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# Material innovation: case studies of tangible working material in technology, art and design

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**Abstract**

There still are unexplored entrepreneurial potentials for collaboration in design, art and engineering. Heimdal & Rosenquist has explored three roles of textiles as tangible working materials in such co-design processes. However, more knowledge is needed about innovative design processes that involve new use of materials. The aim of this study was to identify potentials for sustainable innovation in tangible working materials in design processes. This was analysed in a 'preservation of diverse cultures' perspective from Deep Ecology. Case studies were performed on the design and engineering of innovative use of materials for product development and for design of the environment. Contexts for the case studies were in cement industries, experimental use of cement in design education, 3D printing of plaster, clay and cement based composites, public art in a terrazzo floor in a school and concrete art sculptures in a hospital park. The findings were discussed in relation to ecology to contribute to concepts for sustainable collaborative practices between technology, art and design.

***Keywords: artistic research, participatory design, Deep Ecology, chemical products***

## 1 Tangible working materials for innovation

There is a need for more studies on other materials especially in a cooperation context between industry, academia and education, a cooperation needed to enable innovation (Curaj, 2012). There still are unexplored entrepreneurial potentials for collaboration in design, architecture and engineering. Heimdal & Rosenquist has explored three roles of textiles as tangible working materials in such co-design processes (Heimdal & Rosenqvist, 2012). Whereas their study focus on textiles, there is a need to expand knowledge systematically on other materials. This study contribute to that aim with a specific focus on materials such as plaster, clay and cement based composites because these were the materials where the participant researchers had access to the field (Hammersley, 2007).

A useful starting point for such a study is that there are many innovative applications of plaster, clay and cement based composites in different contexts that can be analysed. Such established practices can be seen as the result of tradition and different ways of thinking according to the art philosopher Varto (Varto, 2009) who claims that ways of seeing the world also influence what is regarded as research. Some practices is often seen to have emerged from natural causes and is therefore regarded as the best and maybe even the only way. However, this may rely on not being aware of other ontological justifications, other practices, other ways of thinking or other theories. It is therefore valuable to see how concrete is used innovatively in different contexts, ranging from education and research to industry and the public sector, and to see how this can be related to research traditions. Design research is a cross disciplinary field that should integrate a sustainable and lasting way to contribute to practice, it is therefore important to be aware of the different scientific traditions practitioners are working within. Thus cross-disciplinary research can contribute to connect different types of practices and professions.

More knowledge is needed about innovative design processes that involve new use of materials. The aim of this study was to identify potentials for material innovation in tangible working materials in design processes. This was analysed in a 'preservation of diverse cultures' perspective from Deep Ecology (Næss, 1993). From a design education perspective and in the context of designers making skills and experience with materials, digitalisation has great advantages, but there are also lost opportunities to engage students with tangible/practical issues around sustainability. It is therefore a need to approach different learning methodologies and spaces and to observe its effect on teaching and learning situations (Stoltenberg & Firth, 2015). Learning spaces are frequently discussed in design research, but there seems to be little focus on how various environment might influence the learning outcomes within the context of teaching sustainable working methodologies and material processes. This justified the research question of how plaster, clay and cement based composites can work as tangible working materials in co-design processes to influence sustainable innovation?

## 2 Case studies in education, industry and public service

The method was chosen based on existing practices and access to the field through participatory research (Hammersley, 2007). In the Nordic countries, there has been a tradition of cooperation between labor, government and unions which has strengthened a sustainable approach to the labor market through participation and social awareness (Aagaard Nielsen, 2010). Increasingly government and research practices demand a better interaction between research, teaching and innovation in business and employment (Curaj, 2012). Therefore a suitable method should generate empirical data from both teaching, industry and public organisations. Case study was chosen as a method (Yin, 2009) based on the nature of the research question and because we had relevant access to the field in various contexts (Hammersley, 2007). This made it possible to do a cross case analysis in a 'preservation of diverse cultures' perspective from Deep Ecology (Næss, 1993). Case study was suitable because it was possible to study a topic – concrete as tangible working materials in co-design that lead to innovation – in a various context such as in cement industries, experimental use of cement in design education, 3D printing of plaster, clay and cement based composites, public art in a terrazzo floor in a school and concrete art sculptures in a hospital park. This was finally discussed in relation to sustainable perspectives on deep ecology, spesifically on 'preservation of diverse cultures' (Næss, 1993).

## 3 Sustainable innovation and Deep Ecology

Innovation has different meaning in various traditions, such as in design where corporate social responsibility (CSR) is enhanced (Melles, de Vere, & Misic, 2011), in social anthropology where change of practices is relevant (Barnett, 1953) or in technology and business (Chesbrough, 2003). In this study a hermeneutic approach was chosen where the aim was to describe the meaning of the different practices using plaster, clay and cement based materials as tangible working materials in co-design processes, described in such a way that it would be understandable and meaningful both for the practitioners represented in the study with their different fore-understandings as well as others from the cross disciplinary field in design practice (Gadamer, 2004).

The sustainable values in the study can be made more visible through perspectives from Deep Ecology, developed by the philosopher Naess (Naess, 1973). Ecosophy was appropriate because it seeks to discuss fundamental ethical and knowledge related issues (Næss, Rothenberg, & Næss, 1989). Næss stated that there are two ecology movements, which are competing for our attention. Ecosophy is not the same as eco-philosophy according to Naess. Eco-philosophy is an academic discipline that does not take a position on moral and political issues; it is descriptive and analytical, while Ecosophy has a clearly normative character. Naess states that 'Ecosophy is a philosophical worldview, total view or system inspired by the living conditions in the biosphere, especially as they appear in ecology including ecologically oriented social anthropology.' As philosophical system a researcher in Ecosophy will emphasize the coherence between all subsystems.

According to Næss Eco-philosophy is concerned mostly with pollution, resource depletion and the usefulness of the Earth to humans. Ecosophy is concerned with the diversity, richness, and intrinsic value of all the Earth. This is the Deep Ecology movement. Deep Ecology is a philosophical system with holistic thinking and a world view based on an ecological understanding of the world and humans place within this world. It emphasizes a positive coherence between all living things and a set of general guidelines for thinking and action. In 1984 he developed, together with George Sessions eight basic principles of Deep Ecology. Throughout his career he developed his theories further and Arne Næss' theory is currently viewed as one of the most important philosophies on environmental issues (Næss et al., 1989). In his book, Ecology, community and lifestyle: outline of an ecosophy, Næss presented his theory Ecosophy T and outlined an 18 point list to be used as a tool for a sustainable discourse. One of these 18 points, 'preservation of diverse cultures', were chosen as a perspective for the case studies, to see how this can be relevant for the study in tangible working materials in various co-design processes. This was done to contribute to develop concepts that connect technology, art and design.

## 4 Findings

The results from the methods show different qualities of tangible working materials in various co-design processes.

### 4.1 Case 1: material innovation in concrete industries

Founded in Milan in 1937, Mapei is one of the leading companies in the production of adhesives and chemical products for building. Mapei claim that their 'longstanding commitment to the environment extends to our facilities, products and processes - from minimizing waste to maximizing use of recycled materials. In addition, the focus of our Research & Development efforts is to formulate ecologically sustainable products and systems which do not include solvents or pollutants.' They aim to use local raw materials to minimize pollution. Mapei claim to be an innovator of environmentally responsible solutions and they manufacture more than 150 LEED-compliant eco-friendly products. An example of research in the company is from Mapei Norway in Odalen with chemically tests on products to make sure of their qualities in use. Such quality tests are related to temperature-responsive contraction, aggregation, dynamic light scattering, aqueous solution, copolymer microgels and chlorides (Al-Manasir, Zhu, Kjoniksen, Knudsen, & Nystrom, 2012): 'From the zeta potential measurements, it is observed that the charge density of PNIPAAM microgels in the presence of an ionic surfactant is significantly affected by temperature and the attachment of the negatively charged PAA groups. The turbidity measurements clearly indicate that the interaction between PNIPAAM and SDS is more pronounced than that of the cationic surfactant.' A sustainable aspect is to develop materials that support Nordic climate and to use local materials to reduce pollution.

**Figure 1. Research and development for for additives quality testing and cement projects at MAPEI.**

### 4.2 Case 2: material innovation in design education

In Product design education at Oslo and Akershus University College an experimental, aesthetic approach was encouraged in the 10 ECTS module 'Experimental use of materials and technics" in the first bachelor study, where design learning was based on each students motivation and where creativity was enhanced. One student wrote about her experiments in concrete, where the topic was to explore how to make concrete to look more like a soft, warm and lightweight material? The study was seeking transfer the qualities of a textile material into concrete: a way to preserve an aesthetic expression into another material:

> 'Wool aggregates: I used yarn aggregates as well as sand and stone in cement mixture. Sample 1A: I cut up the wool yarn and put it into the mix before casting. I witnessed yarn pieces dissolved in the solution and the effect was less than I had thought beforehand. Sample 1B: castings in the mold before I strewed yarn bits on. For sample 2, I greased the mold with release agent, attached nets on the release agent and then poured into premixed white cement. It was a little difficult to keep the yarn in place because it almost dissolved into the cement. This gave a somewhat random pattern,

which can also be quite fine. I have polished the sample and the result was that the yarn stood out more clearly, as well as the grains of sand and stones in the cement became clearer. To think of examples of products where you use some of these techniques, one can make stools or benches where one casts the fabric or yarn on its surface. For outdoor use, one can use material that does not absorb water and moisture.'

**Figure 2. Experiments from product design student: how to get concrete to look more like a soft, warm and lightweight material?**

### 4.3 Case 3: material innovation in clay based 3D printing

The project on Workshop Learning led by a research group at the Product Design Department at Oslo and Akershus University College of Applied Sciences is about design and technology competence in 3D printing. The aim of the project is to expand understanding of how learning occurs and how users gain experience in new 3D prototyping- and production techniques applied in materials such as clay based materials, polypropylen and cement composites. Digital production techniques are integrated into the labor market increasingly. The basis for the project was that there is a continuous development of 3D printers (Rapid Prototyping) to prototypes and products, however, there is little research on how learning occurs through workshop practice (Mjelde, 2006) in clay based materials, polypropylen and cement composites in relation to creative and artistic production techniques in 3D printing. A workshop was organised in collaboration with the Estonian Academy of the Arts (Figure 3). Through developing existing expertise with recently invested 3D printers this competence can contribute to students who eventually can become leaders in the future ceramic production techniques.The project will connect research in product design and research in vocational teaching by focusing on workshop learning in practice in different professional contexts (Brevik, 2014). The aim is to provide insight into how action research, participatory design and case studies can be used as a strategy to develop professional knowledge and experience in research-based development and change processes (Berg, 2014).

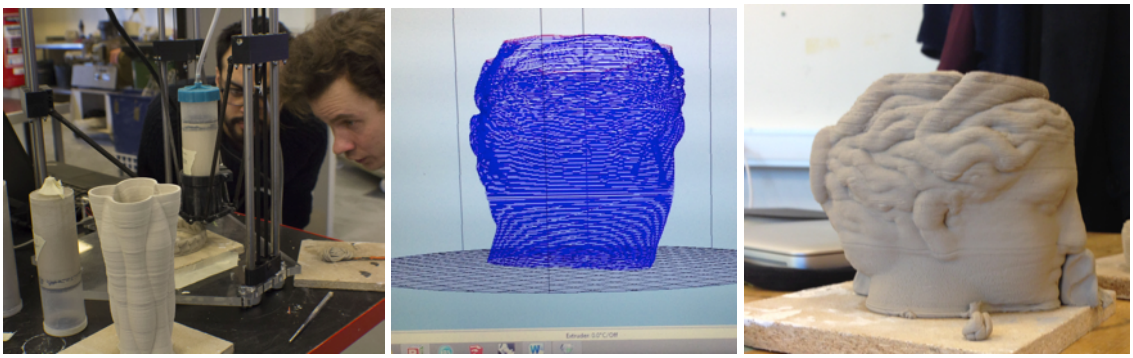


**Figure 3. Workshop in 3D printing of clay based materials and cement composites.**

### 4.4 Case 4: material innovation in plaster based 3D printing

Design has been used to provide more innovation to the society giving its contribution to fulfill needs from a broader range of areas of knowledge different from those more traditional ones related to industrial applications. Examples are problems and needs from medical and veterinary areas, prostheses and implants in particular. This case show how it is possible to fulfill such specific, and sometimes challenging needs, adopting experimental design processes combining different conventional modeling techniques with Rapid Prototyping or 3D Printing technologies. It is challenging to replace the original upper part of a toucan´s (Ramphastos Toco) bill (Figure 4A) or to replace part a human skull (Figure 4C) as part of a cranioplasty medical procedure by prostheses with similar physical characteristics (dimensions, weight, shape and strength).

The first challenge for both cases was the fact that there was no single shape or dimension from the original part as a starting point for the project. For the toucan's bill it was used a dissected bill 3D scanned (optical 3D digitalization system GOM ATOS I 2M) from another bird and plaster molds of the remaining parts, as a reference. For the skull part, it was possible in this case to use other side of the skull without any damage, as a reference, directly from CTI – Computerized Tomography Image of the patient. After editing and treating the mathematics as a result of the 3D scanning as well as of the CTI, using software such as Rhinoceros, Grasshopper and Blender, 3D virtual models were then generated. The prototypes for both were based on ZP150 powder, which is predominantly a plaster powder, were produced by a ZCorp. Z650 3D Printer allowed all the necessary dimensional and shape corrections and final adjustments. The prosthesis for the toucan's bill was produced by Envisiontec Ultra 3D Printer, using the photo polymeric SI 500 resin, and it was implanted using dental cement 3M RelyX Unicem and six tiny (5mm long) bolts (Figure 4B). The prosthesis for the skull part was cast in PMMA – Polymetilmetacrilate (Acrylic) and then properly sanded (Figure 4D).

The case shows that even without the part to be replaced, as a starting point, it is possible to produce a high quality and accurate prostheses, literally bring animals and human beings back to life. In these particular cases, it was clearly possible to minimize all the negative and collateral effects faced by the injured bird (he started eating and socializing just two days after the procedure), as well as by the six year old boy patient (he is now able to do what he likes the most: play soccer – he could not do that since he is two when he suffer an accident). It also points out and confirms the possibility to produce accurate prostheses facing all the most common challenges of the task, by means of procedures such as: 1) 3D scanning of similar parts instead of the original ones as a reference. 2) 3D scanning of the area that could accommodate the prosthesis as a starting point. 3) Different technologies as tools to deal with dimensional differences between a similar part CAD model versus real dimension needs. 4) Production of molds to produce prostheses using more appropriate materials different from those offered by 3D Printing technologies.

**Figure 4A: Missing upper part of toucan's bill. Figure 4B: Missing part of a human skull. Figure 4C: Toucan's bill prosthesis in resin. Figure 4D: Human skull prosthesis in Acrylic.**

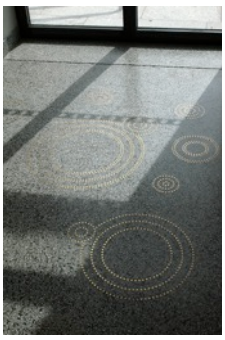
## 4.5 Case 4: material innovation in public art in a school

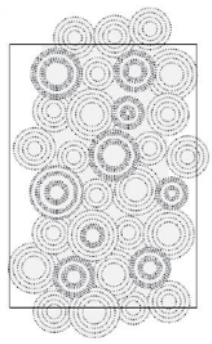
This case study show how cultural preservation happened through a conceptual design and visualisation of an an art project ‘Sargasso’. It was prosecuted in cement-based materials, in a public school including a floor made out of the materials brass, steel in a terrazzo technique. The following text was based on the artists’ own description of the project, and show how the art work preserves diverse cultures:

The longitudinal direction of the schoolyard is facing southeast and morning light falls into the schoolyard when the school day begins. It opened an opportunity to create an art project that uses sunlight and that will have a dynamic expression as the sun moves. The upper part of the oceans swim in light during the day. This vertically illuminated area called the euphotic zone (of gr. 'Good' and 'light'). The exact extent of the area is determined by the clarity of the water, but revolves on average a depth of 200 meters. What defines the area is algae's ability to photosynthesis and is characterized by a huge and varied wildlife. The project was named Sargasso because it is among the brightest of the oceans and because it is bounded by the Atlantic and currents that in some ways adds premise of life in our part of the world.

The artist was inspired by thoughts about light quality in urban space and how light, or rather the lack of light, helps to express social issues. In our consciousness is darkness and poverty linked metaphorically, but in the city, this is manifested genuinely in that the poorest have traditionally been referred to the narrow, shady streets and backyards. When focus is being placed on developing a school that in many ways is in the conflict between old and new Oslo the desire of the artist was to create an art project that openly suggests connections between biology and politics.

For the art project the conservatory and the floor in the entrance hall was chosen by the artist. He wanted to develop a transition zone between inside and outside. One part of the artwork to Hersleb school was an ornament embedded in the floor and consists of brass bolts, steel plates and terrazzo coating. The ornament was drawn digitally and cut out by laser in 1.5 mm steel plate by Norwegian Stopping Industry in Skedsmo. About 12000 brass bolts were manufactured in lathe with a diameter adapted holes. The bolts were threaded through the steel plates and attached to the steel plates with a bonded collar. The steel plates with associated bolts were transported to school where they were placed beyond the molded concrete needle. Subsequently, all the plates/brass bolts applied terazzo surface which after hardening were cut down to the correct height.





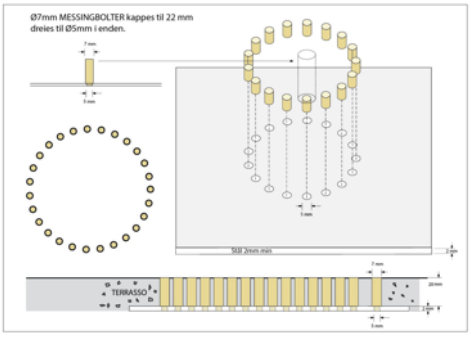


**Figure 4. The aim was an art project that uses sunlight and that would have a dynamic expression as the sun moves.**

### 4.6 Case 5: material innovation in a public park for a hospital

The final case study was based on a participatory design method to create art in public space of a hospital (Berg, 2014). The project aimed to preserva a culture of healing and the process has relevance to emotional design and ethics because the patients were elderly people with severe illnesses, something that influenced the solution that aimed to connect people and to create reflections. Concrete and porcelain tiles were used, and the solution was developed in a collaboration between a landscape architect and an artist and stakeholders at the building site. This text was from the presentation of the project:

'The Window' is intended to be a metaphor for looking outward or inward, forward or backward in time. The form invites to physical interaction through allowing children and adults to be inside the frame. The water and walking stones is intended to create a reflection of form and space and to initiate someone to explore balancing on the water. The wall creates a new room, which conceals and covers and creates room for new moves. Motives are related to migratory birds and their long journeys. The winter season is represented by snow crystals. They are in dialogue form wise with other motifs on porcelain tiles in the garden such as seed capsules and planets on other sculptural elements.

**Figure 5. 'The Window' was intended to be a metaphor for looking into time.**

## 5 Discussion and conclusion: Sustainable working methodologies

Perspectives from Arne Næss' theory on 'deep ecology' (Næss et al., 1989) can enhance issues of sustainability in the case studies. Deep Ecology and Ecosophy T (Næss et al., 1989) is a holistic and comprehensive theory. The later developed Ecosophy T's has eighteen points compared to the eight basic Deep Ecology principles. The eighteen points can be used as an analytical tool for a discourse due to being descriptive, where initial theory can inform the case study analysis (Yin, 2009). The eighteen points were: Pollution, Resourses/ dividing resourses, Population stabilization, Classlessness, Self-governing, Decentralization, Local societies, District development, Self-preservation, Division of labour, Complexity, Diversity, Preservation of diverse cultures, Symbioses (mutual benefits) , Egalitarianism, Fight against humans self-domestication, Field thinking- interplay in nature-gestalt thinking and Docta Ignorantia. This is a wide field and some issues of sustainability for plaster, clay and cement based composites as tangible working materials in co-design processes that can be connected to the 18 points were identified through concept mapping (Maxwell, 2005). These were: Technology, Design education, Conceptual design, Design learning, Emotional design, Innovation, Ontologies, Participatory design, Visualisation, Creativity, Social responsibility and Ethics. These are relevant concepts for sustainable collaborative practices between

industry, academia and education, concepts emerging between Ecosophy and issues identified in the case studies.

These concepts are all connected, and in this study a specific sustainable focus were how to preserve diverse cultures. In the cement industry a sustainable aspect was to develop lasting materials in a harsh climate and to use local materials to reduce pollution. The student example showed how aesthetic expressions were transferred to another material. The 3D print examples showed a mixture of technology and aesthetic experiments. The art project at the school was showing how visualisation and social responsibility became a part of the technological solution. In the final project concrete sculptures was used in an ethical way to connect visitors and family to elderly patients with severe illnesses. In artistic research the art philosopher Varto claims that a researcher should be aware of ideology and ontology both in practice as well as in research (Varto, 2009). In these examples it is shown various types of sustainable ideologies, both concerning pollution and social awareness.

Through his ideas on complexity, Næss claimed that mature and stable ecosystems are characterized by great inventiveness and the multiple uses of resources, and that every society has alternative ways to satisfy its needs: if one factor reduces the possibilities, there are alternatives within the local community. The processes of creative experiments concrete material show various ways of working with innovation. Furthermore, this can be discussed through the idea of Self-preservation. This is about using “soft” and “close” technology; techniques that to a low degree reduces the environmental qualities and diminish local resources. It emphasises that materials and tools can be found locally and also creates meaningful work. In these case studies it was important to use local resources, preserve the natural environment and create meaningful solutions. Also the idea of diversity is of relevance. It discusses, amongst others, different ways of expressions, use of geographical peculiarities and investigations into different expressions.

The conclusion was that innovative practices can be connected to research traditions in both technology, art and design, and that there is a higher potential for sustainability with a complementary research approach according to Naess: The concept of Deep Ecology is interesting from a design perspective, because it emphasises the importance of relational thinking, holistic thinking and system thinking. These are all factors of importance within a holistic design paradigm (Næss, 1993; Varto, 2009). In Deep Ecology, everything is connected with everything else through a mutual, dependent relationship in a long-term perspective. It is a symbiosis, where all parties extract mutual benefits from each other through companionship and that every action affects all life around us. These experiences demonstrate important and tangible contributions to relational and sustainable thinking in design education where technology, art and design connect with complementary practices for sustainable innovation.

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