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Porsmo Stoveland, L.; Stols-Witlox, M.; Ormsby, B.; Streeton, N.L.W.

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THEORY, HISTORY, AND ETHICS OF CONSERVATION

Mock-ups and materiality in conservation research

Lena Porsmo Stoveland*
Conservation Studies
Department of Archaeology, Conservation and History
University of Oslo
Oslo, Norway
l.p.stoveland@iakh.uio.no
Maartje Stols-Witlox
Conservation and Restoration of Cultural Heritage
University of Amsterdam
Amsterdam, The Netherlands
m.j.n.stols-witlox@uva.nl
Bronwyn Ormsby
Tate
Conservation Department
London, UK
bronwyn.ormsby@tate.org.uk
Noëlle L.W. Streeton
Conservation Studies
Department of Archaeology, Conservation and History
University of Oslo
Oslo, Norway
n.l.w.streeton@iakh.uio.no
*Author of correspondence

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Abstract
In conservation, mock-ups are routinely used as surrogate works of art that can be subjected to treatments proposed for use on the original objects. This paper investigates the role of mock-ups in conservation research, specifically, research into dirt removal from the monumental Aula paintings by Edvard Munch housed at the University of Oslo. The mock-ups, prepared to support an empirical evaluation of a selection of novel cleaning systems, inspired reflections on the broader socio-material role of mock-ups in research. This paper relates the philosophical basis for the use of mock-ups in conservation to aspects of perspectivism and applies categories and terminology borrowed from the medical sciences to paintings research. Through the case study, the research context, notion of material agency and the roles of mock-ups in conservation ethics, research and practice are explored.

INTRODUCTION

Mock-ups have been mentioned with high frequency in the conservation literature, and play an increasingly important role in conservation research and practice. A mock-up, which can refer to a substitute material, object or simulation (Table 1), assists conservators in exploring the behaviour and degradation of cultural heritage materials and the effects of active and passive conservation treatments (Stols-Witlox 2020). Through their role as substitutes, mock-ups help to reduce risk to cultural heritage objects and aid in the development of knowledge associated with understanding and caring for a cultural heritage object.

While discussions about mock-ups have focused on concepts such as authenticity (Scott 2015), replication (Lawson and Cane 2016), philological reconstruction (Pugliese et al. 2016) and historical accuracy (Carlyle 2001 and 2006), mock-ups are rarely included in theoretical (postmodern) discourses concerning the history, theory and ethics of conservation and heritage science. Given that mock-ups are primarily created by conservators and heritage scientists for their own purposes, they may provide as much insight into conservation theory and practice as they do into the cultural heritage of the simulated object. Reflections on why and how mock-ups are used in conservation research highlight how knowledge concerning conservation and the safeguarding of cultural heritage is negotiated through engagement with objects – a topic often described in material culture studies by the concept of material agency. Reflecting on this aspect may increase conservators' awareness and ability to evaluate research as a socio-material process.

This paper reflects on the role of mock-ups in research through the example of chalk-glue ground and oil painted mock-ups created to evaluate the potential of a selection of novel cleaning systems for use in Edvard Munch's (1863–1944) monumental, unvarnished Aula paintings (1911–16) (see Stoveland et al. 2019b). To support the view that both empirical observations of mock-ups and theoretical reflections on the interactions between researchers and mock-ups are important for knowledge production in conservation, aspects of the science-based philosophical branch of perspectivism have been considered.[1]

PERSPECTIVISM

In his book *Scientific perspectivism*, Giere (2006) argued that both observing (empirical) and theorising (reflective) in research are matters of perspective

Table 1. The terms and variations used for substitute materials/objects/systems in a selection of conservation/heritage science papers on painting materials, with the earliest date of occurrence based on a preliminary literature search. The list of terms and publication dates has not been exhausted and may be subject to change

Term	Reference
Copy	Ruhemann 1968
Imperfect-	Stols-Witlox 2020
Dummy	Wetering 1995
Film (constructed)	Stolow 1957
Mock	Murray et al. 1991
-up	Berger 1980
Analogue-	Cutajar et al. in press
Model	Berger and Zeliger 1984
Laboratory-	Amadesi et al. 1974
Computer-	Mecklenburg and Tumosa 1991
-system	Pietro and Ligterink 1999
-specimen	Carr et al. 2003
Artificial-	Roy 2003
Kinetic-	Oakley et al. 2015
Reconstruction	Stoner 1996
Photomontage-	Dunkerton et al. 1990
Virtual-	Frøysaker 2003
Historically accurate-	Carlyle 2001
Historically informed-	Bucklow 2012
Philological-	Pugliese et al. 2016
Historically appropriate-	Carlyle and Witlox 2005
Highly characterised-	Carlyle 2017
Replica (constructed)	Wachowiak and Karas 2009
Reproduction	Saunders 1988
Sample (constructed)	Hedley 1988
Test-	Bellan et al. 2000
Reconstruction-	Burnstock et al. 2005
Representative-	Young 2005
Experimental-	Watson and Burnstock 2013
Simulation	Burnstock and White 1990
Mathematical-	Michalski 1991
Surrogate	Reedy and Reedy 1992

and are thus 'perspectival'. According to his view, scientific knowledge is essentially a product of distributed cognitive systems that incorporate human-made objects (in this paper, mock-ups and cultural heritage objects) and concepts, all of which have built-in perspectives that inform our understanding of aspects of the world. Within the context of interdisciplinary mixed-method research, Tebes (2012) proposed that, with its focus on the actual practices of research, perspectivism may provide a more comprehensive philosophical foundation than is offered by the epistemology of either qualitative or quantitative research alone.[2] As conservation is an interdisciplinary field that employs and combines a multitude of research methods, perspectivism may also offer a solid philosophical foundation for practice-based conservation research. This is not meant to imply that all approaches, methods or theories in research are relative, but rather that perspectivism supports the selection and mixing of methods and theories, both empirically based and theoretical, if they contribute to a fuller understanding (perspective) of the material world or of human-object interactions.

MOCK-UPS AND CONSERVATION

Through their composition, construction and research context, it can be argued that mock-ups have built-in perspectives that influence how new knowledge is created in conservation. In the following sections, this idea is explored through considering why and how mock-ups are used in conservation research.

Research ethics and experiments

In response to the ethical, social and legal dilemmas involved in treating cultural heritage objects, the conservation profession has developed a set of ethical guidelines and protocols which aim to preserve the significance of the object (Appelbaum 2013). As substitutes for cultural heritage objects, mock-ups play a central role in scientific experiments (Burnstock and van den Berg 2014). Because of their inherently simplified construction and composition, they facilitate documentation, comparison, sampling, analysis and molecular modelling, allowing in-depth studies under controlled environmental conditions. They also provide conservators and heritage scientists with an opportunity to gain experience with new methods and to fine-tune treatment protocols without experimenting directly on cultural heritage objects.

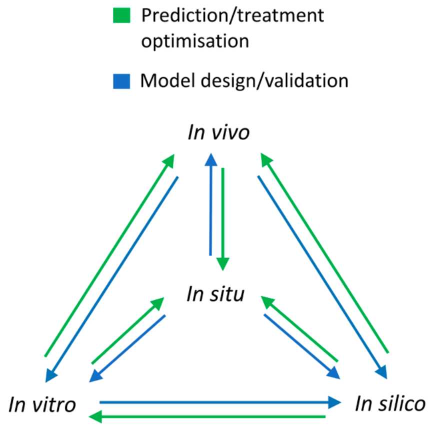

Figure 1. A modified version of a model commonly used to illustrate the *in vitro*, *in vivo*, *in silico* chain in the medical sciences (based on a similar model published in Marcu and Harriss-Phillips 2012). The connection to *in situ* research has been added. Green arrows indicate the ways mock-ups or models are used to predict a reaction or mechanism or to optimise treatments. Blue arrows indicate the information flow that informs model construction and, after the prediction or treatment has been tested, model assessment

Even more strict ethical considerations guide experiments and treatment trials in the medical sciences, which are commonly divided into three broad categories: *in vitro, in vivo* and *in silico* (described below). The knowledge that derives from each category is mediated by the type of mock-up, the instrumentation and the theoretical model (with its built-in perspectives) chosen for the experiment. While Appelbaum (1987) and Reedy and Reedy (1992) used the terms *in vitro, in vivo* and *in situ* to differentiate between ways of evaluating conservation materials, the term *in silico* has, to the authors' knowledge, not been used in relation to conservation. Figure 1 suggests how *in situ* connects with the *in vitro*, *in vivo*, *in silico* chain. Because *in situ* is commonly used to describe conservation research or treatments performed directly on cultural heritage objects, this term is not emphasised in this paper. Table 2 lists examples of conservation research into paint or paintings that fit the *in vitro, in vivo* and *in silico* categories addressed below.

Table 2. Examples of mock-up-based conservation research grouped according to the *in vitro*, *in vivo* and *in silico* categories used in the medical sciences. Some of the publications may fit in more than one category

Category of experiment and mock-up type		
In vitro	***In vivo***	***In silico***
Single-layer, single substance	Multi-layer, composite structure	Computer model, virtual representation
e.g. individual components of a painting material, a painting material	e.g. constructed parts of a painting, a painting	e.g. a logarithm, a modified digital image
Stolow 1957 Mecklenburg 1982 Rie 1988 Erhardt and Tsang 1990 Whitmore and Colaluca 1995 Saunders and Kirby 2004 Heydenreich et al. 2008 Monico et al. 2011 Hermans et al. 2014 Fuster-López et al. 2019	Headly 1988 Ackroyd and Young 1999 Bracco et al. 2003 Gates et al. 2005 Nieder et al. 2011 Mengshoel et al. 2012 Ormsby et al. 2013 Barker et al. 2014 Grandin and Centauro 2015 Bartoletti et al. 2020	Mecklenburg and Tumosa 1991 Pietro and Ligterink 1999 Frøysaker 2003 Ružić et al. 2011 Iedema et al. 2014 Tsaftaris et al. 2014 Oakley et al. 2015 Hendriks et al. 2017 Abate 2019 Grøntoft et al. 2019

In vitro (Latin: 'in the glass') in the medical sciences refers to the performance of procedures in a controlled laboratory environment outside a living organism. In conservation, the term can apply to experimental research performed outside or away from cultural heritage objects, such as the investigation and analysis of microscopic, historical samples removed from the original objects. *In vitro* experiments might aim to determine the specific chemical or mechanical properties of materials, their mechanical behaviour, or their long-term stability under defined conditions. As such they can also involve constructed, naturally or artificially aged single substances, or single-layer mock-ups. In mock-up-based *in vitro* experiments, individual materials or processes can be investigated isolated from other components that may interfere with and obscure interpretation. The results of such experiments usually carry less experimental uncertainty and are more reproducible than those obtained with *in vivo* experiments on multi-layered, composite mock-up structures.

In vivo (Latin: 'in the living') refers to experiments with a living organism (part or whole). Animal studies and clinical trials are two forms of *in vivo* research. Clinical trials have the most in common with *in situ* studies in conservation, i.e. studies on actual cultural heritage objects. Apart from the ethical dilemmas involved in using animals as replacements for humans, animal studies have similarities with mock-up research in conservation and heritage science when the constructed mock-ups are naturally or artificially aged to represent a whole part/structure or cultural heritage object. This category would logically also include cases in which objects with low cultural value are used as replacements in tests, such as those conducted on flea market paintings or objects donated for research. In practice-based conservation, *in vivo* mock-ups seem to be more frequently used than *in vitro* mock-ups because they take into consideration the complexity of an object. A related term that perhaps could be more applicable to conservation is *in substituto* (Latin: 'in substitution'), applied to characterise research performed using replacement objects.

In silico is a pseudo-Latin term used to characterise biological experiments carried out via computer modelling (Miramontes 1992). *In silico* experiments have close similarities to computer-based conservation studies, for instance to those which are used to model molecular interactions to detect or predict future changes in condition, based on data about the materials, the object or the collection and its environment. *In silico* could also be used to describe mock-up-based studies that seek to visualise possible original appearances via virtual reconstruction in order to inform interpretation, treatment or display while avoiding physically affecting the cultural heritage object.

Mock-ups as research objects

The categories outlined above represent different research frameworks in which mock-ups contribute to conservation research. Regardless of the research for which mock-ups were created, the limitations and possibilities associated with each category influence a researcher's reflections and understanding of the chemical, optical and mechanical behaviour of the materials or objects. This implicitly draws on the notion of perspectivism in research. For example, it is part of the built-in perspective of *in vitro* and virtual *in silico* mock-ups that they cannot replicate the molecular condition of a complete part or the whole of an object, which renders translation to real treatment scenarios difficult; and *in vivo/in substituto* mock-ups, with their large number of variables within the mock-up system, may increase experimental uncertainty and lead to an unreliable outcome. Thus, the choice of mock-up system, and therefore of scientific instrumentation and theoretical framework (each with their built-in perspective), needs to align with the research aims. For the systematic evaluation of the potential of a selection of novel cleaning systems considered for the Munch Aula paintings, mock-ups prevented the paintings from being subjected to unnecessary risk. Furthermore, the adoption of an *in vivo*/*in substituto* approach balanced the need for inter-comparable test surfaces with the complexity of a multi-layered structure.

THE AULA PAINTING MOCK-UPS: OBJECTS OF OBSERVATION AND REFLECTION

Munch's Aula paintings have undergone many cycles of soiling and subsequent cleaning (Frøysaker 2007 and 2008). The difficulties and risks involved in cleaning these paintings required research into new and improved cleaning methods (Stoveland et al. 2019b and in preparation). Given the ethical challenges and fragility of the Aula paintings , and their monumental size and location in a public building, they do not easily lend themselves to systematic *in situ* evaluations. Thus, the creation of mock-ups was a central part of the research ethics and design, used to explore the advantages and disadvantages of different novel cleaning systems for unvarnished surfaces. The next section describes the process of making and observing the mock-ups, followed by an examination of the interactions between researcher and mock-up.

Making and observing mock-ups

Information from past analytical campaigns (Frøysaker 2007, 2008 and 2016; Liu et al. 2016, Frøysaker et al. 2019) and experience working with the Aula paintings informed the selection of materials as well as the preparation and composition of the multi-layered mock-ups. As the main issues were the sensitivity to both aqueous and mechanical cleaning systems, the mock-ups were prepared using materials that had general chemical and physical similarities to the sensitive areas of the Aula paintings, such as the areas of white ground in the painting *Alma Mater* (1915–16, 4.5 × 11.6 m^2) (see Figure 2 and 3, top image).[3] Stoveland et al. (2019a) provide a detailed description of the preparation of the mock-ups. The available information suggested that the *Alma Mater* ground consists mainly of chalk and a water-soluble glue (Frøysaker 2016). The researchers decided not to attempt to recreate the canvas knots visible in exposed areas of the *Alma Mater* ground because these had not been observed to the same extent in the other paintings of the series, and it was not clear whether they were the result of sanding of the primed canvas prior to painting or of micro-flaking caused by environmental changes or past treatments (Ibid.).

After preparation, the mock-ups were aged in a weathering chamber for two weeks, then soiled with an artificial soiling mixture (Ormsby et al.

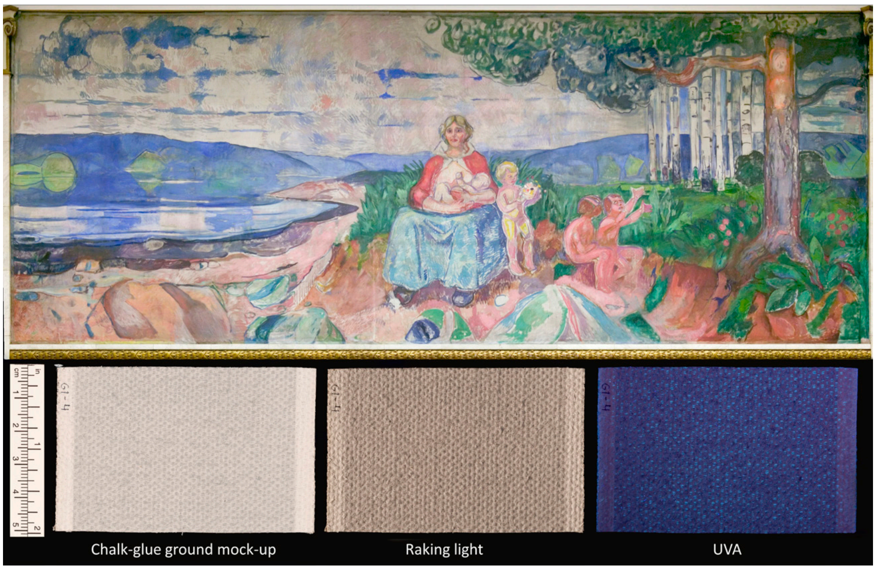

Figure 2. The Aula painting *Alma Mater*, 4.5 × 11.6 m^2 (photo by Svein Andresen/Sissel de Jong). Below it is an artificially aged and soiled mock-up (composed of canvas, glue size and chalk-glue ground) in incident and raking light and in UVA

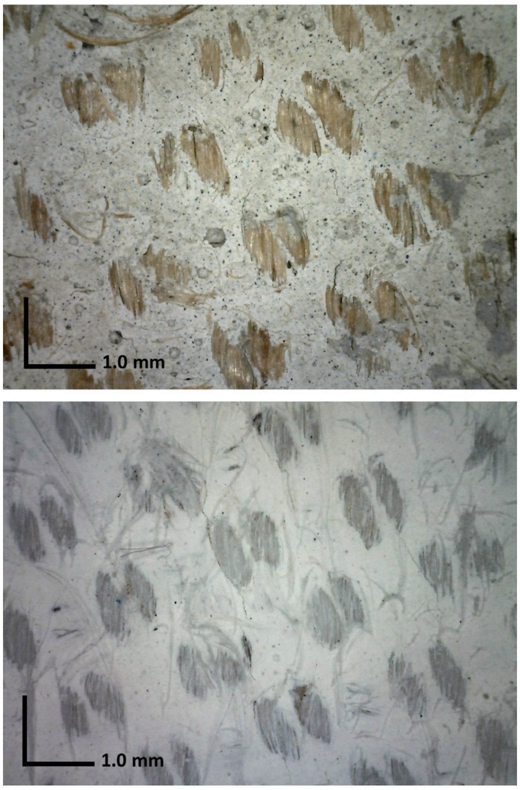

Figure 3. Microphotographs (60×) of the ground of *Alma Mater* (above) and the mock-up (below)

2013) and aged again for another week in the chamber. This step was considered necessary to closely mimic the water-sensitive and powdery physical condition of the aged and soiled surfaces of the Aula paintings as judged by the naked eye. While this process went according to plan for mock-ups made with an upper layer of oil paint, the chalk-glue ground mock-ups deteriorated faster than expected and became more powdery than the original paintings. It was initially thought that the chalk-glue ground mock-ups had been overexposed, as the condition of their ground layer appeared to be much worse than in the *Alma Mater* painting. These concerns were reinforced after carefully swiping a soft sponge over a small area of one of the chalk-glue ground mock-ups, which removed the upper part of the ground together with almost all of the artificial soiling, resulting in a visually clean, bright area. Interestingly however, during this process the ground was removed to the point where the canvas knots were exposed. Thus, inadvertently, a surface was created that was similar to the worn appearance of the ground in *Alma Mater* (Figure 3).

The Aula paintings have a complicated condition and treatment history, including at least five 20th-century cleaning cycles using traditional bread applications (Frøysaker 2007 and 2008). Based on this knowledge, the exposed canvas knots in *Alma Mater* may be attributable, at least in part, to these cleaning treatments, or to partial sanding of the ground prior to the application of paint (Frøysaker 2016). The unexpected response of the mock-ups to the accelerated ageing, soiling and subsequent cleaning forced a re-evaluation of three aspects: (i) the effect of sanding and/or past bread-based cleaning campaigns on the condition of *Alma Mater*, (ii) the initial understanding of the limitations and effects of artificial ageing on the mock-ups and (iii) the decision not to recreate the exposed canvas knots of *Alma Mater*. Thus, the interaction between the researchers, the soiled and aged mock-ups, and the original painting shifted the initial focus of the research. The mock-ups therefore gained a role not anticipated prior to their making and changed the perspectives of the researchers on the experiment and on the original painting itself.

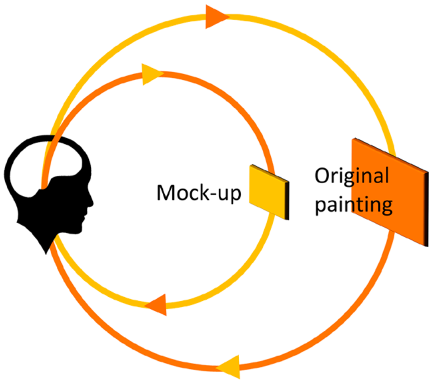

Figure 4. Illustration of the circular exchange process between researcher/conservator/scientist, mock-up and original painting. The researcher interprets and applies information from the original painting (orange) to the mock-up and also interprets and applies information from the mock-up (yellow) to the original painting. This process corresponds to the green and blue arrows between *in vivo* and *in situ* illustrated in Figure 1

Because of the unintended recreation of the exposed canvas knots of *Alma Mater* in the mock-ups, new investigations of the painting were carried out, which also led to a re-evaluation of previous interpretations of minute blue and black particles observed in the ground layer (Frøysaker et al. 2019). During the production of the mock-ups, the particles had been interpreted as contamination and were thus excluded from the ground composition of the mock-ups. However, the new investigations indicated that these particles were in fact original to the ground composition (Frøysaker et al. 2019). As a result, what had been considered as one of the simplest grounds in the Aula painting series, in terms of its composition, was instead recognised as quite uncommon within Munch's oeuvre.

Reflecting on researcher/mock-up interactions

According to Giere (2006), realisations and discoveries, both unexpected and expected, may be considered a product of the distributed cognitive system of researchers with respect to objects (natural or human-made) and their surroundings. The unexpected outcomes described above led to a re-evaluation of mock-up research design and were thus part of the validation process, illustrated in Figure 1, involving *in vivo/in substituto* mock-ups and the *in situ* Aula paintings. What occurred can also be described as a dialectic exchange of information between the researcher, the mock-up and the original painting (Figure 4). According to material culture studies, the recognition of this process means acknowledging the importance of these objects, or what Hummelen et al. (2008) described as 'non-human actors', in the production of knowledge in conservation. Whereas empirical research methods were appropriate for exploring the material changes in the Aula mock-ups, the interactions between researcher and mock-up required abstract research theories, such as those based on the concepts employed within material culture studies. Thus, what started out as an empirical evaluation of cleaning systems using mock-ups also became a reflection on the socio-material role of mock-ups in cleaning research.

The notion of agency plays a central role in material culture and science studies, challenging classic dichotomies between subjects and objects (Latour 1987 and 1999). Agency literally means action, power or active force and is normally associated with human intention. However, agency has also been linked to objects and materiality via the idea that non-human actors can affect human behaviour. The Aula mock-ups indeed seem to have influenced the research process, but does this mean that they have agency? According to Giere's perspectival realism/naturalism, extending concepts of agency (mind, consciousness and intentionality) to objects poses problems, as the ability to consciously act is what fundamentally distinguishes humans from objects (Giere 2006). When agency is bound up by the notion of mind, as posed by Giere, it cannot be extended to objects. However, theoretical perspectives within material culture studies, such as Latour's actor-network theory, conceptualise agency as distributed in relational networks of humans and objects (Latour 1999).[4] This type of material agency can be understood as the process whereby humans interact with objects and in turn become affected by them; as such, this definition is not coterminous with human intentionality and mind (Knappett and Malafouris 2008). Maintaining this view, material agency provided an interesting theoretical perspective to explore why the Aula mock-ups seemed to actively influence the research process.

ETHICS OF MOCK-UPS (IN CONTEXT)

Starting from the philosophical foundation of perspectivism, the instruments and concepts applied to empirical observations on the Aula mock-ups and theoretical reflections thereof can be described as perspectival research tools used in knowledge production. The popularity of mock-ups as a method for gaining practical skills and for optimising and testing materials and techniques may be seen as part of the development of the conservation profession, including the adoption of scientific protocols from the natural sciences and the establishment of ethical guidelines for best practices. *In vitro, in vivo/in substituto* and *in silico* experiments all use simplified models as substitutes for valuable objects. Mock-ups are themselves perspectival research tools, with *in vitro*, *in vivo/in substituto* and *in silico* mock-ups each having slightly different built-in perspectives. Common to all three types of experiments is that they require considerable initial investigations before appropriate representations can be created. Although the intentional simplification (whether human- or computer-made) of mock-ups or models is what makes them desirable in research experiments, mock-up-based research is sometimes criticised for its lack of relevance for practical conservation (Erhardt et al. 2000 and Roy 2003).

The question of the 'representativeness' or 'historical accuracy' of a mock-up is partly related to the availability of accurate scientific data about the original materials or object, and partly to our (in)capability of reproducing individual objects and their change through age. Large amounts of information can be gained through non-invasive analysis, but some information, such as the precise molecular composition and physical microstructure of a cultural heritage material, may be unobtainable using current analytical methods.[5] A fully accurate replication, whether of a part or of the complete object, will likely always be impossible. Thus, if mock-ups are to be considered within an ethical framework, their simplified construction, and to a certain extent their lack of representability, of cultural heritage materials is an unavoidable compromise.

As demonstrated by the events that occurred during the accelerated ageing of the Aula painting mock-ups, it was partly the different procedure that led to a new understanding of the original Aula paintings. This experience inspired reflections on human-object interactions and the 'active' role of mock-ups in conservation research, explored using the concepts of materiality and agency. The sequence of events shows that simplified simulations of cultural heritage deserve a place in both empirical studies and theoretical reflections in the conservation field. By acknowledging the important role of mock-ups in conservation ethics, research and practice, this paper highlights their intrinsic value.

Mock-ups may gain additional value as they age naturally over time, because the changes in their materials can help conservators and heritage scientists interpret those in cultural heritage objects, and they tend to acquire archive status over time. Since the changes that occur in mock-ups can be monitored and documented in detail, their relevance and value for practice-based conservation and hertiage science research increase. It is thus important that mock-ups are documented, archived and kept available for use in future research (Carlyle and Witlox 2005).[6]

CONCLUSION

The treatments developed and applied to mock-ups, together with analyses of the effects of exposure, facilitate the evolution of professional skills and knowledge while reducing risk to cultural heritage objects. The aim of this paper was to promote reflections on the role of mock-ups within conservation research. Scientific perspectivism, according to which both empirical observations and reflective theorising are matters of perspective, provides a fruitful philosophical foundation for both empirical and theoretical research involving mock-ups. The theoretical approach led to an appreciation of their role in practice-based conservation and heritage science research and thus to reflections on their materiality and agency. In the case of the Aula mock-ups, this study demonstrated that, while the mock-ups were designed with a specific purpose in mind, their unexpected responses paved the way for new discoveries and the introduction of new ideas on the research agenda. Applying the concept of material agency to experimental research opens the door to explorations of the interactions between mock-ups, conservators/heritage scientists and cultural heritage objects within practice-based and materials research. Finally, perspectivism largely supports the stance that it is ultimately the heritage scientists and conservators who decide which mock-ups, scientific instruments, theoretical frameworks and approaches are the most appropriate for answering a specific research question or addressing a treatment challenge. While often implicit, aspects of perspectivism resonate with conservation research, both practical and theoretical, and provide interesting material for the development of a new philosophical foundation for conservation.

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NOTES

1 Perspectivism originates in the writings by Friedrich Nietzsche (1844–1900) and was revived in the work of Ortega y Gasset (1883–1955). Perspectivism is a contested view within several fields, including material culture studies, but has gained attention in contemporary philosophy. See, for example, Reginster (2001), Latour (2009) and Massimi and McCoy (2019).

2 In his discussion of the philosophical foundations for mixed-method research, Tebes (2012) connects perspectivism with pragmatism, which also resonates in aspects of conservation research and practice. A review of pragmatism was outside the scope of this paper.

3 The *Alma Mater* painting is considered to be particularly vulnerable to soiling removal. Unpublished treatment report by S. Wiik (1973), Museum of Cultural History (KHM), University of Oslo, Norway.

4 Latour is known for having challenged the notion of facts and objective truths in science, and had a central role in the 1990s ‘science wars’ within academia. More recently,

Latour has spoken up against anti-scientific thinking that creates doubt around scientific consensus on important notions such as climate change (see Kofman 2018).

5 Although there are many factors to consider in research, sampling inherently impacts the research ethics of a study, and the representability of minute samples is, like the representability of mock-ups, questionable.

6 Initiatives such as ARCHLAB enable access to and storage of technical data from experiments and analyses and support sharing and comparing knowledge between researchers (see http://www.iperionch.eu/archlab/). The conservation field is currently without a parallel system for the storage of and access to physical mock-ups.

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