promises to reveal the representations of the objects' movements and gain an in-depth understanding of pedagogical spaces' formulation. As linguistic analysis and gestural analysis of the meanings were brought through the lens of Systemic Functional Theory[22], we apply systemic functional-multimodal discourse analysis in this study. Three case studies are adopted: offline, online, and hybrid teaching settings.

3.1 Measurements

Based on Previc's behavioral 3-D spatial interaction systems[29], we depict the spatial relation diagram of multimodal sources in lecturers' space in Figure 1, in which three levels of lecturers' space were defined. It investigates the lecturers' relative distance perception by investigating their bodily movements. From a relative space aspect, the innermost level of lecturers' space is a space for them to manipulate teaching equipment and demonstrate instructional sources easily. The middle level of lecturers' space refers to action extrapersonal space with more expansive horizontal space for ease of target positioning, in which lecturers illustrate their visual and spatial attention patterns. Lecturers' whole-body movement is supposed to be fruitful to continually interact with students in the outermost level of lecturers' perception space. Lecturers produce three progressive scale gestures (i.e., small, medium, and large) that relate to the embodied spatial spreading of somatosensory perception in line with Previc's peripersonal space. Large gestures cover the greatest distance that humans are attempting to stroke. Medium gestures are human gestures that span between the head and the waist and are less than 0.5 meters apart. In contrast, small gestures are movements that occur in front of a person's chest. Two-dimensional relative distance perception is designed for manifesting the correlations between lecturers and physical space.

3.2 Subject and Research Site

We conducted this study in three different types of daily usage classrooms based on the features of lecturers' natural activities in a real-life teaching situation. We recruited three male participants, given the pseudonyms of George (offline), John (online), and Tom (hybrid), who are university lecturers having around ten years of teaching experience for undergraduate courses and specializing in design and arts disciplines. We implemented around 60 minutes of observation for each lecture. Moreover, we observed lecturers' and students' speech, non-verbal movement, and teaching process; specifically, we recorded lecturers' movements and equipment usage.

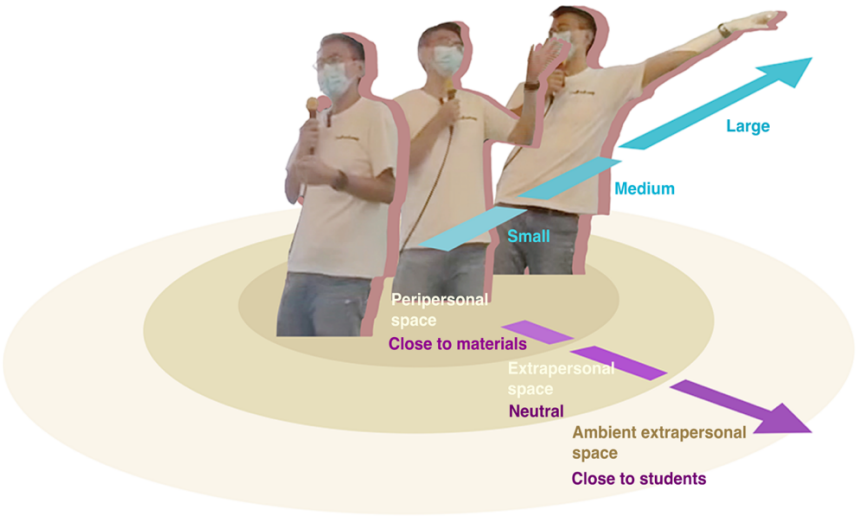

Fig 1. A spatial relation diagram of multimodal sources in lecturers' space taking offline lecturer as an example

3.3 Equipment

The multimodal discourse analysis software ELAN was used to annotate 9611,357ms valid video recordings, 3130,372ms for offline mode, 3066,990ms for online mode, and 3413,995ms for hybrid mode. Three tiers were recorded, annotated, and analyzed, including lecturer action types and representing and presenting action types that revealed lecturers' social involvement, locations, and gesture scales[21]. We also transcribed lecturers' verbal language from video recordings and manually reexamined it through an

online transcription service. Statistics software SPSS is applied to calculate the general data description.

3.4 Procedure

Before the class started, we notified the lecturers and the students that the teaching process would be video recorded. Then a camera was placed at a three-quarter angle about three meters away from the lecturers. During the class, one of our researchers sited in the classroom to observe the lecturers' and students' actions and material usage and monitor the camera consistently working without interrupting the regular teaching processing. We observed and recorded three one-hour-long lectures.

4 Results

4.1 Offline lecture

We annotated the occurred frequency and percentage of total occurrence amounts of lecturer's locations, gesture scale, and action types from George's lecture video recording. We calculated them through SPSS (see Figure 2 and Table 1). The data shows George stayed close to students 1347 times (48.1%), neutral location 777 times (27.7%), and close to teaching equipment 471 times (16.8%) from the perspective of frequency and percentage. He mostly stood close to students during his lecture. George performed large gestures 819 times (29.2%), medium gestures 1412 times (50.4%), and small gestures 201 times (7.2%). The usage rate of medium gestures is significant, and large gestures also show a relatively high frequency. He performed communicative gestures (i.e., indexical actions, 1640 times, 58.5 %; representing action, 731 times, 26.1%) frequently and showed very little in the performative gestures (presenting actions, 202 times, 7.2%). When George was teaching, he involved plentiful social actions. In general, George used gestures effectively, which he mostly used to communicate with the students and the actual teaching site.

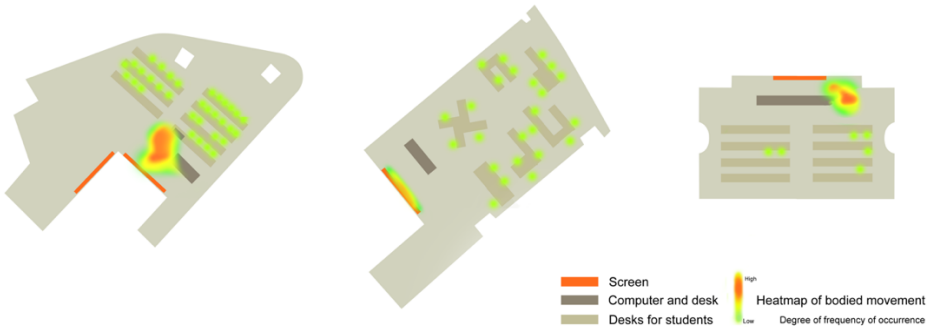

Fig 2. A heatmap of lecturers' and students' bodied movements in offline lecture setting (left), online lecture setting (middle), and hybrid lecture setting (right).

Thirty-three students who wore masks attended the lecture and sat silently during the teaching process. They did not make noticeable movements and barely talked with George. Instructional equipment includes two projection screens, a computer, a laptop, and desks and chairs for placing belongings and students' use. George mainly utilized the laptop for presenting information on screens, and laptops were placed on students' desks. He occasionally strolled between the laptop and the screen behind him, but he generally stood near students. A two-meter-long microphone line limited George's range of motion because he had been lecturing with the microphone.

Lecturer Location		**Close to students**	**Close to teaching equipment**	**Neutral**	**null**	**Total**
	Fre	1347	471	777	207	2802
	%	48.1	16.8	27.7	7.4	100.0
Lecturer Gesture Scale		**Large**	**Medium**	**Small**	**null**	**Total**
	Fre	819	1412	201	370	2802
	%	29.2	50.4	7.2	13.2	100.0
Lecturer Action Type		**Indexical Action**	**Presenting Action**	**Representing Action**	**null**	**Total**
	Fre	1640	202	731	229	2802
	%	58.5	7.2	26.1	8.2	100.0

Table 1. Frequency and percentage of three features of George's Multimodal Use

4.2 Online lecture

We annotated the occurred frequency and percentage of total occurrence amounts of gesture scale and action types from John's lecture video recording. We calculated them

through SPSS (see Figure 2 and Table 2). Since John was online presenting, his location did not count. The data demonstrates that John stroked large gestures 29 times (1.8%), medium gestures 398 times (24.9%), and small gestures 926 times (58%). The usage rate of small gestures is significantly high. Large and medium gestures show relatively low frequency. He performed communicative gestures frequently (i.e., indexical actions, 539 times, 33.8 %; representing action, 736 times, 46.1%) and showed relatively less in the performative gestures (presenting actions, 259 times, 16.2%). John's range of motion is limited, yet he makes clear communicative actions.

Twenty-four students attended the lecture who donned masks and sat silently during the session. Twenty-three students attended online. They did not make any apparent moves and had no communication with John. Instructional equipment includes a projection screen, a computer, and desks and chairs for placing belongings and students' use. John was online and had no full-bodied movements observed. He only used the screen to share instructional materials with students virtually.

Lecturer Gesture Scale		**Large**	**Medium**	**Small**	**null**	**Total**
	Fre	29	398	926	244	1597
	%	1.8	24.9	58.0	15.3	100.0
Lecturer Action Type		**Indexical Action**	**Presenting Action**	**Representing Action**	**null**	**Total**
	Fre	539	259	736	63	1597
	%	33.8	16.2	46.1	3.9	100.0

Table 2. Frequency and percentage of three features of John's Multimodal Use

4.3 Hybrid lecture

We annotated the occurred frequency and percentage of total occurrence amounts of lecturer's locations, gesture scale, and action types from Tom's lecture video recording and calculated them through SPSS (see Figure 2 and Table 3). The data reveals Tom stood close to students who attended in the physical classroom 0 times (0%), neutral location 1204 times (73.9%), and close to teaching equipment 307 times (18.8%) from the perspective of frequency and percentage. He mainly stood neutral position during his lecture. Tom performed large gestures 16 times (1%), medium gestures 400 times (24.5%), and small gestures 977 times (60%). The usage rate of small gestures is significantly high. Large and medium gestures show relatively low frequency. He performed communicative gestures (i.e., indexical actions, 1098 times, 67.3 %; representing action, 194 times, 11.9%) frequently and showed very little in the performative gestures (presenting actions, 219 times, 13.4%). Tom did not make any noticeable

motions, preferring to stand in a neutral posture amid educational equipment, students, and the physical teaching site.

Six students attended the lecture who wore masks and sat in silence during the talk. Thirty-three students participated in the class through the internet. They made no overt moves and did not communicate with Tom. Instructional equipment includes a projection screen, a computer, and desks and chairs for placing belongings and students' use. He stands in the center of the computer screen and the live students most of the time, with three-quarters of his side facing the live students and computer displays and the rest facing the computer screen directly. Because he had been teaching with the microphone, Tom's range of motion was constrained by a two-meter-long microphone cord.

Lecturer Location		**Close to students**	**Closeto teaching equipment**	**Neutral**	**null**	**Total**
	Fre	0	307	1204	118	1629
	%	0	18.8	73.9	7.2	100.0
Lecturer Gesture Scale		**Large**	**Medium**	**Small**	**null**	**Total**
	Fre	16	400	977	236	1629
	%	1.0	24.5	60.0	14.5	100.0
Lecturer Action Type		**Indexical Action**	**Presenting Action**	**Representing Action**	**null**	**Total**
	Fre	1098	219	194	219	1629
	%	67.3	13.4	11.9	13.4	100.0

Table 3. Frequency and percentage of three features of Tom's Multimodal Use

5 Discussion

The study aims to explore the formulation of a pedagogical network through understanding the objects in physical spaces, the representations of objects' movements, and the process of movements' integrations. The results show the following. In the offline teaching scenario, the physical classroom space is large compared with the general classrooms, and the class was in full attendance. There was no requirement for online teaching. George was utterly involved in the offline learning environment. George employed a lot of communicating gestures and concentrated on medium- and large-scale gestures. We speculate that George's bodied movements shaped a vast educational field and linked the students. Due to the students' presence and the teaching aids were situated close to the students. Even though George moved to the projector frequently to emphasize the important information projected on the screen, he swiftly returned to the location near the students and stayed closely with them. We hypothesize that in the

offline scenario, although there was no verbal interaction, George perceived the students' gaze and used many large-scale gestures to build an educational information space. In the meantime, the placement of teaching aids between the students and the lecturer enhanced educational communication. The objects formed an educational network, including the lecturer, the students, and the teaching aids.

The classroom in the online teaching mode is larger than the conventional classroom, and the class had half attendance. John presented a strong desire for social interaction. John employed several communicative actions and concentrated on a minor range of movements. We assume that John could not sense the presence of the students and instructional equipment in the physical classroom. Moreover, the web camera restricted his teaching performance. Therefore, his movements drew a small educational space, and his connection with students was minimal. Despite the outstanding number of John's communicative actions, his bodily information was limitedly released to the students. It is maybe because he could not see the students' gaze, and there was no verbal interaction during the class. We speculate that he utilized a lot of small body movements to construct the educational space, and the space was isomorphic and heterotopic.

Under the hybrid teaching scenario, the classroom was a standard size, the physical attendance of students was low, and most of the students presented online. Tom stood in front of the computer and faced the computer screen most of the time. We assume he needed to pay attention to the students in two scenarios and may focus more on the online students. Tom used many small-scale communicative actions, and only inconspicuous movements were identified throughout the class. He stood between the computer and the students and formed a triangular educational space. We suspect that the computer screen, microphone, and teaching equipment limited Tom, and he barely interacted with students. There were no significant revelations regarding his movements' trace. When Tom was teaching in hybrid mode, the educational space was restricted by teaching aids and multimodal technologies.

This paper verifies the notions of ANT[20] and NST[21] about the connection and fluidity of objects in physical spaces to construct a second space. Although the instructional equipment had passive movements, they significantly affected three teaching scenarios. In this paper, we argue that 1) the lecturers' spatial perception is affected under different teaching scenarios, which may result in the failure of educational network formulation. The form of multimodal teaching scenario (e.g., hybrid teaching mode) was identified, and it negatively influenced the formulation of pedagogical space. 2) The use and placement of teaching aid significantly influenced educational networks' formulation. The students and the lecturer were closely bound in a pedagogical network, when the teaching aids were placed at the position between the students and the lecturer. We claim teaching aids play as active objects to promote the formulation of pedagogical network.

6 conclusion

Today's educational institutions commonly use virtual learning environments like online classrooms or immersive VR classrooms, and the investigation of the use of educational space is underexamined. Our study can project on developing virtual learning environments. Our study analyzed the representations of objects' movements in three real-life classroom settings. The study found the pedagogical network formulations and the processes of the objects that shaped the spaces. Our study differs from previous studies on pedagogical spaces in that we identified the correlation between objects and physical spaces in the educational context. The analysis result shows the importance of studies on pedagogical spaces in the HCI community. Research is ongoing, and we are currently investigating more lectures and planning evaluations through in-depth interviews.

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