Research Article

Christian Kohls*

Hybrid Learning Spaces for Design Thinking

https://doi.org/10.1515/edu-2019-0017 received March 11, 2019; accepted November 11, 2019.

Abstract: As design thinking becomes more and more important in higher education, we need to think about ways to enable educators and students to learn about the concepts and apply them to their own projects. One approach is to create hybrid learning spaces with tools that support design thinking and offer affordances for the various methods, ways of working and thinking. Hybridity dissolves existing dichotomies such as physical-digital, formal-informal, learning-teaching and individual-collective. This article introduces design principles and patterns to develop such spaces for university campuses. We will describe how we identified, applied and tested them. Based on these findings we can provide recommendations for planning new hybrid spaces for design thinking at other universities.

Keywords: Design thinking; blended space; design patterns.

1 Introduction

1.1 Spaces for design thinking at universities

Innovation is an integral part of higher education. The ability to innovate is expected both from research and teaching. Research should generate new and original knowledge. New forms of teaching and learning are required to fit the needs of a modern and progressing society. In addition, a university should prepare its graduates for work life. They should develop creative thinking and problem solving skills as a key competence. In this context, design thinking is a holistic approach to problem-solving, innovation and development work. It combines analytical phases, such as deep understanding, observation, testing, and integrating multiple views,

*Corresponding author: Christian Kohls, Cologne Institute for Digital Ecosystems, TH Köln, Cologne, Germany, E-mail: christian.kohls@th-koeln.de with synthetic phases, such as ideation, exploration, prototyping or storytelling. It is based on practical tools and normative principles, including lateral thinking, cross-disciplinary collaboration, experimenting and tinkering, participation, co-creation and holistic problem analysis, putting human needs into the center of interest (Brown, 2009; Plattner, Meinel & Weinberg, 2009). Taking these values into account, more and more disciplines consider design thinking as a key competence for problem-solving and innovation.

In the context of university teaching, students should learn, understand, experience and use design thinking for their own projects. Moreover, students should transfer their design thinking skills to other work contexts. Thus, we need to empower students to use the methods and apply the principles and norms of design thinking. The creation of dedicated spaces for design thinking can foster the development of such competences because it becomes easier to apply and experience the methods as part of project work.

To create such spaces at universities, we were looking for guiding design principles and patterns in existing educational spaces. We believe that spaces for design thinking need to bridge seamlessly between different modes, such as working in the physical and digital space, planning, building and testing, switch between academic and non-academic approaches, and enable participation of experts and users both onsite and online. This hybridity can be achieved by blending different space concepts (Benyon & Mival, 2015), such as physical, digital, informational, conceptual, social and navigational space. For example, digital projections can augment physical objects with additional information, different textures or user interfaces. Thus, exploration, creation, prototyping and testing happens in physical and digital space. Iterations can be performed more rapidly due to the digital support.

This paper is organized as follows. First, we will define design thinking for this context. It is important to understand the specific values, principles and processes that guided us in planning the hybrid learning spaces. Section 2 describes our planning approach. We will define goals, explore hybridity and discuss design patterns

as tools for planning. Section 3 discusses the resulting ecosystem of workspaces, tools and components. Section 4 evaluates the usage of the different spaces based on tracking, interviews and written reports. Section 5 provides a conclusion and recommendations.

1.2 Design thinking

The term design thinking is now commonly used for many different things. It covers different norms, values and processes. To set the stage for the succeeding sections, we want to clarify the understanding of design thinking we used when we created the learning spaces.

Design thinking is a holistic approach that involves many stakeholders in a co-creative way and combines analytical and intuitive mindsets. The iterative process offers solutions to complex and wicked problems and enables systematic innovation (Meinel & von Thienen, 2016; Uebernickel, Brenner, Pukall, Naef, & Schindlholzer, 2015).

For us design thinking means "thinking in design" or "thinking with design." Creating new forms is a way of thinking and reflecting about both the solution and the problem space. Design thinking enables "reflection through action" (Hestad, Groenly & Rigoni, 2017) and allows a conversation with the artefact (Cross, 2011). It is an explorative process of embodied thinking that amplifies the creative powers of individuals (Brown, 2009).

We can define design as "creative problem solving" under the conditions of bounded rationality (Rowe, 1990). A problem exists if an organism wants to achieve something but the actions necessary to obtain it are not immediately obvious (Thorndike, 1931). There are welldefined, ill-defined and wicked problems (Churchman, 1967). Wicked problems are hard to solve because of "incomplete, contradictory, and changing requirements that are often difficult to recognize" (Rittel, 1972).

For well-defined problems we can derive solutions simply by satisfying a set of requirements. However, most problems are at least ill-defined. That is, we do not know all requirements and our understanding of the problem space is incomplete. Even if we understand the problem space as it is, each solution will change the problem space. For example, cars solve the problem of individual transportation. However, they have complex consequences such as requiring an infrastructure (highways, gas stations) and impacting our environment (pollution, accidents, noise).

Exploring and testing different solutions using prototypes allows us to anticipate the effects of a solution and evaluate the impact on the problem space. Creating a prototype will refine the problem definition and reveal hidden problems. Thus, we use design as a systematic way of problem solving. A good solution is one that satisfies the needs of the environment, it is a fit between context and form (Alexander, 1964). Following Herbert Simon's theories on problem solving, information processing and his science of the artificial (Simon, 1969) and Christopher Alexander's formal theories on pattern languages (Alexander, 1979), design thinking has been popularized by design theorists (Rowe, 1987; Cross, 2011), design agencies such as IDEO (Kelley & Littman, 2001) and engineering schools such as the Stanford School of Engineering or the Hasso Plattner Institute in Potsdam (Plattner, Meinel & Weinberg, 2009).

1.3 Normative values and the design thinking process

Design thinking is both culture and process. The last section showed that design thinking tries to achieve a good fit between the solution and the problems of a context. Thus, design thinking is not only about creating products or services. It is a holistic approach that requires a deep understanding of the field in order to satisfy the needs of an environment, including hidden or emerging problems. Thus, in the literature about design thinking, we frequently find a set of normative values, principles and actions such as lateral thinking, cross-disciplinary collaboration, experimentation and tinkering, failing fast in order to improve, storytelling, participation, co-creation and holistic problem analysis. Human needs are put into the center of interest. Insight is achieved by observation and empathy. Co-creation means to create together with users rather than for users.

While this mindset may already be a better approach to design, there is also an iterative process that supports the goal. In order to find a fitting solution (and subsolutions), we need to create alternatives and select the best fits. These candidates need to be checked and tested, and then refined.

A systematic process blends both analytical and synthetic phases (Brown, 2009). Deep understanding, observation and research, integrating multiple points of view, and testing are mainly analytical tasks. Ideation, tinkering and prototyping are rather synthetic phases. Design thinking integrates diverse methods for creative thinking and innovation and iterates often through the following steps (Plattner, Meinel & Weinberg, 2009): understanding and observation, aggregation (to a point of view) and ideation, prototyping and testing.

While each step depends on the others, it is not a linear process. For example, during the ideation phase, a team may find that further research is required. Likewise, during the prototyping phase it is common that further ideation is needed or newly discovered problem areas need to be explored.

The benefit of such a model is that we can identify specific methods for each of the phases. Moreover, we can identify tools that support the process. Both methods and tools are important when we create spaces and select equipment for design thinking. Such spaces should stimulate and support each of the methods and provide the required tools.

2 Planning Hybrid Spaces for Design Thinking

2.1 Goals

The hybrid learning spaces are linked to certain strategic and operational objectives, which relate both to the university context and to social development – for example, to enable social innovation or social entrepreneurship. At the strategic level, the main goal is to increase the creativity and the innovative potential of student projects. An innovation space should facilitate methodological skills, enable interdisciplinary encounters, and support design thinking. Another goal is to intensify the student's identification with their own university as a place of innovation. Nowadays collaborative learning formats are the main reason for the on-campus encounter because learning materials are available digitally and can be used from home or on the road off-campus. The spaces should therefore be extraordinary places that offer opportunities not available at home.

At the operational level, the spaces should promote project-based and skill-driven learning. They should establish a result oriented on "maker culture" and support playful approaches to the development or mediation of serious content. Interior design in academic teaching contexts is important to foster team-oriented, self-directed and informal learning (Kohlert & Cooper, 2017). The Horizon Report (Adams Becker et al., 2017) picked up this topic in recent years again and again under the themes "Maker Space", "Bring your own device", and "Redesigning learning spaces."

2.2 Hybridity and the blending of spaces

The term hybrid space (or blended space) refers to an interplay of different spaces, such as the physical, digital, informational, conceptual and social space (Benyon, 2014). Blending such spaces is more than just adding the functions of each (not just "best of both worlds"). We believe that entirely new scenarios for creative and collaborative work emerge (that is we enter "new worlds").

There are several domains where blended spaces can be beneficial, including collaboration, education, tourism, or museums (O'Keefe & Benyon, 2015). In particular, blended spaces support hybrid education. Hybrid education aims at dissolving the dichotomies within education such as physical-digital, academic-nonacademic, online-offline, formal-informal, learning-teaching and individual-collective (Köppe, Nørgård, & Pedersen, 2017).

By resolving such dichotomies, one can bridge seamlessly between different types of artifacts, making digital data touchable and graspable, enhancing physical objects with digital information and digitizing physical objects. To get a better understanding how hybridity helps to support the design thinking process, let us consider the different design thinking phases along with their methods and required tools.

Understanding and Observation: One can use common methods of science and research to get a deep understanding. Systematic observation of what happens in the field of interest includes questions such as how do people act, what are the processes, what are common pitfalls? Quantitative surveys, qualitative interviews, and ethnographic methods are used to get a deep understanding. Hybrid spaces support field research by recording, organizing and using information from many resources. For example, smartphones can be used to observe behavior in the field, capture data, run interviews etc. The data can be stored individually or in team folders. When a design team meets on-campus, they should have access to all data and share information, for example by showing results, videos, and open questions on large interactive displays. Moreover, there should be low-threshold ways to use and expand the data in design sessions on-campus.

Aggregation and Ideation: Information can be clustered, filtered, and combined. Existing solution can be analyzed. Each part of an existing concept can be substituted, changed, eliminated or transformed. There are many collections of creativity methods, techniques and tools that describe such operations (DeBono, 1990; Michalko, 2006; Foster, 2007; Kumar, 2012). Methods

include the generation of new ideas by combining existing ones, changing perspectives, using random impulses as thought triggers, changing features in a systematic way, and using ideas from different contexts. Digital tools enable students to restructure information and save different versions easily. Many ideation tools are available both as physical and digital versions. When a team meets on campus, the physical tools are often more playful and allow better collaboration. However, there needs to be a way to easily save work results and capture alternatives for follow-up sessions.

Prototyping and Testing: Prototypes are an important vehicle to test ideas early using simple models. Exploring concepts or models that have impact on the real world on a theoretical level will not show all effects of their practical realization. It is hard to imagine how the objects feel and operate in the real world. Very often there are hidden side effects that can only be seen if the real artefact is tested. Design thinking suggests that creators should have a "conversation" with prototypes to test their real properties. Prototypes can be created in the physical world. Digital tools can be used to capture the results and the process. Likewise, prototypes can be edited and planned in the digital world (3D editing, storyboards, screen design) and then be tested in the physical world (3D printouts, playthrough or click-through).

2.3 Target user group

The hybrid spaces are planned for a campus of the computer science and engineering faculty. The campus runs Bachelor and Master courses for different fields of computer science and engineering. About a third of the curriculum consists of project work. Most projects are run by small student groups of 3-6 students. At the moment, most spaces on campus are classic lecture halls, seminar rooms, or workshop rooms. While these spaces are working fine for traditional teaching of larger groups of 20, 50 or even hundreds of students, there is a lack of spaces for project-based work. Projects often involve design activities, such as app design, planning and construction of machines, or developing new technical concepts, algorithms and business models. Thus, there is a need for more project rooms that are optimized for design-based work and research. The hybrid spaces will be mainly used by professors of software design, product engineering and economy. They are available to all lecturers and staff members of the campus and they can assign time slots to their student groups. Students should

be able use the spaces on their own if they are enrolled to a course with design activities. A project usually runs for 3-4 months throughout one semester. It is recommended that the spaces are booked at least for half a day or for a full day. Students and professors are encouraged to book the spaces for a full week to enable a design sprint.

2.4 Design patterns to plan hybrid spaces

We were looking for working and new solutions for our hybrid spaces using the design pattern approach. A design pattern describes a generative solution to a common problem and justifies the design decisions (Alexander, 1979). In many cases general principles can be used to explain the specific actions or configurations of a pattern. Thus, a pattern provides specific guidance how to solve a problem and explains why the solution works. Identifying and documenting such design patterns is called pattern mining. There are different approaches for pattern mining (Kohls & Panke, 2009). We used a mix of inductive and deductive methods:

- Deriving requirements and factors from frameworks;
- Analysis of existing good practices for interior design at other universities;
- Visits to tradeshows and exhibitions, browsing product brochures, exploring existing rooms;
- Testing of classic and digital tools in our own spaces;
- Participatory design sessions with later users of the space (students, docents);
- Evaluation of different design options with mockups.

In total we identified more than 80 patterns (Kohls & Köppe, 2017; Kohls & Münster, 2018). Some example patterns are: thought triggers to nudge new ideas, interactive whiteboards and walls to elaborate large structures, tools to capture the design process, accessible work materials, playful elements, canvas templates, method cards, design cards, access without login, orchestration of devices, and digital counterparts of tools.

The patterns have proven to be an excellent planning and communication tool for hybrid spaces (Kohls, 2018). They help justifying design decisions and explain which qualities are achieved. For example, the use of Lego bricks and innovation card games in our design spaces first confused some people. The patterns, however, explain what has driven the use of these elements: their combinatory qualities to explore, the playfulness to challenge assumptions, and their inspiring potential. Based on the patterns we planned the configuration of an

232 — Christian Kohls

DE GRUYTER



Figure 1: Ecosystem of workspaces for design thinking: innovation space (top left and center), planning space (top right), thinker space (bottom center), and open education space (bottom left and right).

ecosystem of spaces: an innovation space, a thinker space, a maker space, a planning space and an open educational space in a shopping mall.

2.5 Pattern categories

The identified patterns can be characterized and clustered into categories of different problem groups: work materials and tools, atmosphere, session management, navigation and blended interaction (Münster & Kohls, 2017). The first category is about the materials and tools that should be available in creative spaces. Boxes with work materials are frequently found in design thinking contexts. The space should provide several Thought Triggers that provide impulses for ideas. Examples are random images, story cubes, and stimulus words both in physical and in digital form. For visualization, we provide Pens and Paper as well as digital tablets and interactive whiteboards. **Curious Things** are unusual objects to stimulate lateral thinking. Furthermore, various Work Templates (e.g., business model canvas, storyboard sheets) should be provided.

The atmosphere of the space also plays a special role in creative work. For this reason, we have identified many patterns in the physical space, such as **Ambience**, **Plants**, or **Extraordinary Furniture**. **Extraordinary Furniture** suggests the use of high quality, extraordinary

and functional furniture and surfaces. We also need a **Place of Retreat**, where participants can relax and let the mind wander (for incubation of ideas).

Session Management requires solution patterns to save sessions, restore them and take them into other (physical) spaces seamlessly, i.e., the transfer is automatically supported by cloud-based solutions that can show the same content in different spaces. If a group of students returns to the space a week or a month later, they should continue to work where they stopped. Hence, devices should offer such a possibility. We plan an ecosystem of workspaces, so we need Cross-room Interaction, i.e., a way to transfer sessions between rooms.

Blended interaction is concerned with solutions that enable a seamless integration of the physical and digital world (Kohls et al., 2018). The pattern **Physical to Digital** covers physical actions and artefacts that can be digitized immediately. The complementary pattern is **Digital to Physical**. Objects created in the digital space should not remain only digital but are brought into the real world. Examples are projections onto physical objects, walls or on the floor, the printing with photo or 3D printers, as well as the controlling of robots or Raspberry Pi modules. Rooms that contain several digital devices need some means to connect them and share data (**Device Orchestration**), for example sending brainstorming items from smartphones to interactive walls. We can connect devices to larger units

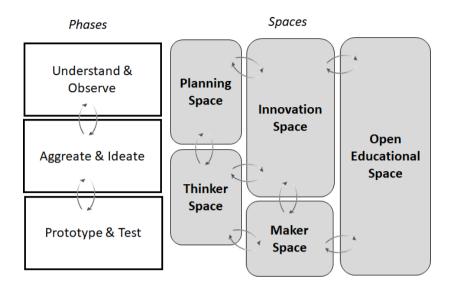


Figure 2: Planned model for the interplay of spaces.

of Coupled Devices. This way several independent devices can be connected to form a larger contiguous workspace.

3 Creating Hybrid Work Spaces and **Building their Equipment**

3.1 Ecosystem of workspaces

The need for different spaces for the various activities is based on the pattern **Ecosystem of Workspaces** (Quillien, 2012) and the design principles for creative spaces (Kohlert & Cooper, 2017). Quillien's Ecosystem of Workspaces highlights that a vivid work environment consists of interplaying spaces that serve different functions such as focused individual work, team work, informal collaboration and formal meetings. She explains how workspaces can enable thought. Kohlert & Cooper (2017) propose that creative spaces should foster wellbeing, collaboration, concentration, and rejuvenation. They explore how materials and haptics, shapes and color, natural elements, tools and furniture contribute to creative thinking, different modes of learning and how they afford social interaction. The configuration of space invites and favors specific activities and modes of thinking. As discussed in section 2.3, design thinking typically dances between different phases: understanding and observation, aggregation and ideation, prototyping and testing. These phases overlap and design teams should move back and force between the phases seamlessly. An ecosystem of workspaces for design thinking should provide places that are optimized for each of the phases. At the same time each space should be functional for all phases, allowing rapid switches between the different work modes. Moreover, we need ways to transfer and access research results, materials, information, ideas, designs, concepts, prototypes, etc. seamlessly between different spaces. This calls for a hybridity where information and work-in-progress designs are not only available locally but transcendent several spaces.

To understand a problem domain, each space is equipped with interactive whiteboards to collect and aggregate research data. Storing information digitally allows a transfer between different spaces. In the phase of understanding and observation, the organization of data is critical. Hence, we have created a planning space that focusses on data collection and planning. It offers a large interactive wall to show, organize and map concepts and findings. Active ideation is supported in each of the spaces, however there is one innovation space that is equipped with hundreds of tools for idea generation. Next door to this space, we find a thinker space. This space is for incubation (ideation through relaxing) and reflection about current design states. Having another interactive whiteboard in this space allows to share results from the other spaces. The phase of prototyping and testing is supported by a maker space equipped with building materials, digital components, and 3D printers. All spaces are on the same floor. For early testing and feedback on prototypes we have installed an open educational space in a shopping mall that supports both co-creation and public presentation. Physical artifacts can be easily transferred from one space to another. Digital artifacts can be created, edited and shown in each of the spaces. The open educational space is in a five-minute walking distance from the campus. The specific configuration of the spaces is based on the patterns presented in the previous section.

Planning space: This spaces is best used for understanding and observing a problem domain. It has a bar table and a 5-meter interactive wall. The attached computer runs a cloud-based software for digital sticky notes (Access to Old Sessions). A team can add information such as data, pictures, sketches, findings, brainstorming items etc. both remotely and being on-campus. Thus, students can do field research and share their data on a large unbound work space (Physical To Digital). When they meet on campus they can compare, cluster and aggregate the information.

Innovation space: This space is at the core of design thinking. It can be used for all phases with a focus on ideation and prototyping. It provides a mixture of physical and digital tools, and supports different methods and social forms (Thought Triggers and Curious Things). At the center of the space is a large height-adjustable table. This table is the stage for new ideas and invites collaboration. One wall has an open cabinet with an abundance of work materials, Lego bricks, cardboard boxes, pens, stickers, idea cards and sticky notes. A table bar at the window front offers additional work space. There are two connected interactive whiteboards as well as three digital screens with apps for creative thinking (Coupled Devices). An arcade machine can be used to play and relax.

Thinker space: The thinker space can be used for discussions, decision making and incubation. It servers both ideation and testing phases. There are sofas, books, and an interactive whiteboard. The library of books offers inspirations. The space can also be used for break-out sessions or individual work (**Cross-Room Interaction**).

Maker space: Prototyping and testing is essential to design thinking. To support this phase, the maker space contains several 3D printers, 3D scanners, whiteboards, workbenches and meeting tables (**Digital to Physical**). It also has VR equipment. This space is mainly used for prototyping and testing.

Open education space: This space is located in a shopping mall close to the campus. It can be used to present early prototypes in order to get feedback. The space can also be used for public co-creation sessions, for market research and project presentations. The space has a digital info display, a large interactive whiteboard, robots, and digital maker blocks such as Little Bits and Rasperry Pi (**Device Orchestration**). It also has workbenches,

counters and stylish seating areas (**Extraordinary Furniture**).

3.2 Equipment

While each space is optimized for specific phases of design thinking, each space should enable all phases if needed. Therefore, there is some basic equipment that we added to each of the spaces. This equipment, too, is based on our identified patterns.

Based on the **Thought Triggers** patterns, we have equipped the spaces with several card decks, images and textual inspirations. The purpose of **Thought Triggers** is to get a push into a new direction. Such inspirations can lead to new thoughts, seeing new things, and considering problems from multiple perspectives. Some triggers state obvious questions that one often forgets to ask, however. There are various types of cards decks:

- MethodKit is a library of concept cards. Each card deck focusses on different domains such as app design, city planning, trends, tech building blocks, human needs etc. Each card provides a visual trigger and a short description. The cards can be combined to create new ideas. They can also be used as checklists or to change perspectives.
- Card decks with short descriptions of methods for creative thinking. Examples are 75 creativity tools, Whack Pack cards, and ThinkPak cards.
- Card decks with text inspirations such as quotes, single words, questions, categories, values (such as fairness, transparency, and sustainability), or transformation rules (such as substitute, minimize, eliminate, rearrange etc.).
- Card decks with existing solutions, often based on design patterns. Examples include card decks with business model patterns, group work patterns, or collaborative learning patterns.

In addition to card decks, there are other forms of thought triggers: boxes with random images, match boxes with idea sparks, fortune cookies with our own texts, boxes with "What if...?" questions, gamification triggers, cubes with questions, actions or words, story cubes with images, and many more. The three small screens at one of the walls auto-start with photo communities for random inspirations. The arcade machine was originally planned to show thought triggers as well.

Beside simple thought triggers there are more complex toolboxes for creative thinking. For example, games like



Figure 3: MethodKid cards in combination with sticky notes.



Figure 4: Prototyping and communication with Lego bricks.

Disruptus, Extraordinaires design studio, or a creative writing box.

The innovation space has hundreds of thought triggers available. The open educational space always provides a selection of thought triggers. Students can take sets of thought triggers to the thinker space, maker space and planning space as they are next door to the innovation space. Moreover, the planning space provides online links to digital thought triggers, such as photo communities.

Most of the spaces have open access to sticky notes, paper and pens in many variations (Sticky Notes). Sticky notes help to write down ideas simultaneously. Teams can cluster ideas, sort ideas, prioritize ideas. Sticky notes have a high affordance to explore and rearrange. The planning space is the only space without physical sticky notes because it provides a large interactive wall dedicated to digital sticky notes.

All spaces are equipped with paper in different sizes, including poster size blocks that can be put on the table (**Pen and Paper**). The paper can be used as a background for sticky-notes. There are also templates for work canvases, such as business model canvas, gamification canvas, storyboards, and wireframes for app design.

These canvas are available as printouts and as digital versions for interactive whiteboards.

The interactive whiteboards provide unbound workspaces and enable visual thinking and collaboration (Visual Thinking). Team members need to be able to see and change visual representations of problems and solutions without any effort. A whiteboard offers a large space to write on. All spaces have (interactive) whiteboards. Students can send photos of their achievements directly to the whiteboards (Device Orchestration, Physical to Digital).

Another important tool for communication are Lego bricks. In our design spaces, we use Lego bricks for prototyping, communication, and serious play. A core benefit of Lego bricks is their capability to build metaphors easily (Blair & Rillo, 2016). A brick can represent anything. Most participants feel more comfortable to use readymade entities instead of creating drawings. The bricks are located in the innovation space. There are boxes available to transport bricks to the other spaces as well.

For prototyping there are other **Building Materials** as well. Cardboard boxes, pipe cleaners, stickers, magnets, stamps and clips are available in the innovation space. 236 — Christian Kohls DE GRUYTER





Figure 5: Building materials and digital building blocks.

We also provide three different 3D printers, a cutting machine, and a laminating machine in the maker space. There are also digital building blocks based on the Little Bits system, available in the open education space.

Finally, each space has some toys and surprises (**Playfulness**). New ideas are more likely to come if one plays around with existing concepts. As von Oech (2008, p. 108) puts it: "Necessity may be the mother of invention, but play is certainly the father." Playing means exploring. In a playful environment our defenses are down, and we do no longer care for conventional rules – whether they are meaningful or wrong. In plays one can challenge assumptions, try and test different alternatives without fearing penalties.

4 Evaluation

While we have planned and designed the spaces based on existing good practice, we still needed to evaluate their performance. We wanted to know which of the spaces actually serve our goals and enhance the design thinking process. Moreover, we wanted to know which of the patterns actually work, whether we achieved the intended hybridity and how hybrid spaces impact the design process. That is, we wanted to know which equipment and which tools are used and what the user experience is. To answer these questions, we used three methods:

- Logging the actual use of the spaces and tools;
- Asking students, research staff and external partners for feedback in interviews and as part of project reports;
- Retrospection of our own sessions in the design spaces (the author of this article is both facilitator and user of the spaces).

4.1 Usage of spaces and tools

To see which space configuration is the most attractive we tracked the actual usage for each of the spaces. Our assumption was that students use attractive rooms more frequently. Moreover, for the innovation space we tracked which tools were used most frequently. This was done by visiting a team during their session, and checking which tools were touched after a session. We also asked some of the teams which tools they used. The following data about room and tool usage is based on this tracking and the author's retrospections on their own design workshops.

Innovation space: The most demanded facility is the innovation space with its large collaboration table and an abundance of tools. It is booked nearly every day and it would be useful to have more spaces of its kind. The space is used by many different project groups. The most frequently used tools are pen and papers (in approximately 80-90% of all sessions), sticky notes (30-40%), Lego bricks (20-30%), MethodKit cards (10-20%), and the interactive whiteboard (5-10%). The use of MethodKit cards can be increased if specific sets are pre-selected and put on the table. Most participants find it easy to work with the cards but have trouble to select a set from the complete library. The usage of interactive whiteboard depends on many factors. First, the whiteboards should be turned on before the session starts. Teams rarely turn them on by themselves. An introduction or short training about common use cases increases the likelihood of using the interactive whiteboard. The interactive whiteboard are more frequently used if a team uses the space for several days. In that case some teams have developed very complex and detailed structures or prototypes using the interactive whiteboards. Thus, the full use of hybridity only emerged when teams used the space for several days.

Thinker space: This space is used rarely. Most of the time it is used in conjunction with the innovation space. For example, larger groups use this room for breakout sessions. However, moving information and concepts between spaces does not work as seamlessly as intended. The interactive whiteboard of this space (a Microsoft Surface) makes access to data from other work spaces difficult, if student are not subscribers of Microsoft's cloud services. Thus, results cannot be moved quickly from one space to another. It is also not possible to integrate capturing of the physical world into the proprietary system. The whiteboard is equipped with cameras and audio for video conferencing. However, without a subscription students cannot use it. The level of hybridity is much lower than planned and the space is not used as intended. Most students use the space to work in teams (pair programming) or for presentations rather than discussing and reflecting about design. For these activities, the equipment is not optimal. A convenient desktop is missing. We are currently planning to change this space into a second innovation space. If we had larger rooms, we would provide an area that integrates a calm and relaxing zone into the work area. The space is used 2-3 times a week.

Maker space: The maker space is also used on a daily basis but only by two or three project groups who work on long-term research projects. 3D printing is used almost every day. The space has a coffee machine and attracts staff members from different departments to step in. Hence, there is a lot of social activity in the maker space. We are currently considering moving the sofa from the thinker space to the maker space. This could intensify the social interaction and increase the likelihood for encounters between staff members resulting in fruitful exchanges. On the other hand, more discussions in the maker space might distract the project groups who are doing actual work in that space. At the moment, this space offers the highest level of hybridity as it is used for many different forms of activities (often in parallel), enables instant digitization of activities and artefacts, and transforms information to physical artifacts.

Planning space: This space has a large interactive wall as the most attractive element. It is used in regular teaching and planning sessions as well. However, students prefer to use the innovation space. This space is only used if none of the other rooms is available. This space is the only place where no additional equipment (such as method cards, building blocks) is available. Thus, the hybridity is limited in spite of the interactive wall. However, if students are instructed to collect data about a problem domain, they make good use of the interactive wall. We also had very fruitful brainstorming and planning sessions in this space. However, a skilled facilitator is needed to provide guidance and explain how the technology can be used to support research. The space is used 3-4 times a week.

Open educational space: The open educational space in a shopping mall was opened every afternoon in the first six months. However, there were many days with a low numbers of visitors. On an average weekday about 300 shoppers passed by within one hour. Of these 300 shoppers, about 10-15 looked into the space. About five stopped and had a closer look at our interactive information display. On average only one person interacted with the members of staff. The number of contacts increased when we had events or student exhibitions. The students had to take action to actively invite visitors. Based on these observations and feedback we got (see next section), the education space now only opens on an event-based schedule. As it takes a lot of effort to prepare events and only a few departments are willing to invest the time, the space is now only used once a week. While the shopping mall is only five minutes away, students and staff members prefer spaces that are on-campus for spontaneous meetings.

4.2 User experience for innovation space

For the innovation space, we asked users to provide written feedback. We asked these questions:

- What is the general experience of using the rooms?
- What worked?
- What did not work?
- What was missing?

The questions were answered by 27 students and 18 external users (from companies). As the answers did not show any differences between the two user groups, the following results integrate responses from both groups.

4.2.1 General experience of using the space

Atmosphere: Almost all users highlighted the positive atmosphere of the space. They said that the "atmosphere triggers crazy ideas", the space provides a "cozy atmosphere", "an atmosphere that motivates team members", a "good atmosphere to get new ideas or perspectives." One user summarized: "The innovation space, which was the space we used most frequently, had an excellent work atmosphere. The attention to detail regarding equipment, opportunities to play, tinker

and try new media – all this showed participants were valued and created a creative environment to generate new ideas." The mixture of different atmospheres was also highlighted: "I liked the different atmospheres of the spaces." One of the external users from a company also pointed out that being at an off-site place helped: "The team liked the innovation space. It was important to get away from the regular workplace atmosphere. Turning off the laptop and being blocked from e-mails or phone calls was very helpful."

Impact on ideation: The space had a positive impact on generating ideas. One user said that the "configuration, content and design of the innovation space increase the creative potential." Another participant said, "I think the innovation spaces are a wonderful facility, even if we took advantage of only a small part of all the opportunities. The tools showed great diversity and gave inspirations to every participant."

Effective collaboration: Several users commented on the collaboration opportunities: "The pure beauty of the rooms had positive impact on the workshop mood and work results." The table in the center of the room helped in the collaboration process: "I liked the central table in the main space. We were all day in motion. Nobody had fixed positions." The room setup also supports different work modes, as one participant points out: "The spaces do not limit creativity or freedom. The furniture allows us to work in different positions (sitting, standing) and the space can be adapted easily for individual or group work." Another user said, "Great equipment, inspiring, stimulating, invites reflection. The spaces foster collaboration."

Tools for design thinking: There were many more positive comments on the equipment and tools: "Great equipment (both digital and physical), room size, atmosphere, acoustics." The mix of tools was appreciated, "I liked the mix of digital and physical media. The diversity of methods and tools was useful." The playfulness of the room was also perceived positively, "the space creates a playful work environment due to the colorful equipment. There are many things to play with, Lego bricks and card games." The tools support the design thinking process, "there are many opportunities to support the design thinking methods." Another positive outcome is that it "enables visual working." Moreover, the space can help to train and learn design thinking, "the abundance of tools helps to understand the design thinking methods."

4.2.2 What worked

Sticky notes: While we observed that many teams used sticky notes, only two persons commented on the tool, "working with a large table to collect sticky notes is very different from placing them on a wall. One can look at the notes from different perspectives and integrate 3D objects or materials on the table." The other comment was, "clustering of ideas was supported by the large wall spaces, and the large table. Visualized ideas can be structured and evaluated."

Thought triggers: For many participants, using card decks was a new and positive experience. They report that "cards help to generate non-obvious ideas" or that "card games and books infuse ideas from other domains." Another user said, "I liked the diversity of the 'creative boosters'." The ideation phase is supported by this room, "each single object in the room inspires new ideas that would otherwise not come to mind." Even though most users only worked with a small subset of thought triggers, the wide range of options had a positive impact. However, some users found the larger number of tools confusing.

Building Materials: Lego bricks were not only used for prototyping but also for communication. This was a positive outcome because our intent was to use Lego bricks for communication and serious play. Two comments illustrate this experience, "Lego [is] good to model situations and understand context + problem in a holistic way", "Lego [is] great for communication, not only for prototyping."

Interactive Whiteboard: The interactive whiteboards were used "to share research results with the team." The general experience was positive, it is a "technology that is fun. Unbound workspace and visualization capabilities are great." The interplay of interactive whiteboards, smartphones and the physical space was also highlighted, "it was perfect to send photos to the SMART Boards." The participants sent photos from smartphones using pictshareit.com, a service we developed for this very purpose. This is a good example where the hybridity of the space enables new forms of collaboration and artifact transformation.

4.2.3 What did not work

Overwhelming: Many users appreciated the large range of tools. But some found it also difficult to select the right ones: "Too many tools can be confusing. There is a need for exploring the tools. We set a time limit of 15 minutes to find a good tool." Some users complained that

they had "not enough time to explore everything." They suggested "organizing materials in a better [wav] (e.g. images, texts, abstract topics such as sport, business). This would improve the accessibility for first-time visitors. Exploring everything takes a lot of time." Others said that there is a "poor overview which materials are available for work." Another user compared the innovation space and the thinker space, "I did not use the thinker space much but liked the calmness in it - a good complement to the overwhelming stimulus in the other room."

Actions to address these findings: We have now started to curate materials and tools depending on the design challenge. We also suggest that teams spend the first 20 minutes exploring and then to stick to one or two tools.

Prepare and practice before: Many users said that they would be less overwhelmed and could make better use of the room if they had some preparation or practice in advance. "It would be better to visit the rooms before the workshop in order to explore the tools. The benefit of the spaces is likely to increase if you use them frequently." The need to practice was mentioned several times. The number of tools can also be distracting as there was "too much playing around during the workshop." For one workshop we had a one hour preparation the day before. This was obviously not enough, as one of the participants explains, "one needs to have an introduction to the room. We had one hour in advance [the day before] and that was not enough. An expert facilitator [who knows how to use the technology] is required."

Actions to address these findings: We are about to publish a small booklet that provides quick introductions to the most important tools. As a next step we will produce short videos that will explain methods and tools.

Use of technology: While most participants like the available technology, they also had the feeling that they could make better use of it, "we did not know how to use the interactive whiteboards correctly. Sometimes our annotations disappeared and we felt insecure about this. The generated PDF was hard to print later." This relates to the previous finding that users need to prepare and practice before. "My 'lessons learned' is that one needs more practice using the technology (digital whiteboard etc.) to avoid distraction." One participant expressed it in a more severe way: "Interactive whiteboard: Drawing did not work well. Training is absolutely required." Thus, hybridity often makes the usage of equipment more complicated and creates new seams.

Actions to address these findings: We have now started to turn on the interactive whiteboard before each session starts. We have added a section about using the whiteboards in the booklet. We prefer when teams book the room for several days rather than for a few hours.

Facilitator: Many participants suggested that a good facilitator would solve the mentioned problems, "one needs a facilitator who knows how to use 'creative techniques' ['creative technologies'] to use all opportunities to the fullest extent." Another user points out that a facilitator could increase the effectiveness, "there have been so many different media, and we used so few. I was blocked from experimenting with the media as we had no time left because the facilitator required results." It is important to note that the facilitator also needs to be trained in using all the available materials, tools and technologies. Otherwise, participants can get frustrated, "our facilitator did not use the more advanced tools. Facilitators need training to use all the tools." If a facilitator suggests the wrong tools or does not explain their use properly, the outcome can be negative. "Story Cubes did not always fit the topic [of the design challenge]. However, they triggered new thoughts. Not always useful for the task. The facilitator should explain that one can roll the dice again if the image does not match. One needs more practice or a better introduction." Both story cubes and images only work as thought triggers if participants get the right instructions. The difference between good and poor facilitation can be illustrated by the evaluation of using the design studio box. This is a box that integrates several thought triggers and design challenges. One group commented that the tool "was not appropriate, a simple brainstorming would have done the job." Another group used the very same tool for a one-day workshop and was very excited about the outcomes: "working in the innovation space was fantastic!"

Actions to address these findings: We offer trainings with hands-on practice to students as part of the curriculum. We plan to have design thinking lunches where staff members and students can explore the available tools guided by an experienced facilitator.

4.2.4 What is missing

We also asked participants what we should add to the spaces. There were only minor suggestions such as optional music (chill-out, coffee shop noises), better lamps with a warmer light, or motivational posters. Some suggested creating other kinds of spaces, such as playrooms with soccer tables or music rooms. Such spaces are often found in tech companies such as Google, Apple or Facebook. We had several comments on the room size. Participants complained that only six persons could work

in the room. However, we designed the space for exactly this team size. Unfortunately, we did not have larger rooms available to create design spaces for larger groups. While we found some ways to improve our spaces, it seems that there is not much missing as one user summarizes, "the configuration is very sophisticated. I don't know what to change."

4.2.5 Achieved goals

Our strategic goal of increasing creativity and innovation in student projects has been partially reached. Students who use the spaces come up with more fresh ideas in shorter time periods. However, a reflection on their ideas shows areas that still need to improve. Project-based, skill-driven, team-oriented, self-directed and informal learning have been increased by using the rooms. Many students reported that they found it very helpful to have hands-on experience for different tools and methods for design. Most users have referred positively to the space configuration and equipment. When we successfully implemented the patterns, we had positive effects and a high level of hybridity allowing different forms of activities and an overlap of formal-informal, learningteaching and individual-collective work modes. However, in some cases we were not able to implement the patterns appropriately due to technical challenges and limitations of interoperability. Thus, achieving a hybridity of physical and digital spaces remains a challenge.

4.3 User experience for open educational space

For the open educational space we asked both members of research staff and students about their experience. As the two groups have different views and goals, we got different answers. While students have the opportunity to present their results and get feedback, members of research staff can show research results and demonstrate the latest technology to a public audience. The research staff also had to supervise students when they did their presentations or surveys. Thus, students used the room only for one day per week for their own projects. Research staff on the other hand, had to be present in the room for longer time periods and they were not only presenting their own research projects. In total we asked nine members of the research staff who frequently used the space. Moreover we evaluated 11 written reports of student groups (a total of 27 students).

4.3.1 What worked

Openness: The concept of the space is well perceived. One member of staff appreciated the openness of the space as it "provides opportunities for experimentation." Another staff member said, "I like the opportunity to dig into new topics outside my regular work scope." The students also liked the concept, as one student puts it, "the space and this kind of public presentation is a very innovative and efficient idea. Students can show their results and share their knowledge with the society."

Equipment: The equipment provides a very good atmosphere and the technical equipment was highlighted by several staff members. Students find everything they need to run their presentations and exhibitions: "It was easy to integrate our artefacts into the room and run our presentation."

Special Events: The most successful use of the space was when we had special events, such as presenting 3D printing or coding with Little Bits for kids. Some children also spend long hours experimenting with our 3D pens. We had some public presentations with guest researchers as well. Special events led to increased visitor numbers, "the largest interest of visitors arises when we had special events. Normal opening hours did not attract any visitors. It's better to have small slots for events rather than opening all day." One staff member points out, "our first exhibition with 3D printers worked very well. This was my favorite topic and it was great to get in touch with visitors." The space also attracts schools to visit with their students.

Empirical studies: Students often struggle to get participants for their empirical research. One staff member observes, "[this is] a perfect space for usability studies. It is hard to find independent test persons [non-experts, not friends/colleagues in the context of a university. Great opportunity for master thesis." In general, the open educational space is seen as an opportunity to get feedback, "it's great to not only give feedback but to get feedback as well. Very important for empirical studies and getting feedback from diverse user groups." We had several student groups who used the open space for survey or prototype evaluation. In general, the space can be used effectively for this task as these reports show: "We interviewed about 20 visitors within 5 hours. We liked the interesting experience and collected many opinions from visitors. This was important for our written homework." Another student group reports, "we attracted about 30-60 persons each day to participate in our survey. To motivate people to participate, we had a small price game (lucky wheel)." These are quite impressive numbers. However, students have to put in a lot of effort to attract visitors,

"to get meaningful data [for empirical research] one needs a large sample. If you are collecting data in the shopping mall on one day only, you have to make sure that enough people are attracted. You have to take action to raise interest. We used augmented reality and virtual reality glasses to make people curious. This increased the number of participants for our survey." Students who failed to prepare such engaging activities had less success. They sometimes only attracted one visitor per day.

Learning Experience: Our observation has shown that the students are highly motivated. As one staff member observes, "student groups perform well when they show their projects to the public." Likewise, students enjoy the opportunity. One group reports, "the public expo was an enriching experience. It was a great feeling to present a project to external persons. And we got feedback to improve our project – an opportunity otherwise not given." Even if the response from visitors was less positive, the experience gave students an opportunity to reflect about their project. One group reflects about their topic, "the expo was great. However, a less theoretical topic would be better for the target audience. [...] When you create an expo, you should have many artefacts that people can take into their hands and try out." The open education space also provides the right environment for open discussions with citizens, "sometimes larger groups enter the room and one can have a good discussion." Students also learned that different target groups have different interests, "we had some good discussions with visitors. Most were young visitors. There were a few older visitors. They said that they did not understand the technology [beacons] and were not interested."

4.3.2 What did not work

Resources: As we have a large open space, we need at least two staff members who are running one work shift. If there are student expos, there still needs to be one staff member to supervise the room. Preparing own expos and projects is time consuming. Hence, we soon ran out of projects. One staff member said, "great and motivating start after opening the space, then we did not have enough projects exhibited." We had been over-optimistic that other departments would join our initiative and use the space. This, however, did not happen as all departments have a high workload. Hence, the staff members came from only one department and got frustrated soon: "Staff members spend too much time in the space, waiting for visitors. They could use their time better to support students on-campus." Another complained, "having two

members of staff on-site takes away too many resources from the team."

Actions to address these findings: The open education space now opens for events only. Staff members are now more motivated to supervise the space because it takes less time and there are more visitors for events.

Bad work environment: One of the pain points is that staff members cannot work effectively even if there are no visitors. The main reason is that the space is very noisy. "It is quite noisy in the shopping mall. It is hard to concentrate on work." Another person said, it is "very hard to work concentrated and effectively in the room. I don't have enough time to work on my other projects anymore." Some staff members were missing their more effective work environment: "No real desktop, my regular work equipment is missing. It is too noisy." It gets even more frustrating if student groups run exhibitions and a staff member is only passively supervising: "It's great when student groups are there to exhibit their results. However, if they use all the space, then I cannot work there at the same time. So I am just there to look after the group without any real function."

Actions to address these findings: Staff member do not have to do their work in this area any more. Moreover, we sometimes run work sessions without being open to the public. Visitors can still observe through the glass windows but the space is less noisy if we do not open the entire front.

Low number of visitors: In general, the space attracts far less external visitors than hoped for. As the space cannot be used for regular work (see previous problem), the main purpose is to get in touch with external visitors. Almost every staff member complained about a low number of external visitors: "There is only little discussion with visitors that are not members of the university." If there is no event going on, the number of visitors drops dramatically: "without exhibitions or events, sometimes we didn't have a single visitor." Students who were running exhibitions in the space observed the same problem, "most visitors of the shopping mall were not interested. So we had to do some advertising. Passing visitors stopped in front of the display but did not enter the room. We had to invite them personally." The student groups figured that most visitors of the shopping mall were in a hurry, "one challenge was to address visitors directly. Most were in a hurry and they did not like to be stopped." It turns out that many people were not even aware that they could enter the open space: "Very few persons enter the space on their own. They are too shy." Another group concludes, "many visitors of the shopping mall were shy. They did not know whether they are allowed to enter the space. We had to

invite people to enter the room. This is bad marketing – people did not know that the space is a public area."

Actions to address these findings: we now invite participants to events or run workshops with a group of students. Hence, the place is always busy when we run an event. Moreover, we intend to make the event calendar more accessible.

Wrong target group: Even if visitors stopped by, they were often interested in other topics. While students run their expos, we still had some 3D printout or programming games on display. One of the student groups complained, "many visitors were more interested in other components of the rooms and staff members of the university explained these components." At other times, visitors were more curious about the space in general, "some people were not interested in our project but the concept of the educational space in general." This could lead to frustration for students, "sometimes it was frustrating that visitors were not interested in our topic [data protection and privacy]." Another challenge occurs if staff members are not experts for the specific domain that is exhibited. One said, "it's hard to be a crew member for the room when there is an exhibition about a topic where I am not an expert. For example, when we had the 3D printers presented, I had to refer to colleagues when more expert questions popped up. Hence, I was not effective at all."

Actions to address these findings: We use the info display to clarify what is currently happening in the space. We also use clear signage to explain how visitors can participate.

4.3.3 What is missing

There are two major issues that have been identified by the research staff. First, we need to provide a clear schedule with upcoming events. Workshops need to be announced at least four weeks in advance. Otherwise external visitors don't know what is going on in that public space. The second issue is to have a dedicated person who takes care of the room and supervises student groups. That person should also organize the room's setup, define topics, set the schedule and advertise events. As one staff member points out, "it is a lot of work to prepare an exhibition and somebody needs to be the driving force."

4.3.4 Achieved goals

The setup was perceived as highly innovative by students, external partners and other universities. Hence, our goal

to intensify the student's identification with one's own university as a place of innovation was reached. The space offers a high level of hybridity because it bridges between formal and informal learning, academic and non-academic contexts and allows all phases of design thinking. Moving physical and digital artifacts from and to the university campus worked seamlessly. The open education space also increased interdisciplinary encounters.

5 Conclusions

Based on the empirical data we captured for the actual usage of the spaces, we can already see which elements and design patterns are the most promising. These findings are helpful for other universities and schools when they are planning their own spaces for design thinking. We have already shown our space setup to several other faculties and even other universities who are now starting to create their own design spaces based on our models and design patterns.

If we consider the different space types, we have a clear winner: the innovation spaces is used most frequently and got the best feedback. The thinker space makes a good impression but it is not used frequently. The open education space is a lot of effort to run and costs a lot of resources. However, it still has huge potential. When used in the right way the effects are very positive. The major challenge is to organize events and motivate other departments to participate.

The most import ingredients for the innovation space are the outstanding atmosphere and the abundance of available tools. The inspiring atmosphere is created by natural elements such as the wooden table in the center, wooden boxes for the equipment, and a (faux) stone wall. The window view helps to relax. The huge number of thought triggers gives this space a playful atmosphere. However, the vast number of tools can also confuse. The best tools have a high affordance for action and are selfexplanatory. Each tool must be easy to understand, it should be usable in many different contexts and offer a high probability for good results. Based on our observations we recommend starting with these tools: sticky notes, a basic set of MethodKit card decks, Lego bricks, pen and paper, word and image cards, and an (interactive) whiteboard. The tools should not be hidden in a cabinet. Users should have direct access to all materials.

To improve the design thinking experience in our spaces, we are currently working on a booklet that provides an overview of the tools and methods and instructions on how to use them. Moreover, we plan

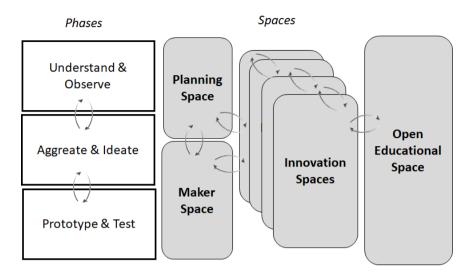


Figure 6: Refined model for the interplay of spaces.

to produce short videos and provide train-the-trainer workshops. We also try to minimize any hazards when working with technology. Thus, we frequently check all digital tools and set them up prior to workshops. We also develop our own tools to make the interplay of different devices more seamless. For example, we developed a web tool that allows instant capturing of work results. Users do not need to log in. Integrating a picture of the current work results (such as sticky notes or prototypes on the table) with a digital whiteboard can be achieved in less than 30 seconds. Participants can then annotate objects of the physical world with digital ink. They can also capture and document different setups or show how a design was developed step by step.

Even though the usage frequency of the different spaces varies, we believe that different space types are needed to support all the phases of the design thinking process. The open educational space offers opportunities for market research, co-creation, prototype presentation and evaluation. The planning space can be used to aggregate and re-arrange field findings on a large interactive wall. This is an opportunity that needs to be leveraged in the future. The maker space is perfect to create prototypes and for communication between students, staff members, and professors. The thinker space does not serve the function to reflect and test ideas yet. We will re-design that space to another innovation space.

The most successful space is the innovation space. It can be used for each of the design thinking phases with a special focus on ideation and prototyping. We are planning to create more innovation spaces based on the experiences with our first innovation space. Each

new innovation space will have its individual character, creating a unique atmosphere. At the same time, students, staff members and professors will find a reliable standard set of tools and equipment in these innovation spaces.

References

Adams Becker, S., Cummins, M., Davis, A., Freeman, A., Hall Giesinger, C., Ananthanarayanan, V. NMC Horizon Report: 2017 Higher Education Edition. The New Media Consortium, Austin, Texas, 2017.

Alexander, C. (1964). Notes on the synthesis of form. Cambridge: Harvard University Press.

Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fiksdahl-King, I., Angel, S. (1977). A pattern language: towns, buildings, construction. New York: Oxford University Press.

Benyon, D. (2014). Spaces of interaction, places for experience. Synthesis Lectures on Human-Centered Information 7(2), 1-129.

Benyon, D., Mival, O. (2015). Blended Spaces for Collaboration, Computer Supported Cooperative Work (CSCW), 24(2-3), 223-

Blair, S., Rillo, M. (2016). How to Facilitate Meetings & Workshops Using the LEGO Serious Play Method. ProMeet.

Brown, T. (2009). Change by Design: How Design Thinking *Transforms Organizations and Inspires Innovation.* New York: HarperCollins Publishers.

Churchman, C. W. (1967). Wicked Problems. Management Science, 4(14), B-141-142.

Cross, N. (2011). Design thinking: Understanding how designers think and work. London: Bloomsbury.

De Bono, E. (1990). Lateral thinking: A textbook of creativity. London: Penguin Life.

Foster, J. (2007). How to get ideas. San Francisco: Berrett-Koehler Publishers, Inc.

244 — Christian Kohls DE GRUYTER

- Hestad, M., Groenly, A., Rigoni, S. (2017). *The little booklet on design thinking*. London: Brand Valley Publications.
- Kelley, T., Littman, J. (2001). The art of innovation: Lessons in creativity from IDEO, America's leading design firm. New York: Currency/Doubleday.
- Kohlert, C., Cooper, S. (2017). Space for creative thinking: Design principles for work and learning environments. Munich: Callwey
- Kohls, C., Panke, S. (2009). Is that true? Thoughts on the epistemology of patterns, In *PLoP 2009, Proceedings of the 16th Conference on Pattern Languages of Programs*. New York: ACM.
- Kohls, C., Köppe, C. (2017) Hybrid Learning Spaces. *Proceedings of VikingPLoP 2017, Viking Pattern Languages of Programs*. New York: ACM.
- Kohls, C. (2018). Finding and Implementing Patterns for Creative Spaces. *PATTERNS 2018, The Tenth International Conference on Pervasive Patterns and Applications*. Barcelona: Iaria. Retrieved from https://www.thinkmind.org/index.php?view=article&articleid=patterns_2018_1_30_70027.
- Kohls, C., Münster, G. (2018). Designing Hybrid Spaces for Creative Work. In R. Sickinger, P. Baumgartner, T. Gruber-Mücke (Eds.), Pursuit of Pattern Languages for Societal Change. A comprehensive perspective of current pattern research and practice. Krems: Edition Donau-Universität Krems.
- Kohls, C., Münster, G., Dubbert, D., Dural, M. (2018). Mobile Apps for Hybrid Learning Spaces. *Journal of Interactive Learning Research*, 29(3), 377-396. Waynesville, NC: Association for the Advancement of Computing in Education (AACE). Retrieved January 27, 2019 from https://www.learntechlib.org/ primary/p/184760/.
- Köppe, C., Nørgård, R. T., Pedersen, A. Y. (2017). Towards a Pattern Language for Hybrid Education. *Proceedings of VikingPLoP* 2017. New York: ACM.
- Kumar, V. (2013). 101 design methods: A structured approach for driving innovation in your organization. Hoboken, N.J: Wiley.
- Meinel, C., von Thienen, J. (2016). Design Thinking. *Informatik-Spektrum 39*(4), 310-314.
- Michalko, M. (2006). *Thinkertoys: A handbook of creative-thinking techniques*. Berkeley, Calif: Ten Speed.
- Münster, G., Kohls, C. (2017). Blended Interaction in innovation spaces. *Proceedings of PLoP 2017, 24th Conference on Pattern Languages of Programs*, Vancouver: Hillside Group.
- Oech, R. (2008). A Whack on the Side of the Head. New York: Grand Central Publishing Hachette Book Group.
- O'Keefe, B., Benyon, D. (2015). Using the blended spaces framework to design heritage stories with schoolchildren. *International Journal of Child-Computer Interaction*, 6, 7-16.
- Plattner, H., Meinel, C., Weinberg, U. (2009). Design Thinking: Innovation lernen, Ideenwelten öffnen. München: mi.
- Quillien, J. (2012). Clever Digs. How Workspaces Can Enable Thought. Ames, IA: Culicidae Press.
- Rittel, H. (1972). On the Planning Crisis: Systems Analysis of the 'First and Second Generations'. *Bedriftskonomen*, 8, 390-396.
- Rowe, P. G. (1987). Design Thinking. Cambridge: MIT press.
- Simon, H. A. (1969). The science of the artificial. Karl Taylor Compton lectures, 1968. Cambridge: MIT Press.
- Thorndike, E. L. (1931). Human learning. Cambridge: MIT press.

Uebernickel, F., Brenner, W., Pukall, B., Naef, T., Schindlholzer, B. (2015) Design Thinking: Das Handbuch. Frankfurter Allgemeine Buch, Frankfurt am Main.