The vocabulary of Learner-Space Interactions Understanding learning spaces experience through the repertory grid method.

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Abstract. Higher education institutions are facing new educational challenges and are striving for an evolution in pedagogical practices. This evolution is accompanied by the need for innovative learning spaces to support students in the development of "21st century skills". Designing these spaces requires a deep understanding of learners' needs and experiences. User-centered design therefore appears as an adequate process to understand learning experiences in relation to spatial design. In this paper, we describe how the repertory grid method has been used to explore students' perceptions of learning environments (N = 26). We identified 381 personal constructs (contrasted word pairs) associated with learning spaces and grouped them into seven categories (22 subcategories), ranked by number of occurrences. This study provides a basis for the development of a vocabulary of learners-spaces interactions, in support of the design and assessment of learning space experiences.

Keywords: human-space interaction, user-centered design, user experience, learning spaces, spatial experience, interaction vocabulary, repertory grid technique.

1 Introduction

The field of Human-Computer Interaction (HCI) has been very active in defining processes and standards for designing (and assessing) interactions between humans and technological items since the 1980s. In more recent years, this field has emphasised the importance of experiential factors in these interactions, accompanied by the shift from more pragmatic HCI frameworks towards broader experiential ones (including subjective, emotional and temporal aspects; Roto et al., 2011). The experiential aspects are often grounded in frameworks from psychology. These new standards have been widely adopted and now partially account for the commercial success of those business actors who consequently introduced them into their core strategies.

The field of building design shares the same concern for "user-centred design" and faces the same client demand for more experiential design approaches. While sharing some concerns and objectives, building design and technology design might have evolved as different disciplines, since the object under scrutiny has not been the same. Today this does not hold true anymore: first, there is an ever-growing demand for providing buildings with the same experiential dimension that customers demand from their technological items and, second, the increasingly higher integration of technology into building design implies that both can progressively be confounded. As noted by Alavi, Churchill, Kirk, Nembrini and Lalanne (2016a), “while the disciplines of architecture and interaction design have met on many occasions, instances of concrete collaborative projects are rare”. It thus appears natural to develop a very consequential approach to Human-Building Interaction (HBI, Alavi et al., 2016a), very much like the one we have observed in HCI. Following the definition of Alavi et al. (2016b), “designing HBI consists of providing interactive opportunities for the occupants to shape the physical, spatial and social impacts of their built environment”. As environments become increasingly interactive, this novel approach intends to support collaborative projects drawing on concepts and methodologies from computer sciences, interaction design, architecture and urban design. In this context, many methods known from HCI are good candidates to support the HBI field.

When designing for user experience (UX), it is critical to understand how important or meaningful a specific aspect is to the actual user and how it will contribute to the overall subjective experience. This understanding can be reached via self-reported metrics or by using methods able to identify the elements of the interaction that are meaningful to the users. The rationale is that users will be able to report on their experience subsequently by using their own vocabulary and personal constructs. The repertory grid (van Gennip, van der Hoven, & Markopoulos, 2016; Möttus, Karapanos, Lamas, & Cockton, 2016) or sentence completion methods (Kujala, Walsh, Nurkka, & Crisan, 2013), both arising from the field of psychology, are alternative ways of assessing UX, without constraining the user by a predefined vocabulary as the one typically used in a standardized scales. This overcomes a limitation that constraints the usage of traditional methods confronting respondents with a vocabulary that either might not be fully understood or might prime answers in an unwanted fashion.

In the present paper we will present the application of the repertory grid method, as an example for a transfer of methods from HCI to HBI and as an example of a method that does not impose a predefined vocabulary on the respondents. We will situate it within a concrete use case dealing with the construction of innovative learning spaces; and illustrate how it contributes to developing a vocabulary and furthering the understanding of the interaction between learners and innovative learning spaces. This will ultimately support further design and evaluation steps.

2 State-of-the-Art

2.1 Designing Innovative Learning Spaces

The design of innovative learning spaces is a recent trend, in response to new societal and economical challenges (Oblinger, 2006). Universities and educational institutions in general indeed need new approaches to teaching and learning such that “21st century skills" empower both students and professionals. In an increasingly technological, connected and globalized world, these skills are critical; they encompass collaboration and teamwork, leadership, critical thinking, creativity and imagination, problem solving, IT literacy, and many more. Acquiring this new skillset becomes a concern for all learners i.e., pupils, students, job seekers, professionals and those learning for extra-professional motives. The design of innovative learning spaces following a user-centric approach is regarded as one response to these new requirements that educational institutions try to address.

Many initiatives have been launched during the past few years in the educational community in order to understand the criteria for successful learning spaces and to eventually apply them in the design of such spaces. Innovation, adaptability, manageability, accessibility, atmosphere or sustainability, are therefore thought by Johnson & Lomas (2005) as critical elements to be reflected in learning spaces projects. Several other dimensions were later mentioned by McArthur (2011): transcendence, engagement, malleability, purpose, ownership, panoramic, responsiveness, inclusiveness and coherence. At a micro-level, Lei's study (2010) described eight elements to consider in a classroom design project: the size of the space, its shape and color, the lighting and thermal conditions, the noise level, the seating and furniture arrangement, and the technology. In order to understand the holistic impacts of spaces on users, Barrett, Davies, Zhang & Barrett (2015) followed a quantitative approach to analyze and model the impact of classroom design on pupils' learning. Their findings show three main classroom characteristics that support the improvement of pupils' learning: the naturalness principle (e.g., environmental parameters that are required for physical comfort, encompassing light, sound, temperature, air quality and links to nature), the individualisation principle (which relates to how well the classroom meets the needs of a particular group of children and is made up of ownership, flexibility and connection dimensions), and the stimulation principle (made up of complexity and colour and related to how exciting and vibrant the classroom is).

Variegated methods have been applied to support the design of learning spaces, from traditional user research methods to architectural data collection or computing techniques. Both in the architectural and education domains, pre- and post-occupancy surveys are widely spread (Mallory-Hill, Preiser & Watson, 2012; Scupelli & Hanington, 2014, 2016) for the assessment of learning environments. The use of mixed methods to understand learner-spaces interactions is also commonplace. In their design studio use case, Scupelli and Hanington (2014) used a mixed-method design involving pre- and post-occupancy measures. They conducted observations, interviews, surveys and diary studies in order to inform the design of a new studio. Later on, they also collected workspace occupancy data using time-lapse videos (Scupelli & Hannington, 2016). At Taylor's University in Malaysia, Han, Leong & Nair (2014) combined benchmarks of classroom design models with focus groups sessions. Another relevant example is Barrett et al.'s large-scale study (2015), which combined the assessment of design parameters through architectural data collection (e.g., measures of room dimensions, equipment and layout), expert judgment, physical measurements of environmental conditions (e.g., lighting levels, temperature, noise levels) and questionnaire-based interviews. Very recently, Healion, Russell, Cukurova, & Spikol (2017) suggested the use of applied computing techniques to track and analyze students and teachers' physical movements to inform learning processes. Initial findings confirm that the physical design of a classroom environment has an influence on group formation and dynamics. Further experiments are now required to characterize this effect and being able to derive design recommendations.

As stated by Yang, Becerik-Gerber & Mino (2013), "physical learning environments should be evaluated by studying both the physical attributes and the students' perceptions of those attributes" (p. 172). In the following we describe the concrete use case that allows us to illustrate the contribution of the repertory grid technique to HBI in the case of learning spaces design. The objective has been to adopt an experiential approach to HBI in our use case. This calls for a thorough understanding of how the learners perceive the learning spaces and the surrounding context. By applying the repertory grid method to our HBI use case, we seek to contribute to furthering the experiential importance in HBI.

2.2 The Repertory Grid Technique

The repertory grid technique (RGT) was originally developed in the field of psychology, and more specifically arose from the personal construct theory approach developed by Kelly in the 1950s (Kelly, 1955). According to this theory, people organize their experiences based on sets of constructs that are individual to each person. These constructs are bipolar attributes, under the form of contrasting words (e.g., beautiful-ugly). The contrast pairs are not necessarily direct opposites; Karapanos & Martens (2008) cited three types of bipolarity: negation (practical-impractical), opposition (professional-amateurish), non-contiguous (easy-powerful).
The repertory grid technique (RGT) supports the elicitation of personal constructs. It requires a selection of stimuli (called *elements*) as a basis for eliciting constructs. The selection might be provided either by participants or by the researchers. Figure 1 illustrates the four major steps of RGT.

(1) Selection: During the first stage, participants randomly pick three *elements* out of the initial set. In our case, these elements are pictures of learning spaces.
(2) Triading: During the second stage, the most critical action takes place, as participants are required to identify how two out of the three elements differ from the third. According to Kelly (1955), participants have to answer the following question: "How are two of these elements similar, and thereby different from the third element?" In our case, we have asked participants to characterize these links between elements by drawing arrows. The process is repeated iteratively until the participant has elicited as many constructs as possible. The resulting contrast pairs are reported on a grid.
(3) Rating: During the third stage, participants rate each element against the construct elicited in the prior triading. Depending on the number of elements in the initial set and the number of elicited constructs, this step can be time-consuming.

(4) Analysis: During the fourth stage, quantitative and qualitative analyses are conducted. The latter allows to understand the constructs and why they are important to the target audience. In addition, quantitative analyses allow to cluster the data and unveil relationships between elements and most salient characteristics of each element.

Fig. 1. The repertory grid process

2.3 Understanding Users' Experiences Through the Elicitation of Personal Constructs

The repertory grid technique has been a success story since its development, being transferred to many other application domains. In 1980, a special issue of the International Journal of Man-Machine studies has been devoted to this topic (Shaw, 1980). In the field of HCI and information systems, the repertory grid technique has been highlighted in several studies as a way to understand users' experiences by exploring how they are making sense of an interaction and what are the dimensions of experience that are perceived as meaningful to them, without imposing a given vocabulary on these users (Hassenzahl et al., 2000; Tan & Hunter, 2002, Hertzum & Clemmensen, 2012, van Gennip et al., 2016).

In the 1990s, Latta and Swigger (1992) elicited attributes of system interface design by help of this method. In this field, it has been widely used for the study of cognition. Later, the repertory grid technique has been deployed in what we would now call the field of UX. Hassenzahl and Wessler (2000) used it in order to understand user needs and concerns based on the evaluation of prototypes and Hassenzahl and Trautmann (2001) used it to compare how a newer version of an online banking system would perform as compared to the older one.

Many authors have explored and demonstrated the added value of RGT for design and evaluation purposes (e.g., Fallmann and Waterworth, 2010; Fallmann, 2006; Hassenzahl and Wessler, 2000). It has also been used in support of theoretical development like aesthetics of interaction (Mõttus et al., 2016) or the concept of usability. Hertzum and Clemmensen (2012) investigated for instance how usability professionals construe usability by eliciting the meaningful constructs they employ when thinking about system use. The results of their study highlighted a discrepancy between the usability definition provided by the ISO 9241 standard and the practices of professionals in the three countries under investigation.

Recently, van Gennip et al. (2016) used repertory grids to elicit personal constructs on experiences from autobiographical memories. Their findings are presented as a repertoire for design, "an empirically founded characterization of the design space of technologies for supporting remembering".

Finally, Hogan and Hornecker (2013) stress an interesting application of RGT by blending it with focus groups. This allowed revealing rich insights in a cost-efficient fashion, as compared to the elicitation of constructs during individual interviews as recommended by the original RGT description.

3 Method

The study was conducted at the University of Luxembourg in October 2016, in the context of a large-scale participatory design project. While our university moved to a new campus in 2015, it rapidly appeared that the traditional classrooms were not able to support the needs of the students and teaching staff. They were also inadequate to promote new approaches to teaching and learning and the development of 21st century skills (e.g., critical thinking, leadership, creativity, teamwork, problem solving).
In order to design innovative learning spaces, we followed an experience-centred design process involving all stakeholders and representative users of these future spaces. The present paper reports on the exploration of users' needs through the understanding of how students perceive their interactions with learning spaces and what meaning they attach to them.

We used the selection and triading steps of the repertory grid technique (see Fig. 1) in order to support participants in eliciting constructs related to their own perception and experience of learning spaces. Note that we only conducted the first steps of the repertory grid process, as we did not intend to rate the examples provided against each construct, but rather to identify a vocabulary of learning spaces as perceived by students. Assessing a learning space on several subjective constructs requires defining a specific context of use: for instance, the perceived comfort of a space might depend on the learning activity to be conducted. This has also been clearly expressed by our participants and explains why the two first steps only of RGT were relevant at this stage for the application to our use case: a rating of constructs, as required by the third step of RGT, seems hard and meaningless without a specific contextualisation of the learning activities under investigation. Moreover, we made the choice to select a large number of examples in the initial set in order to elicit a wider variety of constructs related to learning spaces. As a consequence, this would also have made the rating step unrealistic. Both reasons explain why our application of RGT consists in a reduced adaptation of the original method.

3.1 Participants

A total of 26 students (13 women, 13 men) participated in the study during three focus group sessions (8 or 9 students per session). Their age varied from 19 to 37 years (mean age 26).

Participants were recruited through the university mailing list and posters displayed on the campus. We constituted our sample purposively in order to represent different education levels (6 Bachelor students, 17 Master students and 3 PhD students) and disciplines (Law, Psychology, Computer Science, Economics, Philosophy, Engineering, Education Sciences, etc.)

Participants were from 18 different nationalities, which is representative of our multilingual and multicultural university. The majority of them have studied in several countries (at least their home country in addition to Luxembourg). This heterogeneity is a specific property of the learners' population under investigation; by reproducing the variance in terms of age, gender, discipline, nationality, etc., we have safeguarded our participants' representativeness.

All sessions were conducted in English and all participants were fluent in this language. Participants received 30 euros in compensation for their participation in the study. They all have signed an informed consent form and have been thoroughly briefed on ethical aspects.

3.2 Material

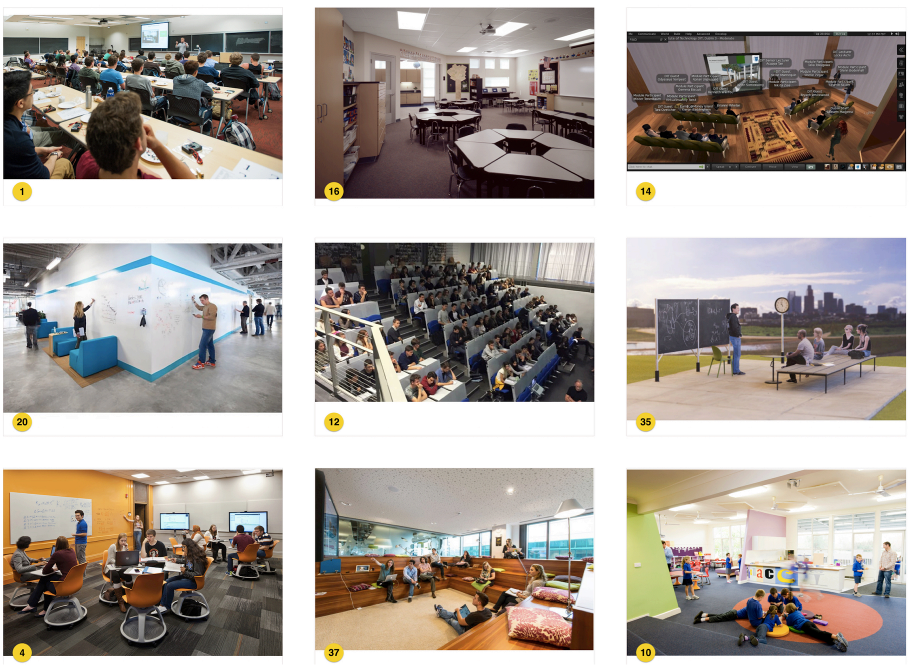

Fig. 2. Sample images used during the study to support the elicitation of personal constructs associated to learning spaces.

Element selection. We selected 37 sample images representing learning spaces on the web (Fig. 2). These images were chosen in an attempt to present as much variety as possible in the type of space and activities, without necessarily representing innovative spaces only. As innovative learning spaces are often thought of as blended spaces combining physical and digital spaces, we also included some pictures representing interactive or virtual learning spaces. None of the pictures represented existing spaces from the University.

The images were printed on A4 plasticised paper in order to be easy to manipulate. Each image was assigned a number from 1 to 37 in order to facilitate the completion of the grids by participants.

In the Repertory Grid Technique, the elements (here, the pictures of learning spaces) represent aspects considered important within a specific domain (Tan & Hurter, 2002). A preliminary focus group was conducted with UX designers, teachers and educational scientists in order to pilot test and validate the material used in the study.

It should be noted that in its original form, RGT does not rely on the reproduction of real experiences to be used as stimuli. In the case of HBI, the various spaces and experiences that this technique allows to compare make it difficult to offer users a real experience-based stimulus. For our specific use case, we would have liked to produce additional material in support of real experiences, such as e.g., 3D virtual environments for exploration, sound files, or furniture samples to try out. The access to a sufficient amount of different spaces to produce this additional material would however have been impossible; instead of producing a very reduced set of stimuli or relying on spaces unequally represented in terms of experience richness (i.e., some spaces being pictured only, while others are supported by additional materials), we opted for keeping the set of materials broad and homogeneous. This explains why we relied on pictures, allowing to represent a broad set of spaces, without introducing particular biases for selected spaces.

Triading grids. We gave participants A4 sheets, including grids to complete (Fig. 3) by informing picture numbers and characterizing relationships between pictures.

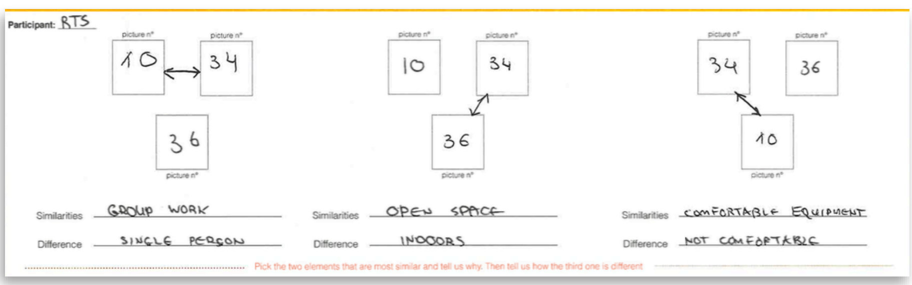

Fig. 3. Examples of triads and contrast pairs completed by a participant

3.3 Procedure

We used the repertory grid technique during 90-minutes discussion group sessions focused on learning experiences. The exercise lasted 30 minutes and was titled "What do learning spaces mean to us?"

We first gave all students standardized instructions on how to compare triads of pictures in order to elicit personal constructs. We used an example with triads of chocolate bars in order to clearly illustrate the process without orienting their responses on learning spaces.

All images were placed on the table without any predefined order. Participants completed the task individually and in silence. We instructed them to pick 3 images randomly for each trial, to inform their numbers in the grid (Fig. 3) and to draw an arrow to link the two elements that they perceived as most similar, as compared to the third element. The participants have been instructed to keep going until the end of the exercise (Fig. 4). We defined a standardized duration of 20 minutes for this step. Based on our observations, saturation of ideas was reached at this point for most participants (students for instance commented on the fact that they could not come up with additional constructs). Participants were allowed to use the same triad several times in the case they could elicit several constructs. They were also allowed to write down the same (or a similar) construct yet associated with different triads.

Fig. 4. Students comparing triads of images during the repertory grid exercise

3.4 Coding

We used a general inductive approach to analyse the data collected through the repertory grid exercise. The two authors of this paper (R1 and R2), experts in user experience (UX) design, clustered all contrast-pairs under the format of an affinity diagram based on the respective similarities or differences between participants' constructs. The goal was to structure the large amount of data we collected by grouping each contrast-pair into a distinct and relevant category (with a minimum of miscellaneous constructs). We labelled each of the six categories (+ miscellaneous).
Later, two additional raters (R3 and R4), who did not participate in the data collection, independently classified the construct-pairs using the defined categories.

Out of 381 contrast pairs in total, 234 were classified within the same subcategory by all raters. Cohen's Kappa $\varkappa$ was run to determine the strength of agreement between raters on the classification of elicited constructs at the subcategory level. There was substantial agreement between the raters' categorization, as demonstrated by the following statistical analyses: Cohen's Kappa is respectively $\varkappa = .728$, 95% CI [.678, .778], $p < .001$ for the agreement between initial coding and R3, and $\varkappa = .727$, 95% CI [.678, .778], $p < .001$ for the agreement between initial coding and R4. According to Landis & Koch (1977) and Altman (1999), this indicates a substantial agreement between our raters. At the category level, inter-rater reliability is even higher: $\varkappa = .836$, $p < .001$ between initial coding and R3 and $\varkappa = .775$, $p < .001$ between initial coding and R4.

4 Results

Based on the identification of meaningful constructs, our results illustrate what are the most important aspects of a learning space for users. We first describe the categories of constructs elicited by our participants, before comparing our findings to some taxonomies described in previous studies. In the last section, we will discuss the use of this vocabulary repertory for the design and evaluation of learning spaces.

4.1 Categories of constructs elicited by our participants

Participants identified 15 contrast pairs on average (SD = 3.76), with a minimum of 8 and a maximum of 24. We therefore collected 381 contrast pairs in total, including some constructs cited several times (either by the same participant in relation to different elements, or by several participants).

Table 1 shows the seven categories and 22 subcategories of constructs elicited by our participants in relation to learning spaces. We decided to keep doubles (similar constructs cited several times) in order to reflect the prevalence of each category based on the number of occurrences.

Nearly a third (32.8%) of identified contrast pairs are related to the *Physical Context*. This category encompasses both properties of the physical environment, such as luminosity, colours and textures or space dimensions, and the underlying perception of user experience in terms of comfort or innovativeness. This dimension is very close to the Naturalness principle described by Barrett et al. (2015) and defined as "the environmental parameters that are required for physical comfort. These are light, sound, temperature, air quality and links to nature" (p. 119).

As we talk about learning spaces and since we provided the participants with pictures representing predominantly physical spaces, the prevalence of constructs in this category is not a surprising observation. It is nevertheless interesting to apprehend which aspects were the most salient in their perceptions. Elements related to the physical context at a more detailed level were classified in the *Spatial Configuration* category. Altogether, 48% of identified constructs relate to properties of the physical environment, either at a global or a micro level.

Table 1. Categories and subcategories of constructs, explained and illustrated by examples. Distribution of elicited constructs (N = 381) per category (ranked by order of importance).

Category	Subcategory	Examples of constructs	N	%
Physical context	Contrast pairs that relate to the properties of the physical environment and the underlying perception of user experience.		**125**	**32.8 %**
	Indoor/Outdoor	Indoor/Outdoor, Nature/No nature	40	
	Colours & Textures	White/Colourful, Wood/Plastic	21	
	Luminosity	Luminous/Dark, Natural Light/Artificial Light	20	
	Comfort	Comfortable/Uncomfortable	19	
	Innovativeness	Innovative/Traditional, Modern/Old School	15	
	Dimensions	Spacious/Small, Open space/closed room	10	
Social context	Constructs related to the perception of surrounding people in terms of presence, relationship and behaviour.		**94**	**24.7 %**
	Collaboration	Teamwork/Individual, Cooperative/Isolated	34	
	Privacy	Public space/Private space, Isolation/Crowd	17	
	Presence of people	Presence of students/Empty space	11	
	Hierarchy	Unhierarchical/Hierarchical, no teacher/teacher	11	
	Pedagogical practice	Frontal course/Self-learning	10	
	Target users	For students/for kids, Adults/Children	7	
	Group size	Small groups/Large groups	4	
Spatial configuration	Contrast pairs that are descriptive of the spatial setting at a micro level.		**58**	**15,2 %**
	Room type setup	Formal setup/Round table, Round/Squared	40	
	Seating	Chairs/no chairs, Sitting on floor/chairs	10	
	Flexibility	Flexible/Rigid	8	
Technology and resources	Constructs related to the technological context and the available resources at disposal.		**51**	**13.4 %**
	Technological resources	HighTech/No Tech, Computers/No computers	27	
	Virtuality	Real space/Virtual space, Offline/Online	14	
	Non technological resources	Writable walls/ unusable walls	10	
Emotions	Constructs related to users' emotions and feelings triggered by the space.		**31**	**8.1 %**
		Interesting/Boring, Enjoyable/Stressful, Creative space/Limiting space		
Task/activity context	Contrast pairs related to the type of activity or task that is actually conducted or that is best supported by the space.		**19**	**5 %**
		Lecture/Playing, For relax time/For study time, Playful atmosphere/Classroom		
Miscellaneous	Constructs that were not classified in any of the previous categories.		**3**	**0.8 %**

Beyond physical properties, our findings demonstrate that elements linked to the *Social context* are the second most identified constructs (24.7%). The perception of surrounding people in terms of presence, relationship and behaviour is indeed a meaningful factor when it comes to learning spaces. Nearly all participants generated contrast pairs that relate to the idea of learning in groups versus in isolation; at the very least, they noted the presence or absence of people in a learning space. The notion of privacy also appears as a salient topic: some participants even associated pictures with a projected "noisy" experience. Finally, the social context also involved elements linked to the pedagogical practice supported by a specific space.

While the category *Physical Context* describes properties of the physical environment at a global level, the category *Spatial Configuration* (15.2% of identified constructs) encompasses contrast pairs that are descriptive of the spatial setting at a more "micro" level. The room setup, type of seating and perceived flexibility of a specific space are the three salient elements in this category. Innovative approaches in HBI might change the perception of these elements in a near future, especially through the design of "responsive places" where users will be able to dynamically reconfigure the spatial configuration of a specific room (Alavi et al., 2016b). This would serve the so-called "dynamic classroom orchestration" described by Dillenbourg and Jermann (2010) as a characteristics of a good learning environment. In their model, the Physicality factor encompasses both the constructs of our Physical Context and Spatial Configuration categories.

The next category, accounting for 13.4% of elicited constructs, is *Technology and resources*. Contrast pairs identified by our participants relate to the technological context and the available resources at disposal. The presence of technological resources has frequently been identified as a relevant factor in the learning spaces presented to our participants. It is indeed mentioned in the literature as a key element of learning space design (Graets & Golber 2003; Lei, 2010; Han et al., 2014). Virtual spaces have also been opposed to real spaces and it would be interesting to analyse more deeply the perceptions and experiences associated with the ever increasing use of technology in education. One particular case is that of blended spaces, which will be increasingly popular in spaces supporting the learning of 21st century skills and combining physical and virtual properties.

Fig. 5. Word cloud representing a sample of constructs elicited in the category Emotions

Constructs related to users' *Emotions* and feelings triggered by the space constitute 8.1% of all constructs identified. They refer for instance to notions of interest and boredom, enjoyment or stress, and also to the perceived coolness or friendliness of a specific space. Relaxation, fun or inspiration, are additional examples of words used to describe learning spaces (Fig. 5).

Finally, 5% of contrast pairs relate to the type of activity or task that is actually conducted or that is best supported by the space. This is what we called the *Task/Activity Context*. Participants describe for instance that space can have a rather playful atmosphere as opposed to a classroom atmosphere, or they oppose the relaxing property with the calling for studying. This illustrates well how such spaces contribute to shaping the tasks and activities they can host.

Structuring the participants' contrast pairs has proven extremely useful to extract the major categories of constructs, representative of how users perceive the learning spaces used in our illustration material. This structure is instrumental for building a comprehensive understanding of aspects that contribute to shaping users' experiences. The construction of meaningful constructs is not a straightforward and easy task and needs to be conducted with great care. Based on similar wordings used throughout different categories, one might think that the ideas expressed are similar or identical. The interpretation, however, needs to occur on the level of the contrasts and not on the level of a single word. This also explains why the same word can be used to contribute to building different categories, cf. « friendly » which has been used in contrast with « cold », with « unfriendly » and with « serious » (Fig. 5).

4.2 Comparison between our findings and previous literature on learning spaces

Unsurprisingly, several constructs elicited in the present study were already identified in previous literature on the design of learning spaces (Lei, 2010; McArthur, 2011; Han et al., 2014). What differs is the categorisation of constructs and the fact that RGT informs us on the prevalence of some dimensions over others. Yhang et al. (2013) classified physical attributes of a learning environment into three categories: ambient environment (e.g., temperature, acoustics, lighting), spatial environment (e.g., classroom layout or furniture) and technology-related attributes. This is very similar to our *Physical Context*, *Spatial Configuration* and *Technology and Resources* dimensions.

The measures used by Scupelli and Hanington (2014) in their design studio case study also overlap, yet with less extent, with our categories. This is the case for the aesthetic appearance, color, quality of finishes, or furniture quantity and quality. They were grouped by Scupelli and Hanington under the theme "Aesthetic", but are mainly part of the *Physical context* and *Spatial Configuration* categories in our study. Similarly, while Scupelli and Hanington categorized the level of privacy under the theme "Acoustic", this construct is to be found here in the *Social Context* category. Finally, several elements identified by Han et al. (2014) through a focus group also overlap with our findings (e.g., comfort, lighting, classroom layout, aesthetics, technology). Unfortunately, it is not clear in their paper how the opinions expressed during the focus group have been translated into design requirements. Overall, the main limitation of focus groups is the influence of group dynamics on the expression of individual experiences. As compared to RGT, this could consequently reduce the richness of constructs elicited by participants.

While this dimension has not been mentioned very frequently by our participants (N = 8) one can note that the flexibility of a space is frequently mentioned in the literature as a key requirement for an experiential and innovative learning space. This notion of flexibility is cited under several names: flexibility (Han et al., 2014; Barrett et al., 2015), adaptability (Johnson & Lomas, 2005; Han et al., 2014), malleability or responsiveness (McArthur, 2011). One can assume that flexibility is a dynamic characteristic that is harder to perceive on pictures than other physical properties of a learning environment. Our findings will be discussed within the next section.

5 Discussion

Our results have unveiled the underlying structure of our participants' perceptions of learning spaces. Thereby, they have also demonstrated the usefulness of using the repertory grid technique for these purposes. While several constructs were already identified in previous literature on the design of learning spaces, the categorization and relative importance of each dimension to a population under study is essential and might be uncovered using RGT. In contrast to questionnaires, which tend to constrain the assessment of user experiences by using predefined items, the repertory grid method allows to uncover the structure of a system or an environment as provided by real users (Hassenzahl & Wessler, 2000). Design or architecture practitioners willing to design spatial experiences matching users' mental models can therefore rely on this method, regardless of the type of environment or experiences they are designing for. The access to mental representations, without any interference by predefined concepts and vocabulary, is an advantage that RGT brings to the researcher's and practitioner's toolbox. It illustrates its usefulness for deployment alongside other methods. Both in the architectural and education domains, pre- and post-occupancy surveys are widely spread (Mallory-Hill, Preiser & Watson, 2012; Scupelli & Hanington, 2014, 2016). While being cost-efficient, this technique however restricts the assessment to predefined dimensions, by often covering concerns that were chosen by the researchers and not necessarily based on the perspective of end-users. RGT might be for instance used as a basis for the design of pre- and post-occupancy measures from the perspective of the population under study.

In the educational domain, the interest of the vocabulary repertory on learning spaces experiences, established through the present study, is threefold. (i) At this stage, our classification is rather descriptive than prescriptive (Curtis et al., 2008), yet it highlights properties of learning environments that are given more or less attention and therefore can serve as a starting point for the exploration of users' needs. (ii) It can be used either as an evaluation framework of spatial learning experiences, or as a coding scheme in the analysis of HBI work. (iii) Hence, it can also serve as a basis for the development of theoretical models about learning spaces experiences. Future studies in this area could compare whether the way learners construe their spatial experiences aligns or differs with our classification. As highlighted by Hogan and Hornecker (2013), using the repertory grid technique during a focus group session allowed us to collect much more constructs than we would have unveiled using an individual interview approach. Our goal was indeed to gather a sound basis of constructs in order to build the present classification.

In those cases requiring a larger sample size or a remote study to investigate learners' needs, the constructs elicited in the present study might also serve as a basis to the construction of a survey investigating spatial experience in relation to learning spaces. Hence, in addition to directly supporting the identification of relevant and suitable dimensions, it can also "indirectly" support this process by improving the survey construction in a way that is most meaningful to the target users when assessing their experience with a space.

Interestingly, with regard to our findings, one should note that the constructs identified by our participants encompass both objective and subjective parameters of users' perceptions of learning spaces. On the one hand, the objective items have no affective valence (neither positive nor negative); they describe factual information (e.g., indoor or outdoor learning space). On the other hand, subjective items are tinted by a value judgment (e.g., comfortable vs. uncomfortable learning space), one extreme of the scale being negative, the opposite being positive. From an objective perspective, the *Social Context* category for instance informs whether the interaction took place in a public or a private place, in the presence of other people or not and whether the students were involved in a collaborative activity or working alone. The subjective perspective is mainly focused on the feeling of relatedness and further informs about the emotional component that shapes the relationships and, ultimately, the overall experience in a space while not being alone. Obviously, objective parameters of a space influence, consciously or unconsciously, the perception of subjective parameters. Whether the space is public or private can for example have an impact on the user's level of stress or enjoyment. Similarly, the luminosity or specific furniture provided in a classroom can influence the perceived level of comfort associated with this place. However, the relationship between constructs is not straightforward and greatly depends on the context of use. In Dillenbourg's classroom orchestration concept (2013), space constraints and spatial configuration are for instance perceived in relation to the instructional design and the requirements underlying the activities to be conducted. The classroom is therefore viewed as an "ecosystem". In our study, going beyond the two first steps of the repertory grid technique would have implied asking participants to rate each learning space against the elicited constructs *and in a specific context of use*. However, without any information on the learning context, it is impossible for the participants to assess for instance whether a space is perceived as comfortable or not. This made necessary the adaptation of RGT to our use case by focusing at this stage on its two initial steps.

Additionally, contextual elements might also account for the rather low proportion of constructs elicited in the category *Emotions* in our study (8.1%) and thus question the choice of space pictures as elements for construct elicitation. While physical space properties might appear as obvious triggers of constructs when comparing photographs, we assume that emotional dimensions are harder to project on this basis. Emotions are typical momentary experiences felt during the interaction and the feeling one has in a specific place is hardly reproducible on a picture of an unknown place. This is a limitation of RGT, which is not specific to the present study but yet might be addressed by relying on stimuli allowing the access to enriched experiences.

While HBI researchers could ideally rely on immersive experiences into existing physical spaces as elements to compare in an RGT triading task, this might often be unrealistic from a logistical perspective. Innovative technologies such as Virtual Reality (VR) therefore appear as a good match to meet both experiential requirements and logistical constraints. Even though intangible representations of elements have been traditionally used in RGT (e.g., pictures of products to be compared without experiencing them with all senses), giving the opportunity to participants to immerse themselves in the experiences of products or spaces would allow a better use of RGT in the context of UX design. This is a peculiar aspect we would like to explore in future research; we have explained above why this approach could not have been deployed in our use case without limiting the scope of stimuli or biasing the results towards a subset of stimuli.

Similarly, some dimensions identified in previous studies on learning spaces, such as Stewardship (Scupelli & Hanington, 2014) and its associated feeling of lacking agency over one's environment, were impossible to uncover in the present study because the spaces used as stimuli did not belong to the users' daily environment. In order to account for the importance of the context and to investigate emotional experiences further, our future work will encompass an evaluation of experimental learning spaces *in-situ*. In combination with other UX methods (e.g., observations, interviews, participatory design), we will use the repertory grid technique once again (including rating and analysis steps) to assess real spatial experiences with full scale experimental spaces implemented at the University. We will explicitly ask the participants to assess these spaces based on specific contexts of use, which have now been defined as priority learning spaces to be designed and implemented at the University (e.g., a collaborative space for debate activities or a co-creation space). This will allow to overcome the limitation that the picture-stimuli might have imposed in the study we report on and to apply all steps of the RGT.

We also intend to compare teachers' and students' perspectives in order to see whether significant differences can be observed when comparing the perceptions of these two end-users' groups. The inclusion of every category of stakeholders and end-users is a prerequisite in any user-centered design process and supports the generation of design solutions able to address the major needs of all target users.

6 Conclusion

User-centred design is all about transferring the focus away from deciders and designers towards actual users. Since designers cannot take meaningful and, in the case of building design, high-stakes decisions based on their sole expertise or "common sense", it is of paramount importance to develop a profound understanding of spatial experience in general, and of learning spaces interaction in particular. In general, methods drawn from psychology, such as the repertory grid technique, are particularly well suited to support this process of exploration and understanding. Learning and teaching in the era of 21st century skills calls for such thorough analyses in order to enable successful learning outcomes and positive experiences.

In particular, we have shown how the repertory grid technique broadens the toolbox for practitioners and researchers in HBI from the earliest stages on, by creating design-relevant information. The added value of RGT, in comparison with most other methods, is that it allows accessing mental representations without interference as imposed by pre-defined concepts and vocabulary. As compared to projective techniques or cultural probes (Gaver, Dunne, & Pacenti, 1999), which can also be deployed to understand the meaning attached to spaces by end-users without constraining the expression of their thoughts, RGT offers a more systematic analysis framework. These advantages make it especially useful for supporting i) the design activities (e.g., identifying and naming the most important dimensions to be considered for the relevant population of users) and, ii) the evaluation of design outcomes (e.g., creating scales and instruments based on the mental models unveiled by RGT, as opposed to relying on standardized and generic instruments only).

Our study also provides concrete directions for further research with in-situ contextualisation and the deployment of all four stages of the technique ranking next on our research agenda. The latter will allow integrating further quantitative analyses, thereby enabling cluster analysis and salience assessment. Overall, RGT thus offers concrete advantages for HBI. Its main limitations, as demonstrated by our use case, are the following: i) depending on the amount of stimuli to be included in the study, RGT has to rely on proxies of experiences in most cases instead of enriched experiences; ii) RGT can be a time intensive method to deploy on a large sample, especially if one attempts to adapt the method by using immersive or experiential stimuli ; iii) it does not uncover all aspects of a lived experience, especially those that are related to the daily use of a learning space (e.g., sense of ownership, control over one's environment or interdependencies between several spaces).

By exploring the subjective meaning of learning "spaces", professionals involved in HBI have the opportunity to build meaningful and fulfilling learning "places". The ever-growing integration of technology in buildings and urban environments further stresses this need for user-centric approaches able to provide "interactive opportunities for the occupants to shape the physical, spatial, and social impacts of their built environment" (Alavi et al., 2016b, p. 3409). Taken together, complex projects will call for combined methods able to provide a complex picture of learner-spaces experiences. RGT is a good candidate to be included, while the reduction to a single method might not sufficiently account for the complexity of an HBI project.

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