# Performative Roles of Materiality for Collective Creativity

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## ABSTRACT
This paper seeks to develop a better understanding of the contribution of materiality for creativity in collaborative settings, exploring the ways in which it provides resources for persuasive, narrative and experiential interactions. Based on extensive field studies of architectural design workplaces and on examples from art works, we show: how the variety of material features expands communicative resources and provide border resources for action, in their peripheral, evocative, and referential function; how spatiality supports the public availability of artefacts as well as people's direct, bodily engagement with materiality; and finally how materiality is part of performative action, looking at temporal frames of relevance and emergence in specific events. We conclude with implications for the development of novel interface technologies.

### Author Keywords
Materiality, collective creativity, design, learning.

### ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## INTRODUCTION
There is a broad spectrum of artefacts in cooperative work settings and each of these categories needs separate attention. Some are products (or tools), such as books, machines, furniture, door handles, appliances, clothes, ladders. Apart from enabling people do their work, protect themselves, move around, they may engage through their specific design or the care and competence with which they have to be handled. Other physical artefacts are representations of the work that emerge as part of the work process (physical models, building elements, documents of all sorts). Here materiality is a crucial aspect of the representation, giving participants clues about all sorts of conceptual and material aspects of the work. Again other artefacts (a wall, the odd object lying around, etc.) may be just 'evocative', aspects of the environment that stimulate, remind, constrain. One of the virtues of these tangible artefacts (within a space that itself has material qualities) is their engaging capacity. They ask us to experience through seeing, touching, smelling, maybe also gesturing, heaving and moving. Involving all the senses is to do with richness of 'informational cues'. More importantly, materiality supports intuitive and simultaneous manipulation, mobilizing our tacit knowledge and enabling participation. Studying the role of materiality and material practices is made timely by the rapid developments in interface technologies that address the physical environment, the body and multimodality, for example tangible, enactive, multimodal and mixed reality interfaces.

An interesting area for research that has been poorly addressed is to study how materiality features in creative and collaborative settings as for example design or learning. Literature on creativity has mostly focused on individual cognitive processes neglecting the influence of material features and the collective character of creativity. With the exception of few studies of pupils the roles of physical artefacts in creativity remains unexplored [34, 22]. Moreover studies have focused on individual behaviour, personality and cognitive processes [38, 16]). Others like Csikszentmihalyi [2] have attempted to consider also contextual and cultural factors. However, when speaking about the creative surroundings, he considers "being in the right place" or inspiring environments as "comfortable" places. Similarly Robinson and Hackett [28] describe the conditions for creativity that are useful in organizations considering changes to systems of thought and introducing the concept of domain as cultural systems bounded by training and practice and shared knowledge. Previous work argues that the collective emergence of creativity and its interactional aspects have been neglected [29, 17] as well as the possible roles of materiality and its ability to speak to "multiple senses". In fact also communication studies have been lately criticized for having had a semiotic bias that resulted in considering materiality in a limited way. A critique is proposed by anthropologist Ruth Finnegan [5], who argues that an anthropological approach challenges "…the focus on 'meanings', 'symbols' and 'verbalised articulations'" and instead draws attention to "…the role of human-made artefacts and their multi-sensory dimensions" (p. 7). The result is a distancing from the written word and intellectual meaning towards the variety of ways of human interconnection – e.g., sounds, touch, sight, movement,

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material artefacts – and the "significance of shared experiences, dynamic interactions, and bodily engagements beyond the purely cognitive" (p. 8). For these reasons we advocate an anthropological approach with ethnographic observations to investigate the role of materiality in contributing to creative practices. Moreover, we propose to complement these with examples from other disciplines such as art and architecture where practical and reflective works have considered the role of materiality for experiential communication and imagination.

In this paper we address two questions: 1) What features of materiality can contribute to creativity? 2) What can be their role in collective processes? Our aim is to provide a conceptual understanding of how materiality can contribute to creativity in collaborative settings and indicate fruitful avenues for technology development.

### Artefacts in CSCW and Design Studies

CSCW researchers have increasingly come to realize that material work settings and the artefacts that populate them play a crucial role in the seamless and effective alignment of cooperative work and in the ways accountability is ensured. Schmidt and Wagner argue that "the concept of artefacts as used in CSCW is murky, ripe with all sorts of mentalist and cognitivist precepts that impede and confuse the investigation of the infinitely variegated array of actual material practices" ([32] p. 390). They suggest to reserve the concept of artefacts to concrete, physical objects, with which abstract, non-physical qualities (meanings, ideas, norms and so on) are always associated, but whose materiality affects the ways we relate to them, experience and use them. The question than, is how to study materiality as part of material practices. Ethnomethodogically informed ethnographic studies demonstrated that material artefacts play a crucial role in coordinative practices and there are numerous examples of artefacts whose 'biography' and the practices surrounding them have been studied in depth; flight progress strips [13], patient records [9], and the plethora of artefacts that support architects in their work [31]. This research shows that material artefacts make work visible, structure communication (e.g. between doctor and patient), provide a workspace and template, ensure due process, help manage interdependencies that transcend local interactions, and so forth. For example Henderson [10] describes how architects and product designers communicate through sketches and prototypes. She looks at artefacts as "network-organizing devices," individual and interactive thinking tools, and organizers of interdisciplinary communication. The focus has been on demonstrating how material work settings and the artefacts that populate them play a crucial role in the seamless and effective alignment of cooperative work and in the ways accountability is ensured. Connected with this research, there is a growing interest in technologies that integrate with the physical environment of artefacts and space and, connected with it, in 'embodied interaction' and 'tangible' and 'multimodal' user interfaces. More and more studies draw attention to the performing body, to spatiality, and to the haptic qualities of physical artefacts as crucial for interaction, experience, and understanding. Underlying this debate are notions that have proved inspiring, such as that the 'tangible is more social' [4]. An important resource for understanding creativity in collaborative settings and the role of materiality are studies on design and learning. This is because designers use and produce a diversity of artefacts in different media and materials, and learning how to design requires students acquire expertise in expressing and developing a design concept through these artefacts. But when we look at studies of design practice, we see that design is commonly regarded as an act of individual creation with an interest in the underlying cognitive processes, and in "cognitive artefacts", such as sketches and drawings [24]. Researchers tend to look at visual design thinking as a rational mode of reasoning [8]. This focus on the individual and on the cognitive is maintained when analyzing how designers imagine physical forms and the materials from which an object-in-design will be constructed. Goldschmidt refers to concepts such as "long-term memory" and "figural conceptualizations", arguing that designers refer to both, relevant conceptual knowledge and knowledge about previously analyzed and experienced examples or precedents, for imagining specific materials, forms and their arrangement [7, 8]). Schön and Wiggins [33] have presented a similar view, arguing that design consists of sequences of seeing-drawing-seeing, which allow the designer to bring more and more facets of their knowledge into conscious thought. Although Schön is often quoted as having talked about the designer's reflective conversation with materials [33], his emphasis is on the conversational relationship with a medium, whereby the role and features of materiality remain largely unexplored. In [21] collective creativity is considered but the focus is on providing a system to share visual images not considering collocated interaction and material artefacts. In conclusion, the collective emergence of creativity, designers' interactions with the physical environment and the role of materiality in its ability to engage all our senses have been neglected in design research.

### Our Approach to Studying Materiality

While CSCW and design studies have mostly approached materiality as providing accountability, affordances, coordination, with our studies we strive to orient research to new roles as for example the persuasive, the performative, the experiential. These concepts are grounded in field work in a particular setting were participants learn by doing architecture design. Moreover we complement these examples of collaborative activity with experiences from architecture and contemporary arts that have a long tradition in exploring the relations between creativity and materiality. There is a strong interest in materiality in design and architecture, for obvious reasons. Studying the work of designers has exposed us to materiality in a way which few other areas of work offer. This is to do with the

fact that designers (of architectures and other tangible products) produce and communicate through a great diversity of design representations in different modalities, scales and materials, and that design work proceeds through the constant transformation of these representations in a process of ongoing refinement and increased specificity. In design practice, materiality is seen as more than a technical property of the materials from which a building or designed artefact is made from, "it is a precondition that promotes ideas, creativity, and pleasure in architecture, and it guides us to the loftiest aspirations of theory", writes Jorge Silvetti in his introduction to 'immaterial/ultramaterial', a description of projects that "sought to extend the materials' spatial, tactile, and experiential potential through the employment of these imaginative techniques" ([20], p. xvi). What becomes clear when looking at projects such as these are two things: First, material artefacts engage us with all our senses. Materiality comprise physical properties such as texture (roughness or smoothness, details), geometry (size, shape, proportion, location in space, and arrangement in relation to other objects), material (weight, rigidity, plasticity), energy (temperature, moisture), as well as dynamic properties [28]. Many of these properties are 'dimensions of touch'. Secondly, our interactions with materials are not just 'physical' but they spur our thinking, help us communicate ideas that would be difficult to communicate through words alone, adding an 'experiential' dimension to our action. While the concept of affordances of artefacts is fundamental to an analysis of the use of material artefacts, it is not sufficient for addressing the very intricate interrelationships that emerge in people's interactions with and through artefacts. We use a diversity of resources for understanding these subtler aspects of materiality. The majority of examples we selected for this paper is from fieldwork we carried out observing and making technological interventions in project based work of students of architecture at an Academy of Fine Arts where aimed at developing a tangible computing environment. We used a variety of collection methods like participant observation, interventions, interviews, video records, and artefacts analysis. The analysis is informed by workplace study methods such as grounded theory and interaction analysis. In addition we try to learn from how artists and architects play with and exploit materiality. This is why we will often refer to examples from art work to back up our arguments.

## THE RICHNESS OF MATERIALITY

### Material Diversity of Representations

Designers customarily work with representations in different media. Even in a small design project (such as the ones we observed when working with students of architecture and interaction design) they may produce a diversity of representations, from (metaphorical) text, diagrams, comics, and video clips to 'sketch models', virtual models, and physical prototypes. This abundance and wide range of design representations has been observed by many others (e.g. [23]). The argument is that important design decisions occur in the transitions and translations between representational formats and scales. Working with architectural students, Iwamoto points to how "translations between rapid prototyping and full-scale mock-up, between seamless form and standard sheet material, and between computer model and spatial or phenomenological effect" helped them cope with the "later translation of the digital information to full scale" ([14], p. 35). We can see this conscious use of different representational formats and media also in some art work. For example Robert Smithson, in his art work Mono Lake Non-Site, uses a rich set of representations for letting both, concrete experience and imagination, merge. In this particular art installation he plays with the 'Dialectic between Site and Non-Site' (the real site of a project and the non-site of the gallery space): "… the rocks indicate collecting and placing, the bins frame or establish boundaries, the photographs suggest walking or moving about the site, the maps indicate location, and so on" ([11], p. 54). All these examples point to a more general set of material practices: making use of a diversity of representations in different media and materials for conveying and exploring different (conceptual, technical, aesthetic) aspects of a design or a piece of art. It is not just the diversity of representations that is fundamental for design work but their richness. Lawson points to the fact that "design conversations are extraordinarily compact since they are full of references which in turn point to huge chunks of information". This is possible since "enormously complex and sophisticated sets of ideas can be referred to using simple diagrams, catchphrases (for example, 'round shapes in square containers') or even single words (for example 'belvedere')" ([18], p. 445). Metaphors and materials are important vehicles for communicating complex concepts and ideas and designers can point to sets of extraordinarily rich visualizations in their conversations. Designers often use material features as resources for narration and persuasion. Figure 1 shows some examples from students work. The small image stuck into the white foam block (left) tells a story about envisioned future use. The pieces of material inserted into the model of a famous building (middle) point to the original furnishing of the space. The detailed shingles (right) tell of the great care the students took in communicating the charm of a seemingly decrepit wall. These material techniques widen the spectrum of communicative resources by evoking sensual experience.

### The multi-modal aspects of materiality

This richness partly originates in the materiality of some of these representations and, more precisely, in their multimodality. The small image in Figure 1 tells its story in combination with the white foam block into which it is stuck and the map on which the block is positioned. This mixing of modalities is common practice in architecture. We observed some of the techniques architectural students

**Figure 1. Narrative, persuasive aspects of material features.**

use when they build models. In the architectural studio or classroom materials often are present in the form of random collections (left-overs from previous projects, samples etc.). Selecting and probing different materials is an important activity.

As part of this students may explore the surface (texture, details) of a material, its tactile properties, its temperature, smell, and moisture, since it is these qualities that carry ideational, interpersonal and textual meaning. We also observed students produce a variety of scale models, using different materials and techniques. While a small 'sketch model', rapidly put together from crumbled foil and clay, may help them visualize the design concept, other, more elaborate models my help them develop aspects of a building, such as spatial layout, colour or interaction with daylight. Such as in this example of a series of models students built to convey the idea of "something that flows out of a crack in the mountain".

While in the rough sketch model (Figure 2) a piece of soft plastic material visualizes the 'flowing', the small cardboard model that has been inserted into a large clay model of the valley (left) stresses the compactness of the flowing building, and the half relief (below right) conveys the rhythm of the spatial layout. Here each model has its own 'mode' of expression, with the series seen together forming a multimodal representation of the design concept. As we can see from these (and other) examples, materiality connotes a variety of qualities that are connected to our different senses (vision, sound, smell, touch) and vary with parameters such as thinness, transparency, porosity, lightness, etc. It is this multi-modality that turns the materiality of an artefact into a source of rich experiences and occasion for multiple action. Ormerod and Ivanic's [22] research on children's (art) work and their practices of meaning-making comes closest to our notion of how to

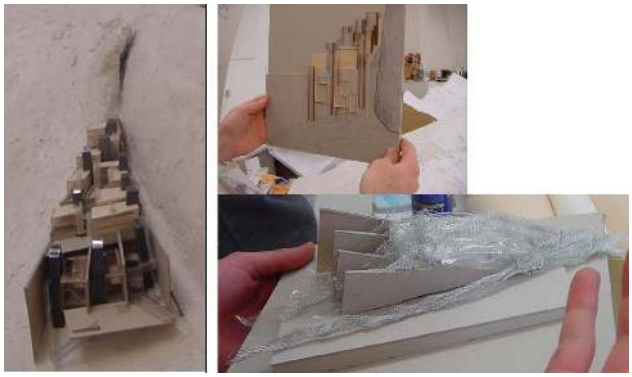

**Figure 2. Different representations of the same design Narrative, persuasive aspects of material features.**

**Figure 3. Equipping models with touch sensors**

analyze materiality. They look at text as material objects with distinct physical features and investigate how children choose from a range of semiotic systems (written sentences, maps, diagrams, pictures) and materials (surfaces, substances, tools) for conveying meaning; how they discover how physical and visual techniques can be made to represent more abstract kinds of information, such as for example atmosphere, emotions; how they assemble layers of different kinds of material into extremely complex, multi-textured spatial environments. While some physical and visual techniques can be made to represent more abstract kinds of information, such as vibrancy, fragility or motion [22], others are more directly representational of what a building will actually look like.

Other representations as the augmented model with touch sensors in Figure 3 combine material features with multimedia that add a narrative element for interactive presentations. We may add light, sound, air, and smell as materials that matter. James Turrell's creations of objectless light spaces materialize light. Wide Out (1998), for example, suggests an endless expanse. The viewer walking towards the blue light, even though losing the feeling of Euclidean geometry, is totally immersed into an objectless coloured field, which feels material. Designers recognize sensory components as materials. Toshiko Mori describes an augmented foam bench: "This bench thus performed multiple roles as a tactile artefact (foam), reactive material (temperature-sensitive paint), audible element (sound installation) and light-interactive agent (light installations). The bench exemplified a simplicity and integrity of materials yet displayed a complexity of functions and interactions as experienced by various senses" ([20] p. 64).

### Expanding communicative resources

As we have argued, CSCW research has largely (though not exclusively) focused on 'inscriptions' of all sorts and their material, graphic expression (patient records, flight progress strips, sketches, CAD plans, wallboards, etc.). Our examples point to the richness and diversity of material features and how these engage and activate our senses – bodily, tactile, olfactory, auditory and visual. Connected with them are different modes of expression, e.g. from abstract to concrete, from the literal to the metaphorical, from flat to solid. The notion of "something that flows out of the crack of a mountain" is communicated by the shape of the material, its shimmering, semi-transparent look, and

its lightness. The power of material artefacts like the ones we studied is that they may communicate qualities or ideas "in a more subtle, elegant, discreet or economical way than a natural language is capable of" ([27] 1992, p. 109). The messages conveyed by these artefacts are coded in a language which cannot be separated from the 'medium' itself. There is a strong narrative and persuasive element connected to material features. The shingles on the model of the wall of a building (Figure 1) tell of decay but also communicate a sense of history and place – this is where people have lived for decades and it is worthwhile preserving the building (this was the students' design suggestion). These resources, if exploited consciously, expand actors' opportunities for communicating and cooperatively exploring. Brown and Duruid [1] think of material artefacts as having 'border resources' for shared interpretation. They call the border those aspects of an artefact and its periphery that is available to each person involved in a particular interaction with the artefact. When a machine malfunctions, its sound may move from the periphery of the users' attention to the centre. Other examples they discuss are the noise of a keyboard which may be seen as constitutive of the typist's rhythm, or the bulk of a book, which may be indicative of genre, inviting to read or deterring. Border resources establish and evoke particular conventions (e.g. of use). Specific of design work is the clever use of border resources but also their reinterpretation. We have seen that some of the materials the students work with are clearly indicative of properties of building materials, such as the plastic sheets that can easily be recognized as transparent material to look through and let light in. But design work is also about playing with the conventional associations a material evokes, thereby extending their experiential potential. The notion of material features being border resources helps us identify the interpretive conventions associated with particular features as well as the interactions they suggest. For example, the informality of the materials and their physical arrangement on the big shared model signals that these are temporary traces of work-in-progress.

## SPATIALITY - ARTEFACTS IN SPACE

### Spatiality as a thinking tool

Another important property of physical artefacts is their geometry (shape, size, proportion, arrangement) and their location in space. Spatiality facilitates interaction, as we know from studies that point at the role of visualizations, such as sketches or large print-outs of plans, as interactive thinking tools, organizers of interdisciplinary communication (e.g. [10]). In his description of Aby Warburg's famous library, his assistant, Fritz Saxl writes: "The arrangement of books was … baffling, … Warburg never tired of shifting and re-shifting them. Every progress in his system of thought, every new idea about the inter-relation of facts made him re-group the corresponding books" (quoted in [19], p. 229). Warburg himself wrote how important it was for him to have all the books and

**Figure 4 Friederike Mayröcker's working space, shared models in architecture design students.**

images which he used in his studies of the psychology of artistic creation be arranged on a large table, so that they could be instantly reached, compared and contrasted. He arranged his Mnemosyne on panels covered with back cloth. "One must see them in their material configuration", argues Michaud, "being attentive to the spaces between the images, their variations and their repetitions, the ways in which the reproductions are concentrated in certain areas of the panels … " ([19], p. 244). Spatiality, having things within 'instant reach', being able to group and regroup them physically were essential for Warburg's identifying tensions, analogies or contradictions between the seemingly disparate objects he collected.

There is another aspect of spatiality that is to do with things being cluttered, messy, un-orderly or clean and nicely laid out. While Warburg's arrangement is orderly, providing overview, suggesting relationships, writer Friederike Mayröcker prefers to be immersed in slips of paper, manuscripts, newspapers cuttings, brochures, folders, and books, in piles, hung up like laundry, on the piano, the TV set (Figure 4 left). Schmatz describes this 'creative density' as constitutive of her work: "Her discoveries (in this chaos) are submitted to a poetic exercise, which – folded across the workspace – extends into the perceptive-sensual apparatus of the writer and reader" ([30], p. 197). It is not just the presence of a great diversity of texts but the physicality of the arrangement, with e.g. paper clipped onto a clothes line, which enables the chance encounters that stimulate Mayröcker's writing. Also our own fieldwork observations show how engaging in an immersive mass of material may support intensity in design situations.

### Artefacts as Workspaces, Scale and Dimensionality

As Aby Warburg's work practice shows, spatiality is supportive of things (such as the relationships between seemingly disparate objects) to be quite directly accessible and shared. We observed students making their design interventions publicly visible through placing materials on a large plaster model of a mountain valley, visualizing a path or a river (Figure 4 right). This was a model of a region in the Alps which was shared by everyone in the project, where each of them located their own project and

where all of them discussed joint interventions. Whenever we visited, the model mirrored the actual status of students' discussion, showing things that were changed or added, either jointly or by one of them. The material traces they left, made from wool or modelling clay, participated in stating the mutable and temporary status of their design ideas. In his interviews with expert designers Lawson heard them describe how important it is for them "to see things encapsulated in one small image". Herman Hertzberger, for instance, told him: "It's a sort of imperative for me, you know. I insist upon having my concentration on quite a small area, like a chess player. I could not imagine playing chess in an open space with big chequers" ([18], p. 447). The concentrated view helps blend out details and focus on essential conceptual aspects of a design. On the other hand, we found design students having enormous difficulties to imagine things in full size. There is a need for them to experience a thing in different scales and from different angles, performing the kind of translations we already pointed at as an important aspect of design work. They use different techniques of working with scale and dimensionality.

As the student with the saw who made close-up photographs of a material feature, exploding the small detail by projecting it onto the wall, thereby giving it an oversize spatial dimension. The dents of a saw, blown up and projected, turn into something else (Figure 5). Students may also perform walk-throughs through a model with an endoscope. They, for example, carried their models to the site, producing images of them as if in real size in real physical space, probing how the environment reacts to the model (Figure 6). These simple techniques help designers view and evaluate an object in relation to other objects within the physical space. Playing with scale and dimensionality brings different aspects and properties of an object to the fore. It becomes 'measurable', with the body and other features of the physical environment (the high-rising buildings in the background) providing a frame of reference.

### Spatiality and Direct Engagement

Materiality matters in how people interact in collaborative settings due to the public availability of material artefacts and embodied actions in the physical world. In physical space, bodies and artefacts are put into relations that are meaningful in themselves and suggest particular interactions, depending on scale and dimension. Our direct

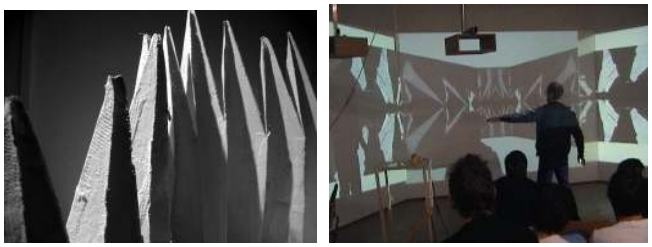

**Figure 5. A small detail into a spatial collage.**

**Figure 6. Views from a model in an outdoor environment.**

engagement with artefacts and the direct feedback provided by materiality become part of the shared resources for coordination and expression. This has also been observed by others (e.g. [4, 25]). Verbeek and Kockelkoren [36] introduce the notion of 'engaging objects'. Referring to the writings by the American philosopher Albert Borgmann, they define as engaging the capacity of objects to absorb people's attention, thereby increasing their engagement with each other and the world. This engaging capacity reaches beyond an object providing a specific functionality. The physical qualities of an object have an important part in this engaging capacity and engagement is supported by haptic directness. When handling a physical object, we are in direct haptic contact with it, receiving haptic feedback. Directness means that there is no 'interface' other than the shape, texture, temperature, and moisture of the object itself. Hull's 'art of gazing with my hand' is a telling example. Hornecker and Buur [12] argue that haptic directness provides an isomorphy between manipulation and result – we can watch the effects of our activities while performing them - and that it enables simultaneous interaction. Haptic directness is a crucial part of model building. The two students think aloud and converse while inserting small pieces of materials in their model, moving these pieces and observing how these materials and their positioning affect the model. They cannot only see the pieces, they are in touch with them. The experiments with the Texture Painter we described preserve some of this haptic directness. The model of the saw can be touched and moved around, while the act of 'painting' becomes dematerialized and indirect. Still, holding a paint brush provides a different, more direct experience of 'painting' than manipulating the mouse. What our analysis adds to the notion of 'embodied interaction' [4] is to do with the haptile and locomotive properties of material artefacts. Rodaway [26] distinguishes between different kinds of touch. 'Reach-touch' "is more than just the exploration of objects held in the hand, it can involve the whole body actively 'sizing up' and 'interacting' with tactile space" (p. 52). 'Extended touch' and 'imagined touch' indicate that human touch can reach beyond the immediate geography of the body. This is visible in our example of students blowing up small details of an object (its picture) or scaling down pictures of buildings to the size of a person and how this lets artefacts and their environment mutate in surprising and inspiring ways (e.g. Figure 5). Here students explore an artefact's size, shape, proportion, location in space, arrangement in relation to other objects using different kinds of touch. It shows how haptic experience of material

artefacts can "generate a range of distinctive geographies, giving both much detail about our own bodies, objects touched and the wider environment in which they are situated" ([26], p. 54).

## PERFORMING MATERIALITY

### Making Artefacts Communicate

The way we communicate and experience is fundamentally tied to the way our bodies relate to material features. Warnier includes motricity or movement (of our bodies and of objects in space) in his analysis of materiality. He describes the connections of the (moving) body with the environment of artefacts and space "as a dynamic synthesis of sensori-motricity in a given materiality … Its boundaries are flexible. They can be extended to include lots of objects, the dynamics of which are successfully incorporated in the synthesis" ([37], p. 7) Fashion designer Issey Miyake emphasizes this dialogue between the moving body and material. Speaking about his work, he explains: "From the beginning I thought about working with the body in movement, the space between the body and clothes. I wanted the clothes to move when people moved. The clothes are also there for people to dance and laugh" (quoted in [20], p. 71). The expressivity he observes (and as a designer aims at) is to do with the qualities of moving bodies and materials on the one hand – things moving lightly, swiftly or slowly - with qualities, such as the transparency, roughness, colour, suppleness of the material on the other hand. We can interact with artefacts in an expressive way exploiting their materiality. To take a detail and explode it, to view a model as if in real size in a real physical space or to take pictures of a model from different angles are all activities that have a performative aspect. This leads to a more general observation of people performing artefacts to make them communicate.

Carving out bits and pieces of a foam model is a simple instantiation of performative action with material artefacts. The student first carved out the shape of the model in Figure 7, in several steps. The shape was used to create a hollow model that he then cut into two pieces, thereby gradually transforming it into something else. Even the residues of materials may be significant; they may convey the sense of the space being carved out of the model. These leftovers do not simply disappear (unless put into a bin), they witness some of the action that has been taken and the design decisions that motivated it. It is not the different states of this model that capture our attention but the process of carving out; and the student moving on from model to model, 'as if' producing a performance of a design concept in the making. Using technologies may make this more obvious, as the student with the saw let us observe. He took pictures of the saw in movement, produced a series of sketches and drawings, and built different models, thereby exploring the notion of architectural space. As part of this task he placed one of the physical models he had created out of the movement of the saw on a table, using the Texture painter (Figure 8). This is a tool for 'painting' virtual overlays - textures, images or video - on to physical objects, such as models, in real time. Painting is done with a 'real brush', which is tracked with a video camera. Users can apply (mixtures of) different images on an object, change brush type and size, and transform the images by scaling and rotating them.

**Figure 7. Carving out, from solid to hollow, and cutting.**

By applying colour, inserting movement and context, and varying its dimension in relation to other objects in the physical space the student changed the properties of the artefact itself. Due to its physical presence within the space, 'painting' the physical model with the Texture painter became a performance, with the student moving around the model, touching it with his hands, approaching to have a closer look to then take a step backwards, gesturing, etc. The student's movement within the space, which engaged his whole body, brought a strong expressive element into his interactions with the model. Furthermore, the imperfections of the physical model, of its shape and surface, merged with the digital paint of images and video in surprising ways. A central performative aspect is the relevance of the process rather than a final product (a final digital physical configuration). The process allows experiencing the metamorphosis of representations. Interventions and transformations are at the heart of the performative use of materiality, which allows creating new insights through different configurations of physical artefacts, bodies and digital media. Next, we deepen the analysis of the temporal unfolding of material practices.

### Material Events and Temporality

There is a temporal dimension to the diversity and richness inherent in materiality. Let us revisit some of the examples we described so far. They point to different time frames. The creative density exhibited by Friedericke Mayröcker's office is one that has accumulated over years, in which the poet added layers and configurations of materials she wanted to be present in her work environment (Figure 4 left). There is no obvious (narrative, chronological, etc.)

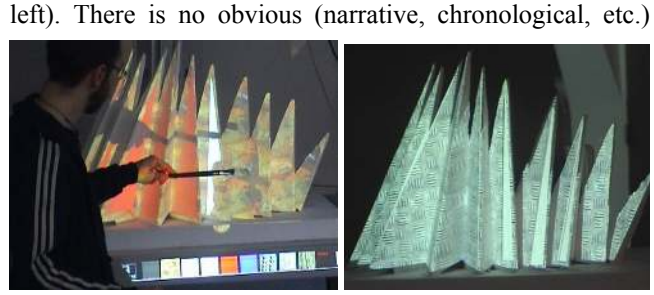

**Figure 8. Transforming a model with the Texture painter.**

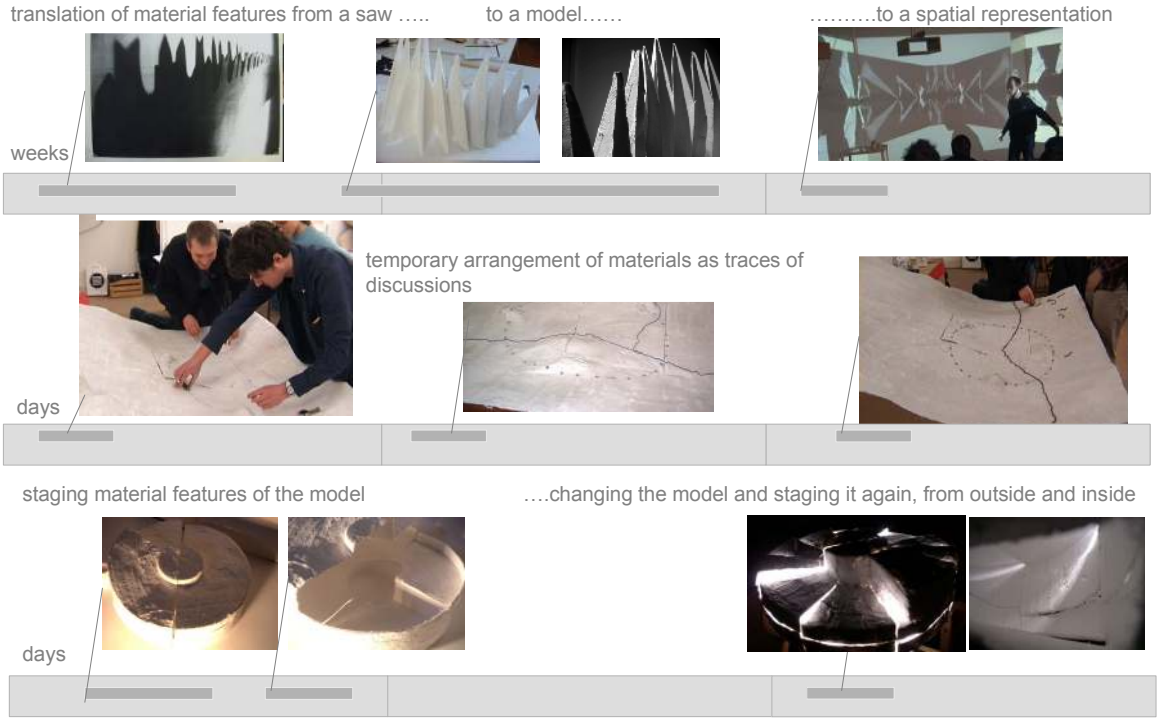


Figure 9 Material events

order. The three models visualizing "something that flows out of a crack in the mountain" exhibit a somewhat different time frame (Figure 2). These models have been developed in several months of work and they are indicative of a shifting focus in the students' thinking. Although they have been produced in a sequential order, they maintain their relevance as they communicate complementary aspects of the design project.

Let us look once more at the first semester student who studied a saw and its movements, translating it into a physical model (Figure 9, see also Figure 5 and 8). In a later session, using different light sources, he highlights details of the model that exhibit distinctive material features, such as the dents of the saw. Using multiple projections he transforms a collage of these details into a spatial installation. We can look at this as a particular material feature 'circulating' through different representations, in a sequence, helping the student to explore its significance for creating an architectural space. Each transformation deepens the student's understanding of the material and makes the design concept mature. These students explore the properties of concrete step-by-step, with one discovery leading them to the next design intervention. Another type of temporality can be identified in the ways the students make use of the big shared model (see also Figure 4 right). Here we observed a more ephemeral apparition of material features, with students, from day to day, leaving material traces of their design thinking on the model or overwriting them in the next collaborative design session. These (temporary) traces serve as indices to planned or discussed interventions in the mountain valley. They change or disappear with the progress of students' discussions. Also the 'carving out' example has a temporal dimension. It shows how one model is transformed, over the course of a few days, to perform different visual effects through its changing shape and material features. This resonates with Russian designer Vladimir Tatlin, who held that design should "derive from exploring and exploiting a material's intrinsic qualities, and be considering how it might combine with other materials" ([6], p. 53). A more general point is illustrated by these examples: There is a temporal framework connected to material features which elucidates how these emerge in specific events. Hence our notion of 'material events'. These events range from: long-term activities, such as creating a material-dense work environment or design space; to creating design representations from different materials or exploring a specific material through circulating it through different representations – gradually transforming and translating the design concept or even 'jumping' between formats, scales and media (all activities of medium durée); to short communicative events (leaving temporary traces).

**Materiality in Performative Events**

Our analysis points to a diversity of material resources for collaborative creativity. The different material features of an artefact engage our different senses and are connected to different techniques of working with materials – perceiving, expressing and experiencing. The spatiality – an artefacts size, shape, proportion, location in space and

arrangement in relation to other artefacts and people - invites the exploration of material features in performative acts. Experiencing how artefacts emerge, are transformed, translated into other media in time, as part of specific events has an important part in how concepts are developed and understandings created. Victor Turner [35] studied the experience of a culture through analyzing its expressions, showing how experience, expression and perception form an intricate relationship. Perception occurs when we experience a thing that imposes certain qualities that create new insights for the participant [3]. The 'creators' of an artefact engage with it through a diversity of techniques of working with materials –shaping, augmenting, joining them, and so forth. This 'expressing' contributes to their understanding of concept and next steps to take. Time is an important dimension in this circle of perceiving, expressing, and experiencing [15]. Material features play an important role in performative events for collective creativity where participants construct a fictional space to make their shared object of design come alive. In this space imagination is fostered by interactions between participants and material features serve as creative constraints and evocative resources [17]. If followed over time, interactions with material artefacts reveal how features are transformed to create new insights, e.g. a model is cut out of a foam block (Figure 7), soft plastic material turns into a metaphor for something flowing (Figure 2); or material features are translated from one medium into another one, e.g. students taking a picture of their models, exploding details in the space (Figure 9, upper series). These transformations (of material features) and translations (of features in different media) are core strategies of collaborative expressing and experiencing. For design work (as for any work that involves physical manipulation of materials) durability – the fact that things are not just disposable, simply dissolve – may be looked at as a border resource. This resonates with our observations of the mutations and transformations of materials artefacts, and of the physical environment over time, with change over time serving as a border resource. Someone watching Aby Warburg rearrange the books in his library witnesses changes in his thinking (even if those may not be easy to interpret for an outsider). Physical manipulations, such as the students cutting out parts of a model, leave traces which convey a sense of the activity and the thinking behind it. The mutations of the model (bottom of Figure 9) tell of a hand carving out spaces.

## CONCLUSIONS

In our analysis of material practices in architecture and examples from art works, we have identified a variety of issues that allow us understand why and how materiality can be supportive of creativity in collaborative settings as design and learning. What can be the role of computational media and interfaces in light of the three sections above?

The section "The Richness of Materiality" described the variety of material features (and the diversity of techniques to exploit them) expanding actors' communicative resources, contributing to their practices of narration and persuasion. Material features, in their peripheral, evocative, and referential function, provide border resources for interaction. The analysis indicates the impossibility of replicating the richness of materiality in virtual environments. The examples reported show that the contribution of material features is in the combination of properties (texture, geometry, material, energy, dynamic). While some of these can be simulated singularly for example with haptic interfaces it is hardly possible to simulate complex combinations. Important aspects in the examples are the ambiguity and fuzziness of material features, which do not well align with the exactness of virtual reality. In contrast to simulation the analysis indicated as fruitful strategies forging connections and creating translations thereby better supporting the evocative, communicative, and "border resource" role of materiality. These connection and translations were operated by technology in some of the examples we reported with augmentations using sensors (Fig 3) and projections (Fig 7 lights projection and Fig 8 mixed reality).

The section "Spatiality - Artefacts in Space" reported how spatiality, scale and dimensionality in supporting actor's direct, bodily engagement, create relations of bodies and artefacts that are meaningful in themselves. Spatiality becomes a thinking tool in different expansion and concentration strategies. Computational media can affect our perception of space by dynamically playing with scale and dimensionality. However, the examples report how the disposition and spatial arrangement is an important narrative feature and in contrast to strategies as cave environments the analysis points to more ubiquitous approaches (figure 5 a configurable space, Figure 6 ubiquitous mixing of dimensions).

The section "Performing Materiality" uncovered the temporal and performative aspects – the fact that material artefacts have a history, emerge as part of specific events in time and become part of performative action – along with sensory motricity these turn into important resources for creativity. Possible applications of computational media and interface technologies raise two questions. First can instrumented environments support and recognise multimodal expressions (bodily gestures like painting are tracked in Figure 8) producing performative engagements with mixed (physical and digital) media? Second, can applications capture experiential aspects of situations using sensors (tracking objects, physical and physiological states, multimodal expressions) and make them available through rich representations of histories in the environment?

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