An Analytical Framework for Designing Future Hybrid Creative Learning Spaces: A Pattern Approach

Dan Zhu[1(✉)] and Yeqiu Yang[2]

[1] School of Design and Creative Arts, Loughborough University, Loughborough LE11 3TU, UK
D.zhu2@Lboro.ac.uk
[2] Department of Design, Politecnico Di Milano, 20133 Milan, Italy
Yeqiu.Yang@polimi.it

Abstract. Existing frameworks which serve as reference for the design of creative space in educational institutions and organizations, have shown some limitations. On one hand, current spatial design theories concerned with hybrid spaces and digital technologies are limited; on the other hand, the analysis of digital technologies' influence on spaces conducted in Information System and Computer Science research fields rarely uses a spatial theory as a foundation [1]. The aim of this ongoing research is to develop an analytical framework that integrates creative space types and a blended space model in support of the design of future hybrid creative environments (FHCS framework).

The current findings have shown that many different social-spatial design solutions exist in both physical and digital spaces, and which are systematically organized as a pattern language. Identified pattern candidates are from specific application domains (e.g., spatial design, HCI Design, E-learning, and game design), and they capture and represent design knowledge of experts. Therefore, the pattern language from Christopher Alexander et al. [2] seems an appropriate approach to bring together design guidance and tools from different disciplines, in a vocabulary that can be shared across disciplines. Through a pattern mining process, various pattern frameworks and many pattern candidates that are related to the design of hybrid creative learning spaces have emerged from the analysis. As a result, 323 patterns are derived from four disciplines, and 13 generic pattern clusters have evolved in relation to the hybrid design themes.

Keywords: Design patterns · Creative spaces · Hybrid working and learning

1 Introduction: Learning in Hybrid Creative Spaces

Conventionally, space for creative learning activities in educational contexts is often defined as a built formal physical environment; and these environments can also be informal spatial clusters that encourage exchange and social networking based on face-to-face interactions [3]. Users perceive and evaluate learning spaces through their architectural properties and physical settings (e.g., spatial layout and furnishing, lighting,

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colours, smells, sounds and technology, status, and image) [4]. Nevertheless, in recent years we have seen a significant shift to a more hybrid form for learning since the beginning of Covid-19 pandemic in 2020, and many higher educational institutions and are likely to embrace "hybridity" beyond the pandemic. At the same time, "extended reality" has an emerging presence in our everyday life, and with the future of the internet and metaverse, the combination of augmented, virtual, and mixed realities will become an essential medium for social, business, learning and working engagements. Nowadays, the term hybrid space (or blended space) is widely used as an interplay of physical and digital spaces. An urgent call is raised for designers to rethink the current design practice to accommodate the future challenges when designing creative spaces in transition to hybrid form of learning.

2 Background

The expression "Creative space" integrates two concepts, "creative" and "space". The term "creative" is associated with activities related to design and innovation process. "Space" conventionally refers to a built environment in various scales, from an urban context, architectural space, interior layout, to small single elements such as a furniture. The existing models/frameworks that serve as reference for the design of hybrid creative spaces in educational institutions have shown some limitations. For example, most of the studies in the design field of creative spaces are limited to the built environment and have not given enough attention to contemporary issues such as hybrid learning and emerging technologies [5–12]. Although some frameworks developed design principles for creative spaces, they failed to acknowledge the importance of the connections of design components in a form of network [10–12]. Therefore, it is difficult for designers and users to understand upcoming design issues and set the priorities in the design process.

On one hand, current spatial design theories concerned with hybrid spaces and digital technologies are limited; and on the other hand, the studies of digital technologies' influence on educational spaces conducted in "Information System and Computer Science" [13–15] and "Education" research fields [16–20] rarely use a spatial theory as a foundation.

3 Theoretical Framework

3.1 Spatial Design Theory

In a built environment, Thoring et al. [21] identify five space types associated with creative processes from the literature and empirical studies. They are personal space, collaborative space, making space, presentation space, and intermission space. For designers to develop hybrid spaces, in Fig. 1 the authors present key issues that are suggested in digital spaces as well as physical ones. Moreover, to adopt existing spatial design knowledge and theories in the context of hybrid spaces, architects and interior designers need a new model to bridge the physical and digital environments, as well as new useful design tools derived from other disciplines.

Creative Space Types	Physical Space summerized by Thoring et al. (2018)	Digital Space summerized by the authors
Personal space	allows for concentrated 'heads-down' work (thinking, reading, writing), deep work, and reflection; requires reduced stimulation to avoid distraction	access to single-user digital space, storage and resources; applications to support; allow control of personal territories; easy transitions between personal devices and shared devices.
Collaboration space	is used for group work, workshops, face-to-face discussions, client meetings, or student– teacher consultations.	access to multi-user space and digital storage; share and display knowledge; provide a clear structure for access to collaborative functionality and media content; provide alert to indicate changes; application support synchronization across digital spaces; provide meeting area
Presentation space	is used to share, present, and consume knowledge, ideas, and work results in a one-directional way (presentations or exhibitions)	provide a platform for display of work and social interaction; knowledge transfer; highlight presenter or work; encourage feedback; Provide software to support multi-user interaction; control interfaces and activities; easy transitions between personal devices and shared devices.
Making space	is used for model making and building; allows experimentation, play, noise, and dirt.	Access to user space, storage and resources; provide simulation of physical tools and training; provide software to support multi-user interaction and shared digital areas; access to software and training materials; application support synchronization across digital spaces
Intermission space	connects other space types; is used for breaks, recreation, and transfers; includes hallways, stairs, cafeterias, and outdoor areas	provide reflection and relax space; disengage and play; simulation of nature or outdoor space; navigation portals; facilitate knowledge transfer; facilitate casual exchanges; enable collective breaks; provide recreation and gaming zone; provide overview of the space for easy navigation between digital spaces

Fig. 1. Key design issues suggested for both physical and digital spaces.

3.2 Blending Theory

Following Lefebvre's theory, we understand "space" as a combination of different "fields" – for example, physical space, mental space, cultural space and social space [22]. Cicognani further adds that "cyberspace" can be considered as the 'fourth partition' of the space that co-exists with the other "fields" [23]. When mixing physical space and digital space, or mixed reality, it comes to many forms and combinations as stated by Milgram and Kishino when introducing *Virtuality Continuum* [24]. From an architectural perspective, facilitated with emerging technologies, a hybrid creative space brings together at least two distinct modes to create a new spatial typology, with a physical space flowing within a digital space and vice versa seamlessly.

Built on *Conceptual Blending Theory* [25], Benyon proposes a *Blended Spaces framework* to bring digital and physical spaces together [26]. This framework consists of four distinct domains, physical space, digital space, generic space and blended space. For designers to create a good blending, characteristics that shared by both physical and digital spaces should be constituted with four attributes, ontology (e.g. room layout and furniture), topology (e.g. spatial relations between objects), volatility (e.g. movement through the space), and agency (e.g. people).

In addition, Benyon and Mival identified five hybrid design themes through an empirical study, and they are *Territoriality, Awareness, Control, Interaction and Transitions* (TACIT) [27]. The blended spaces framework and TACIT framework intend to encourage designers to consider essential aspects of the physical and the digital spaces, and produce new blended spaces of emergent properties. As explained in Table 1, both *territoriality* and *transitions* have emphasis on the infrastructure of the spaces. *Territoriality* concerns the spatial relations between people and spaces, for examples the layout of a classroom, a whiteboard, or a door; and *Transitions* emphasizes on the integration of different spaces, including navigation, easy access and touch points. On the other hand,

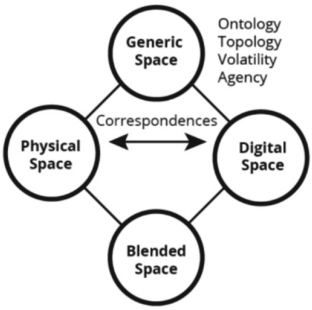

Fig. 2. Blended space framework by Benyon [26].

awareness, *control* and *interactions* deal with the contents of the spaces (people and activities). *Awareness* associates with the mindsets in both collaborative and individual activities, for example, the former requires shared attention, and the latter requires a divided one. *Control* refers to social control of group activities and technological control of software application. *Interaction* is concerned with the user interfaces, usability, accessibility and the articulation of the tasks during the interaction between people. In TACIT framework, each theme is elaborated as a separate theme; however, the relations among the five hybrid design themes are not fully addressed.

3.3 An Analytical Framework for Future Hybrid Creative Spaces: FHCS Framework

New concepts such as "hybrid campus" and "metaversity[1]" start to gain attention in recent years. According to Raes et al. [19], hybrid spaces have been explored and conceptualized in the literature, as well as experimented at a small scale, but it is still at its infancy and has yet to reach its potential as an effective medium facilitating learning process in higher educational institutions.

In this context, the authors develop an analytical framework for designing future hybrid creative spaces (FHCS framework) based on Benyon's *Blended Space model*. Figure 3 illustrates how FHCS framework can be applied to facilitate the design of creative spaces for learning. For the physical space, the authors focus on five types of creative spaces mentioned in Fig. 1. The digital space consists of more diverse forms, such as applications, data, actions and events. In the generic space, where characteristics are shared by both physical and digital spaces, four attributes (ontology, topology, volatility, and agency) [26] should be considered. In the hybrid/blended space, TACIT themes seem to be a relevant starting point for the development of a new spatial typology of future hybrid creative learning spaces. The FHCS framework also indicates that design tools from both physical and digital domains can be combined to support the design of hybrid creative learning spaces.

[1] A metaversity is a higher education university recreated as a digital twin utilizing virtual reality in the metaverse. https://www.victoryxr.com/metaversity.

Table 1. Five hybrid/blending themes (TACIT) explained by Benyon and Mival.

Hybrid/blending themes (TACIT)	Explanation	Example
Territoriality	Concerns spaces and the relationships between people and spaces	The layout of a classroom, a whiteboard, or a door
Awareness	Those practices through which actors tacitly and seamlessly align and integrate their distributed and yet interdependent activities	Given real time information of the status of the participant, or the progress of the task
Control	Control of the software systems and social control of the collaborative activity	The person who is in the control of the group activity might be closer to control panel of a touch screen
Interaction	Concerned with the user interfaces, with usability, accessibility and the articulation of tasks between collaborating individuals and groups	People shift from a group discussion to share a graph from their device
Transitions	Blended spaces are rarely completely integrated. Instead there are touch points where the digital and physical are brought together and where people transition from the digital to the physical or vice versa	A display screen shares the content from a wearable camera

To develop hybrid learning environments, it is not necessarily to create more space, but new qualities of space to accommodate the limited amount of space resource [28]. Subsequently, new typologies of teaching and learning spaces are to be investigated. In line with Benyon [26], through the FHCS framework, the authors propose a new spatial typology that is formulated by two sets of parameters, creative space types and hybrid design themes (see Fig. 4).

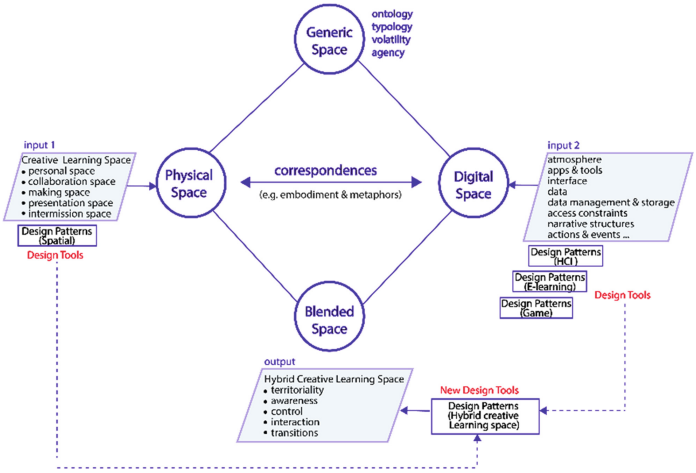

Fig. 3. FHCS framework adopted from Benyon & Mival's Blended space model [27]. It indicates the hybrid creative learning space can be designed with a new collection of design tools derived from both physical and digital spaces (Drawn by authors).

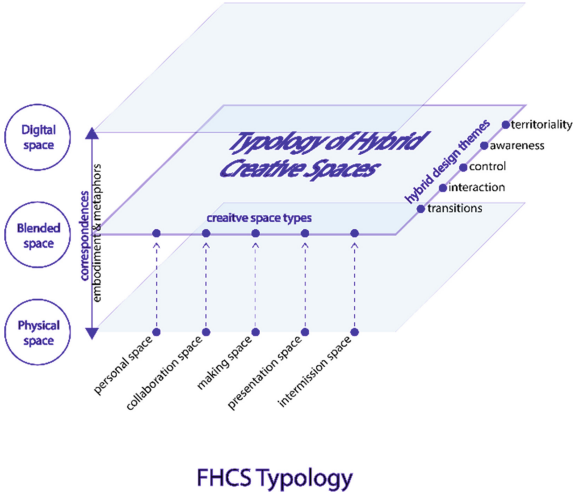

Fig. 4. FHCS Typology is formulated by two sets parameters, creative space types and hybrid design themes (Drawn by authors).

4 Research Approaches and Methods

The aim of the present research is to develop an analytical framework that integrates creative space types and blended space models (FHCS framework), in support of the design of future hybrid creative learning environments. The review of the literature has shown that many different social-spatial design solutions exist for both physical and digital spaces, and they have been systematically organized in a form of pattern

language. Identified pattern candidates are from various specific application domains, and they capture and represent design knowledge of experts. Therefore, the pattern language from Christopher Alexander et al. [2] seems an appropriate approach to bring together design guidance and tools from different disciplines, in a form that can be understood and shared across disciplines. Moreover, it can offer a connected network of design patterns that continues to grow and evolve through the knowledge and experience input from experts.

4.1 Design Pattern Research

The term design pattern refers to practical knowledge crafted by experts and transferred into different contexts and shared with others. Originally, the idea of formulating a language of patterns to describe open-ended solutions to specific problems comes from 'A Pattern Language' by Christopher Alexander [2] within a field of architecture and urban planning. This work provides many insights and applications beyond the initial field. The core of a design pattern can be seen as a local functional statement: "for problem P, under circumstances C, solution S has been known to work" [13]. Its method can also be applied to many types of complex system at different scales, where patterns and pattern languages serve as the building blocks and frameworks for the understanding and the design of systems [29].

Ten years after publication, Alexander's idea of pattern languages was adopted in the field of Software design and Human Machine Interaction design. Today Alexander's seminal work has greatly influenced many disciplines and domains, for example, game design, service design, collaboration, education, creative space, innovation, etc. Pattern language is recognized both a research tool and a practical tool to write out the explicit knowledge that lies in an area of a profession, and subsequently transferred into different contexts and shared with others.

Successful applications of pattern language can be found in the design of educational environments. For example, the project of Campus Eishin Gakuen in Japan is considered the most complete development of the pattern language by Alexander [30] and its generative process evolved with all stakeholders in the school. Thoring et al. [31] developed a design toolkit using pattern language approach to facilitate the design of creative spaces. It led to a result of "Idea Lab" which was co-created with all stakeholders by applying this toolkit. Kohl et al. [32] discuss good practices to create hybrid learning on campus by designing and connecting existing spaces at the computer science campus of TH Köln.

4.2 Pattern Mining

This discovering phase is referred as Pattern Mining, a term commonly used in the field of computer science, which describes a process focusing on identifying rules for specific patterns within the available data. This metaphor emphasizes the importance of discovering and analyzing the existing design structures and implicit knowledge of the experts from different perspectives. In order to establish a set of mining criteria

concerning contemporary issues on the topic, the authors have collected insights from the following sources:

- Reports of organizations on requirements for future hybrid learning environment, and potential solutions. For example, Hybrid Environments for Universities (an international and interdisciplinary expert manifesto 2020) [28].
- Expert interviews from six unique perspectives, design practice, design education, information technology, art, social media, and policy making.

In the process of identifying the relevant patterns, the findings from existing frameworks can be considered as driving factors. Using a mix of methods, the proto patterns are derived from seven relevant areas in literature: Architecture, spatial Design, HCI Design, Game Design, E-learning, Collaboration and Co-creation, and Creative Thinking and Innovation.

5 Results and Discussion

5.1 Design Requirements for Hybrid Creative Learning Spaces

In order to establish successful hybrid creative environments at educational institutions, insights are gathered from recent literature, organization reports, and expert interviews. In Table 3, the authors summarize important design requirements related to hybrid creative learning spaces.

5.2 Design Patterns for Hybrid Creative Learning Spaces

Through the pattern mining process, various pattern frameworks and many pattern candidates have emerged from the analysis. Most of these pattern frameworks include a reasonable number of patterns (in the range from 40 to more than 200), and follow a standard pattern format describing the *context, problems, solutions, examples* and *relation to other patterns* as well as their connectivity in the network.

A design pattern describes reoccurring problems or design challenges in a given context, many design instructions and design patterns resemble Alexander et al.'s Pattern Language approach. Potential patterns are mined from seven disciplines, they are architecture and urban planning [2, 34], spatial design [5–12], HCI design [35–40], game design [33, 41–43], E-learning [15, 17, 19, 32, 44–46], collaboration and co-creation [47–49], and creative thinking and innovation [49–53], in total 35 sources.

To mine related pattern frameworks and patterns from a large pool of selection, two rounds of screenings were conducted. The first screening was based on the design requirements for hybrid creative learning spaces, leading to more than 600 initial design pattern candidates derived from seven disciplines:

- Patterns in Architecture (22 pattern candidates)
- Patterns in Spatial Design (54 pattern candidates)
- Patterns in HCI Design (126 pattern candidates)
- Patterns in Game Design (166 pattern candidates)
- Patterns in E-learning (118 pattern candidates)

Table 3. Overview of design requirements for hybrid creative space for learning (Drawn by authors).

Design requirement	Explanation
Space as a platform or network for ideas	space or various platforms (physical, digital and social) to manifest ideas and support collaboration with diverse stakeholders; large space lets the mind expand and allows building and testing more and larger sized models; open resources
Social interaction, micro multination	creative people are more important than space, so space should facilitate meeting and exchange cross-location and cross-cultural
Human-centric, culture, and identity	Culture of spaces, reflect identity; symbolic aspects; share and communicate feeling and thoughts; evolve culture to the hybrid workplace, reinvent work models around a human-centric design and reinforce the connection of people with the organization's culture
Biophilic design	Window view, outdoor landscape, greenery, inspire creativity, let the mind relax and expand
Playful experimental atmosphere	Games, toys invite to experiment, risk- taking, and allow failure; integration of spaces and activities; positive energy and people
Software and hardware support	Integrate synchronous hybrid working and learning with proper hardware, software, staff training on technology adaptation
Flexible space, changeability	fixed or saved space; gradient space; flexible hours and locations
Ownership of space	Freedom; bring your own thing (BYOT), and personal IoT devices or wearables
Multi-sensory stimuli (visual, tactile, olfactory and acoustic)	Visible materials, books, and other information can inspire new ideas and increase creativity. materials, smells, cooking, and sound inspire creativity. Enhance or compromise visual and audio cues that is missing online
accessibility	Visibility; physical and digital accessible invites and encourage to create and to experiment; access to open source

(*continued*)

Table 3. (*continued*)

Design requirement	Explanation
integrating technology &Infrastructure	Infrastructure needs to guarantee connectivity, devices, and open access licenses. Support with technology and tools to enhance productivity; access to basic endpoint infrastructure; support information flow between physical and virtual workspaces, implement motion sensors and facial recognition
Space management	Space scheduling system. Mange integrity and risk. From data integrity and security to the reliability of internet connections. Activity coordination
Reduced stimulation, back to analogue	White space, empty space fosters creativity, invites people to project their own ideas into it
Bodily awareness and movement	Visible movement or own movement (e.g. walking, sports) facilitates creativity
Techiture	The amalgamation of technology and architectural elements
making spaces	Space that allows to make things manually fosters creativity
Creative labelling	designating a space for creative work, or historic creative surroundings can set a mood or mindset receptive for creativity

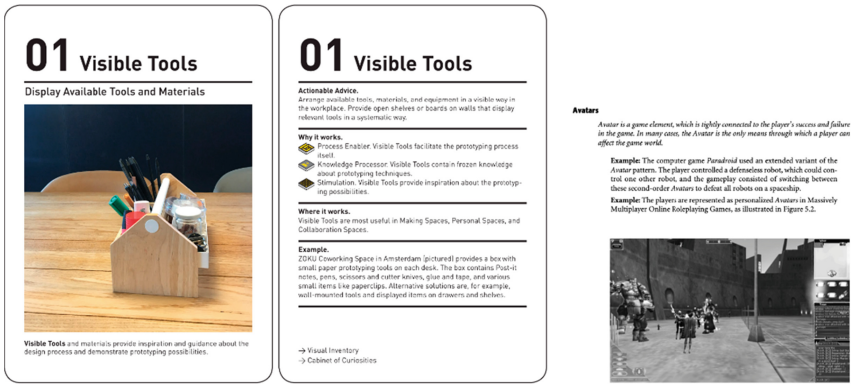

Fig. 5. Examples of pattern descriptions in standard format [10, 33]

- Patterns in Collaboration and Co-creation (46 pattern candidates)

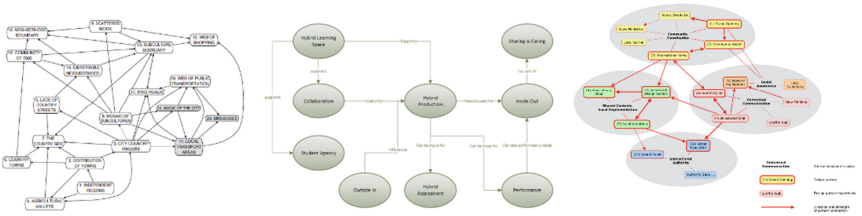

Fig. 6. Examples of pattern language networks [2, 8, 18]

- Patterns in Creative Thinking and Innovation (86 pattern candidates)

Given their relative importance and time restrictions, during the second round of screening, the authors put emphasis on the patterns that fit the following criteria:

- Relevant to hybrid social-spatial design.
- Relevant to creative process in educational contexts.
- Supported by empirical evidence.
- Completeness of the pattern language, including pattern descriptions, hierarchies of the patterns, and indication of the internal links among patterns.

In the category of Architecture and Urban Design, pattern candidates offer many classical architectural design guidelines, however they are not directly linked to hybridity or creative processes, therefore not efficient for hybrid creative environments. Although other categories, such as Collaboration and Co-creation, and Creative Thinking and Innovation, suggest useful patterns for social interaction and collaboration, they do not give any indication on spatial design. A as consequence, these categories are not part of this study. As a result, 323 patterns candidates (or proto patterns), are derived from four disciplines (Spatial Design, HCI design, E-learning, and Game Design).

- Patterns in Spatial Design: 49 pattern candidates [10]
- Patterns in HCI Design: 112 pattern candidates [36, 39]
- Patterns in Game Design: 126 pattern candidates [43]
- Patterns in E-learning: 36 pattern candidates [46]

Figure 7 shows the hierarchy of the proto patterns in their original clusters and sub-clusters. They can be explained using established theories and are commonly built on an empirical basis, for example, pattern candidates from Game Design [43] were formulated based on the players' experiences in various popular video games, and those from Spatial Design [10] were implemented and evaluated through the real site project "the Idea Lab". Because of the diversity and richness in content, proto patterns presented in this study can be considered as a starting point for developing a pattern language of hybrid creative learning spaces.

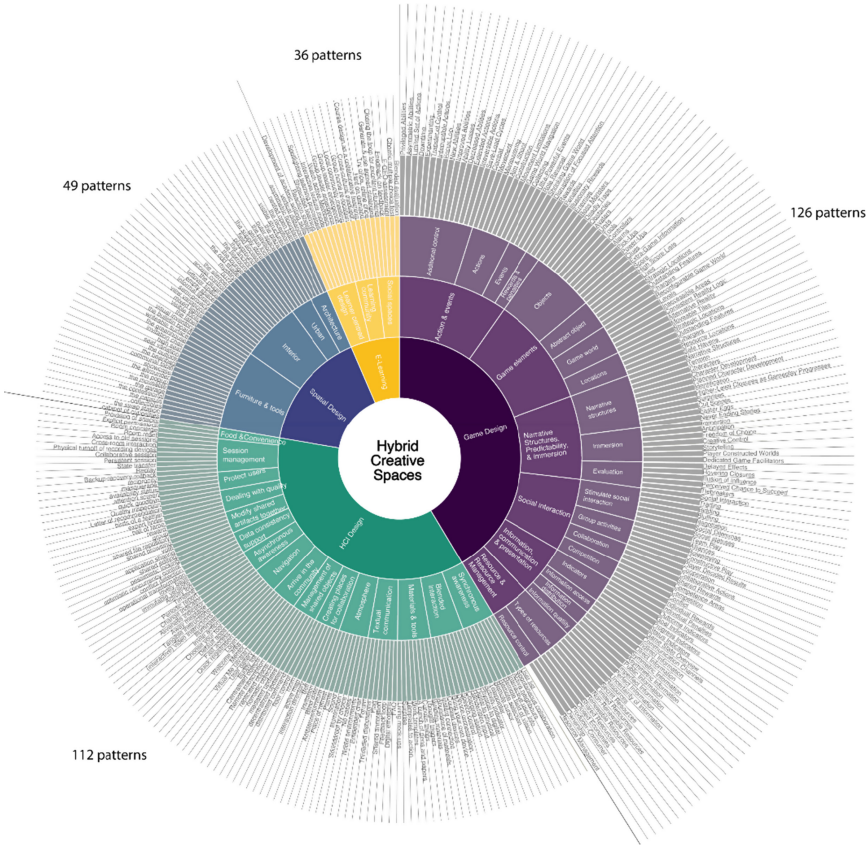

Fig. 7. 323 proto patterns from four disciplines (Spatial Design, HCI design, E-learning, and Game Design), organized in their original clusters and sub-clusters (Drawn by author).

After a further analysis of the proto patterns' possible application, 13 generic pattern clusters have evolved. In Fig. 8, the 13 pattern clusters have been mapped in relation to hybrid design themes, whereby 6 clusters are located at the intersection of two different hybrid design themes, they are *group support, resource and resource management, community support, base technology, blended interaction, narrative structures, predictability* and *immersion.* It suggests that potential links between the five hybrid design themes that yet fully addressed by Benyon et al. can be further investigated. In addition, the pattern clusters at the intersection may play important roles in the whole network of pattern language of hybrid creative learning spaces. For example, they might be the core pattern clusters that influence other clusters in the network; or act as bridges that must be crossed to reach other pattern clusters. However, these hypotheses need to be verified in the future study.

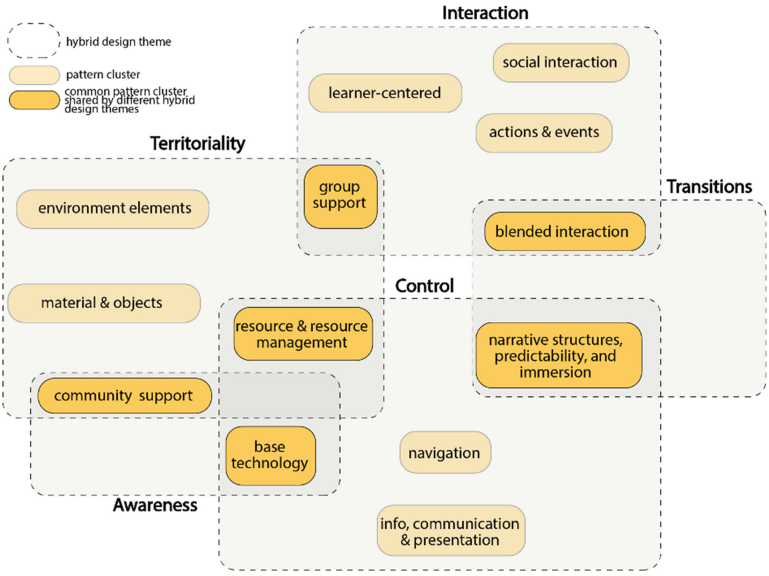

Fig. 8. Five hybrid design themes and how they are addressed by 13 generic pattern clusters proposed in this study (Drawn by author).

6 Conclusion and Future Work

To design future hybrid creative learning spaces, this ongoing research project aims to develop a FHCS framework that addresses design issues from both physical and digital spaces, as well as to use a pattern language approach to bring together useful design guidance and tools from different disciplines. Moreover, this project could grow into a network that continues to extend and evolve with the input of knowledge and experiences from experts. Based on current findings, the proto patterns collected from four disciplines have proven their validity in the original context, and combing them offers a huge potential for solving problems that might not easily be solved in isolation, which is also in line with the interdisciplinary approach encouraged by many architects and pattern language theorists [29, 54–56]. However, the proto patterns have to be transformed or updated for hybrid creative spaces, based on the FHCS framework. Future work will include the evaluation and validation of the patterns, and the analysis of their connections. The following actions are currently planned:

1. Development of a spatial typology for hybrid creative environments and its implementation into the blended space framework.
2. Multi-case study in three design institutions (UK and Belgium), including interviews and observations of their creative learning spaces.
3. Network analysis on proto patterns to identify their new links, and evaluation of the links through a focus group.
4. Pattern writing workshop (focus group workshop) with experts.

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References

1. Mütterlein, J., Fuchs, C.: Digital technologies and their influence on spaces. In: Proceedings of the 23rd Pacific Asia Conference on Information Systems: Secure ICT Platform for the 4th Industrial Revolution, PACIS (2019)
2. Alexander, C., Ishikawa, S., Silverstein, M.: A Pattern Language: Towns, Buildings, Construction. Oxford University Press, New York (1997)
3. Asheim, B., Coenen, L., Vang, J.: Face-to-face, buzz, and knowledge bases: sociospatial implications for learning, innovation, and innovation policy. Environ. Plan. C Gov. Policy **25**, 655–670 (2007)
4. Melhuish, C.: Architecture and Anthropology, Architectural Design Profile 124. Academy Editions, London (1996)
5. Wycoff, J., Snead, L.: Stimulating innovation with collaboration rooms. J. Qual. Particip. **22**(2), 55–57 (1999)
6. Dillon, P., Loi, D.: Adaptive educational environments: theoretical developments and educational applications. UNESCO Observatory Refereed E-Journal **3** (2008)
7. Moultrie, J., Nilsson, M., Dissel, M., Haner, U., Janssen, S.: Innovation spaces: towards a framework for understanding the role of the physical environment in innovation. Creativity Innov. Manag. **16**(1), 53–65 (2007). https://doi.org/10.1111/j.1467-8691.2007.00419.x
8. Luz, A.: The [design of] educational space: a process-centred built pedagogy. In: DS 46: Proceedings of E&PDE 2008, the 10th International Conference on Engineering and Product Design Education, pp. 339–344 (2008)
9. Bustamante, F.O., Reyes, J., Camargo, M., Dupont, L.: Spaces to foster and sustain innovation: towards a conceptual framework. In: 2015 IEEE International Conference on Engineering, Technology and Innovation/International Technology Management Conference, ICE/ITMC (2015). https://doi.org/10.1109/ICE.2015.7438661
10. Thoring, K., Mueller, R., Desmet, P., Badke-Schaub, P.: Design principles for creative spaces. In: DS 92: Proceedings of the DESIGN 2018 15th International Design Conference, pp. 1969–1980 (2018). https://doi.org/10.21278/IDC.2018.0233
11. Mäkelä, T., Leinonen, T.: Design framework and principles for learning environment co-design: synthesis from literature and three empirical studies. Buildings **11**(12), 581 (2021). https://doi.org/10.3390/buildings11120581
12. Mor-Avi, A., Scott-Webber, L.: Creativity flourishes using hybrid space patterns. In: Gil, E., Mor, Y., Dimitriadis, Y., Köppe, C. (eds.) Hybrid Learning Spaces, pp. 233–248. Springer, Cham (2022). https://doi.org/10.1007/978-3-030-88520-5_13
13. Kohls, C., Wedekind, J.: Investigations of E-Learning Patterns: Context Factors, Problems and Solutions (2010). https://doi.org/10.4018/978-1-60960-144-7
14. Kohls, C.: Hybrid learning spaces for design thinking. Open Educ. Stud. **1**, 228–244 (2019). https://doi.org/10.1515/edu-2019-0017
15. Kali, Y.: Collaborative knowledge building using the Design Principles Database. Int. J. Comput. Support. Collaborative Learn. **1**(2), 187–201 (2006). https://doi.org/10.1007/s11412-006-8993-x
16. Mor, Y., Winters, N.: Design approaches in technology-enhanced learning. Interact. Learn. Environ. **15**(1), 61–75 (2007). https://doi.org/10.1080/10494820601044236

17. Mor, Y., Mellar, H., Warburton, S., Winters, N.: Practical Design Patterns for Teaching and Learning with Technology. Sense Publishers, Rotterdam (2014). https://doi.org/10.1007/978-94-6209-530-4
18. Köppe, C., Nørgård, R.T., Pedersen, A.Y.: Towards a pattern language for hybrid education. In: Proceedings of the VikingPLoP 2017 Conference on Pattern Languages of Program, pp. 1–17. Association for Computing Machinery, New York (2017)
19. Raes, A., Detienne, L., Windey, I., Depaepe, F.: A systematic literature review on synchronous hybrid learning: gaps identified. Learn. Environ. Res. **23**(3), 269–290 (2019). https://doi.org/10.1007/s10984-019-09303-z
20. Goodyear, P.: Design and co-configuration for hybrid learning: theorising the practices of learning space design. Br. J. Edu. Technol. **51**(4), 1045–1060 (2020). https://doi.org/10.1111/bjet.12925
21. Thoring, K., Gonçalves, M., Mueller, R., Desmet, P.: The architecture of creativity: toward a causal theory of creative workspace design. Int. J. Des. **15**(2), 17–36 (2021)
22. Lefebvre, H.: The Production of Space, 1st edn. Wiley-Blackwell, Hoboken (1992). https://doi.org/10.4324/9781315565125-7
23. Cicognani, A.: Thinking beyond. In: 14th eCAADe Conference Proceedings on Education for Practice, pp. 87–98 (1996). https://doi.org/10.52842/conf.ecaade.1996.087
24. Milgram, P., Kishino, F.: A taxonomy of mixed reality visual displays. IEICE Trans. Inf. Syst. **E77-D**(12), 1–15 (1994)
25. Turner, M., Fauconnier, G.: The Way We Think: Conceptual Blending and the Mind's Hidden Complexities. Basic Books, New York (2002)
26. Benyon, D.: Presence in blended spaces. Interact. Comput. **24**, 219–226 (2012). https://doi.org/10.1016/j.intcom.2012.04.005
27. Benyon, D., Mival, O.: Blended spaces for collaboration. Comput. Support. Coop. Work: CSCW: Int. J. **24**(2–3), 223–249 (2015). https://doi.org/10.1007/s10606-015-9223-8
28. Ninnemann, K., et al.: Hybrid Environments for Universities. Waxmann, New York (2020). https://doi.org/10.31244/9783830991793
29. Leitner, H.: Pattern Theory: Introduction and Perspectives on the Tracks of Christopher Alexander. CreateSpace, Graz (2015)
30. Alexander, C., Neis, H., Alexander, M.: The Battle for the Life and Beauty of the Earth: A Struggle Between Two World-Systems, Center for Environmental Structure Series, 1st edn. Oxford University Press, Oxford (2012)
31. Thoring, K., Muller, R., Luippold, C., Desmet, P., Badke-Schaub, P.: Co-creating an idea lab: lessons learned from a longitudinal case study. CERN J. Exp. Innov. **2**, 30–37 (2018). https://doi.org/10.23726/cij.2018.743
32. Kohls, C., Dubbert, D., Münster, G.: Patterns for a hybrid campus. In: Gil, E., Mor, Y., Dimitriadis, Y., Köppe, C. (eds.) Hybrid Learning Spaces, pp. 249–263. Springer, Cham (2022). https://doi.org/10.1007/978-3-030-88520-5_14
33. Nystrom, R.: Game Programming Patterns, 1st edn. Genever Benning (2014)
34. Mehaffy, M., Kryazheva, Y., Rudd, A., Salingaros, N.: A New Pattern Language for Growing Regions: Places, Networks, Processes. Sustasis Foundation (2020)
35. Streitz, N.A., Geißler, J., Holmer, T., Konomi, S.: i-LAND: an interactive landscape for creativity and innovation. In: Conference on Human Factors in Computing Systems - Proceedings, pp. 120–127 (1999). https://doi.org/10.1145/302979.303010
36. Kohls, C., Munster, G.: Designing hybrid spaces for creative work. In: Pursuit of Pattern Languages for Societal Change 2017: A Comprehensive Perspective of Current Pattern Research and Practice, pp. 242–265 (2018)
37. Barfield, W., Hendrix, C., Bjorneseth, O., Kaczmarek, K., Lotens, W.: Comparison of human sensory capabilities with technical specifications of virtual environment equipment. Presence **4**, 329–356 (1995). https://doi.org/10.1162/pres.1995.4.4.329

38. Macintosh Human Interface Guidelines, 2nd edn. Addison-Wesley Professional (1993)
39. Schümmer, T., Lukosch, S.: Patterns for Computer-Mediated Interaction. Wiley, West Sussex (2007)
40. Borchers, J.O.: A pattern approach to interaction design. AI & Soc. **15**, 359–376 (2001). https://doi.org/10.1007/BF01206115
41. Barney, C.: Pattern Language for Game Design. CRC Press, Boca Raton (2020). https://doi.org/10.1201/9781003119029
42. Antonaci, A., Klemke, R., Specht, M.: Towards design patterns for augmented reality serious games. In: Brown, T.H., van der Merwe, H.J. (eds.) mLearn 2015. CCIS, vol. 560, pp. 273–282. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-25684-9_20
43. Björk, S., Holopainen, J.: Patterns in Game Design. Charles River Media, Boston (2004)
44. Georgiakakis, P., Dimitriadis, Y.: Eliciting design patterns for e-learning systems. Comput. Sci. Educ. **16**(2), 105–118 (2006)
45. Goodyear, P.: Educational design and networked learning: patterns, pattern languages and design practice. Australas. J. Educ. Technol. **21**(1), 82–101 (2005)
46. Hayashi, K., Shibata, S., Inoue, N., Adachi, S., Iba, T.: Online education patterns, part 1: patterns for linking separate worlds. In: 26th European Conference on Pattern Languages of Programs (EuroPLoP 2021), pp. 1–16. Association for Computing Machinery, New York (2022). https://doi.org/10.1145/3489449.3490003
47. Iba, T.: Collaboration Patterns - A Pattern Language for Creative Collaborations. CreativeShift Lab, Yokohama (2014)
48. Dubbert, D., Kohls, C.: Patterns for ad-hoc online collaboration. In: 26th European Conference on Pattern Languages of Programs (EuroPLoP 2021), pp. 1–16. Association for Computing Machinery, New York (2022). Article 12. https://doi.org/10.1145/3489449.3489984
49. Kohls, C.: Patterns for innovation: 6 patterns for idea implementation. In: Proceedings of the 24th European Conference on Pattern Languages of Programs (EuroPLoP 2019), pp. 1–8. Association for Computing Machinery, New York (2019). Article 7. https://doi.org/10.1145/3361149.3361156
50. Manns, M., Rising, L.: Fearless Change: Patterns for Introducing New Ideas. Addison-Wesley, Boston (2005)
51. Yoshikawa, A., Iba, T., Mori, H.: A pattern language for designing innovative projects: project design patterns. Int. J. Entrep. Small Bus. **36**(4), 491–518 (2019). https://doi.org/10.1504/IJESB.2019.10020373
52. Kohls, C.: Patterns for creative thinking: idea generation. In: Proceedings of the 20th European Conference on Pattern Languages of Programs (EuroPLoP 2015), pp. 1–11. Association for Computing Machinery, New York (2015). Article 30. https://doi.org/10.1145/2855321.2855352
53. Kohls, C.: Creativity patterns: 5 habits. In: Proceedings of the 10th Travelling Conference on Pattern Languages of Programs (Viking PLoP 2016), Leerdam, The Netherlands (2016). https://doi.org/10.1145/3022636.3022645
54. Alexander, C.: The Nature of Order: An Essay on the Art of Building and the Nature of the Universe. Center for Environmental Structure, Berkeley (2002–2005)
55. Salingaros, N.: The structure of pattern languages. ARQ – Architectural Res. Q. **4**, 149–161 (2000)
56. Neis, H.: From a pattern language to a field of centers and beyond: patterns and centers, innovation, improvisation, and creativity. In: Stark, W., Vossebrecher, D., Dell, C., Schmidhuber, H. (eds.) Improvisation und Organisation: Muster zur Innovation sozialer Systeme, pp. 143–166 (2015)