Chapter 10

COMMUNICATING INTERDISCIPLINARY SCHOLARSHIP: CONCLUSIONS FROM COSCH

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ABSTRACT

The study of cultural heritage requires the expertise of many disciplines as different as history and optical science. Each discipline brings its discrete research methods and know-how. Complementary knowledge is gained, gradually, through effective collaboration, which is not always easy. The articulation and communication of respective research questions, ways of addressing these questions, and expected outcomes, are a challenge in all collaborative projects. This concluding chapter discusses how the COST Action, Colour in Space in Cultural Heritage, has addressed and managed this challenge, through the case studies described in the present book and other activities. The authors draw conclusions from COSCH research activities and note some general points that bear on the success of diffusion of interdisciplinary research and its future.

Keywords: interdisciplinary research, communication, cultural heritage, science, optical technologies, COSCH

> It is everyone's responsibility to improve interdisciplinary communication, something that starts and ends with willingness, plenty of patience, and an open mind.
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> (Darren Kocs 1993, 1060)

The study and documentation of cultural heritage require the expertise of many disciplines as different as history and optical science. Each discipline brings its discrete research methods and know-how. Complementary knowledge is gained, gradually, through effective collaboration. The articulation and communication of respective research questions, ways of addressing these questions, and expected outcomes, are challenges common to all collaborative projects. This concluding chapter discusses how the COST Action, Colour in Space in Cultural Heritage (COSCH) has addressed and managed these challenges, through the case studies, described in the preceding chapters, and other research and training activities conducted between 2012 and 2016. We reflect on earlier projects that also shared the goal of "bridging the gap" between disciplinary approaches and mindsets, specialist research methods and tools, while showing the distinctive approach of the COSCH network. We draw conclusions from COSCH's four-year engagement in the interdisciplinary debate by noting general points that, in our view, bear on the success of future research and its diffusion.

On the Perceived Notion of "Two Cultures"

"The scientist has the habit of science, the artist the habit of art."[1] The concept of "two cultures" has persisted since it was forcefully proposed in the 1950s. It is not only widely understood, but also cultivated in the English-speaking academia, as evidenced by a recent, double issue of *Interdisciplinary Science Reviews* (James 2016) that elaborates on its legacy. Originally coined by C. P. Snow (1956) to convey "a gulf of incomprehension" between scientists and "literary intellectuals" (Snow 1959), the phrase became a byword for the perceived irreconcilable differences between science and technology on the one hand, and arts and humanities on the other. Snow spared no criticism for educated people being proud of their ignorance of science. Scientists, on the other hand, often find it difficult to accept the philosophical and speculative nature of academic cultural discourse. "To . . . an engineer every problem has a solution."[2] The value of arts and humani-

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1 Flannery O'Connor, *Mystery and Manners: Occasional Prose*, Selected and edited by Sally and Robert Fitzgerald, New York: Farrar, Straus and Giroux, 1957, p. 65.

2 Oleg Vishnepolsky, "Best People Get Fired for Cause: Tragedy of the Modern World," 12 December 2016, online at https://www.linkedin.com/pulse/best-people-get-fired-cause-tragedy-modern-world-oleg-vishnepolsky, accessed 18 December 2016.

ties scholarship is in the quality of a critical argument and the transparency of its sources; humanities research does not aim at solving a problem or proving something. Historical interpretation of the past, of which the study of material cultural heritage is a manifestation, is always incomplete and therefore tends to be ambiguous. Documentation should reflect this. Truth and accuracy are expected from hard science (Graff 2015, 38). Science and technology are empirical and validated through repetition of operations that yield same results. In contrast, arts thrive on creativity, unpredictable originality, and the uniqueness of the creative process. Material heritage, being an expression of culture, cannot be measured through spatial and spectral optical means alone. For example, an early application of 3D laser scanning, stereomicroscopy, and image processing to the analysis of Rembrandt van Rijn's painting *The Tribute Money* (National Gallery of Canada, Ottawa) has revealed that the artist's signature in monogram and date 1629 were applied at the same time (Baribeau et al. 1992, 73). The results of this scientific examination are valuable, but insufficient to confirm either the attribution of the painting to Rembrandt or the year it was made. A combination of other complementary methods is necessary, including the interpretation of artistic and historic evidence. Our network COSCH faced up to the challenge of making multidisciplinary collaboration more cross-disciplinary (for further discussion see chapter 1).

While acknowledging that disciplinary expertise demands the highest possible specialism, COSCH's prime objective was to push the limits of cross-disciplinary research through direct integration of discrete research practices in the case studies, described in the preceding chapters, and other activities. In the second half of the Action the thematic working groups were mixed to help this integration. Can such interdisciplinary, collaborative research be communicated to the wide range of stakeholders involved in the study and preservation of cultural heritage, without compromising disciplinary specialisms and without resorting to popular science? This book represents an endeavour to do just that.

The discourse of the arts and humanities is to some extent approachable by scientists and engineers. This cognitive position is rarely reciprocal, however. COSCH was a trans-domain COST Action (TD 1201) in Materials, Physical and Nanosciences. How can a humanities scholar, or other non-scientist, professionally involved in cultural heritage, contribute constructively to research into the material and physical sciences pertaining to cultural heritage, much dependent on modern digital technologies and computer science? Although non-technical expertise is critical to cultural heritage studies and is valuable in conservation projects, the interaction between a heritage scientist and the object curator has traditionally been typically limited to the latter's selection of objects in need of treatment, and acceptance of the results of the technical examination; its documentation was rarely shared with non-scientists.

Active engagement in the scientific process poses a problem for many historians and other cultural specialists. Art historians, for example, have a notorious reputation of lagging behind other disciplines in the adoption of computing; its benefit is by no means universally recognized. "The art history community is ambivalent about the value of digital research, teaching, and scholarship," reported a major survey (Zorich 2012, 8). The larger community of humanities scholars seems unable to shed a similar reputation established, *inter alia*, by an influential report from the Summit on Digital Tools for the Humanities, held at the University of Virginia in 2005, which accepted (Frischer and Unsworth 2005, 4) that "only about six percent of humanist scholars go beyond general purpose information technology and use digital resources and more complex digital tools [such as GIS and 3D visualization] in their scholarship." This and many later reports recognize the humanities preference for rather conservative research practices and solitary research, above technological innovation and collaboration. The latest research by DARIAH-EU (Dallas et al. 2017) into research practices in the arts and humanities indicates widespread use of digital tools, but predominantly as basic as word-processing and consultation of online resources.[3]

A convincing, evidence-based case for the acceptance of more advanced digital research methods and their wider adoption by the arts and humanities communities, as one of means of interdisciplinary engagement, must continue to be made. With increasing success initially in North America and the Anglophone world, but gradually growing elsewhere, funding initiatives from the National Endowment for the Humanities (NEH) in the USA, and from the Arts and Humanities Research Council (AHRC) in the UK, have served to heighten interest.

Interdisciplinary Precedents to COSCH

An application of a particular spectral or spatial analytical/recording technology to material cultural heritage is proven beneficial when it enables new insights into the studied object; ultimately supporting its conservation, public display, and other forms of communication and dissemination. Examples are plentiful. Multispectral imaging made it possible to reveal two texts of previously unknown treatises of Archimedes, concealed, alongside his five other treatises, underneath the text of later Byzantine prayers (Archimedes Palimpsest Project 2000–2008). In the areas covered with modern forgeries and where the ink was too faint, and the parchment too stained for the multispectral imaging to work, X-ray fluorescence using synchrotron radiation was applied successfully. These outcomes were

3 We wish to thank Orla Murphy for drawing our attention to this particular area of DARIAH's research presented at https://dariahre.hypotheses.org/285.

a result of a long collaborative research project involving the owner of the palimpsest, the Walters Art Museum in Baltimore, USA, where it is housed, the Rochester Institute of Technology, and the Stanford Linear Accelerator Center of the University of Stanford (now SLAC National Laboratory); the project credits some thirty scholars, conservators, and other contributors. The Digital Forma Urbis Romae Project (from 1999) was another exemplary collaboration between the same university's Department of Computer Science and the Department of Classics, the Sovrintendenza ai Beni Culturali del Comune di Roma, with dozens more scholars and many volunteers contributing in the USA and Rome. The project involved the spatial recording, using laser range scanners, of 1186 extant marble fragments (some 15 per cent) of the map of Rome in the early third century (approx. 18 m × 13 m) which originally decorated the interior of the Templum Pacis in Rome. To enable as complete digital reassembly of the fragments as possible, the available historic drawings of lost fragments were also digitized. All this material has been catalogued in a database, alongside the 3D records of the fragments and inscriptions, and in-depth historical information. The cutting-edge technology of the 1990s has aged, superseded by more robust systems, better data processing algorithms, higher resolution scans, but the methodology of the Forma Urbis Romae project and its transparency remain exemplary. Errors in 3D scanning, the noise introduced, missing data, and automated digital "repairs" that could otherwise give a false impression of the original artefacts are illustrated and explained. Some sixteen years on, the data sets and metadata from both projects remain freely accessible online and, as scholarly resources, are still indispensable. Based on this exemplar, the sustainability of interdisciplinary collaboration is clear-cut on the grounds of its continued scholarly value.

Unlike these two projects, COSCH did not start with the digitization of particular historic objects in mind. Scientists, engineers, and providers of spatial and spectral solutions (mostly academics) with previous experience in collaboration with cultural heritage scholars and professionals, proposed an agenda for enhancing instruments, their calibration, precision of measurements, data acquisition and processing, and the fusion of multimodal data. The focus was on applications to cultural heritage. The case studies, described in the preceding chapters, were designed collaboratively, and carried out in discussion with the COSCH group at large and under scrupulous peer-review.

There have been notable earlier scholarly projects that, like COSCH, sought to perfect the applications of digital technologies to the study and documentation of cultural heritage. Those involving 3D digitization included CARARE, 3D-COFORM, 3D-ICONS contributing the relevant know-how and 3D content to Europeana Collection, and V-MusT—all with a strong emphasis on international collaboration for online access to virtual surrogates of cultural heritage, and on education;

building centres of excellence and providing advice and training. No comparable project served as a direct model to COSCH's concurrent consideration of spectral and spatial technologies and algorithms, with the potential for their integration in recording practice and in the semantically structured representation of relevant knowledge. COSCH was not committed to contributing digital content to existing European repositories. However, by designing COSCH case studies (chapters 2–8) and the COSCH^{KR} knowledge representation (chapter 9) we were able to interact with broader communities of heritage practice, and communicate our research to other audiences. Some data sets, 3D visualizations, and other outputs of COSCH studies have been made freely available for use and further research.

Every large-scale, international collaborative project faces a challenge of making internal and external communication effective. Has COSCH benefited from lessons in communication from earlier research collaborations? What makes communication effective is rarely studied by the cultural heritage projects themselves. Learning through trial and error and benefiting from individual experiences tends to be a prevailing *modus operandi*, and was such for COSCH. Despite the wealth of internationalized and globalized modern research, an effective universal strategy that could guide new collaborations is not available. Is such guidance possible? Looking at examples from the history of twentieth-century interdisciplinary collaborations, Graff (2015, 5) concludes: "There is no single path to interdisciplinarity, no single model, no single standard for successful development. The process and results vary across disciplines and clusters. Like disciplines, interdisciplines are diverse in paths, locations, relationships to disciplines, organization and institutionalization." The awareness of these differences makes communication more attentive to individual needs and expectations.

The COSCH Experience of Interdisciplinarity

COSCH was established to facilitate the discussion of cross-disciplinary research into applications of optical technologies to material cultural heritage. It was strictly an international networking initiative and unlike the aforementioned projects did not benefit from direct funding of research. The COSCH Memorandum of Understanding (2012) stipulated an overall direction for the Action, the starting point and ultimate goal, mainly from the scientific and technological perspectives. No specific interdisciplinary tasks were defined, except the generic objective to develop a common understanding through a dialogue. The rationale behind COSCH and its interdisciplinary purpose have been summarized as

> [O]ne of the latest international and interdisciplinary efforts in perfecting documentation of extant material cultural heritage. The emphasis [was]

> on non-invasive documentation, based on accurate recording of colour and geometry of objects, using multispectral and 3D imaging. Despite recent advancements in colour science and optical measuring techniques there are still many unresolved questions concerning the lack of shared standards in colour and shape measurements. There is no common understanding of best practice. Access to high quality 3D records, based on precise surveying methods, is limited—this hinders the understanding of benefits and limitations of such techniques, constricting their wider adoption in professional museum and heritage practices, and other areas of study. COSCH [drew] on earlier interdisciplinary research and [relied] on strong engagement of users from across cultural heritage domains. COSCH [was] designing new case studies and developing new digital tools for enhanced, *shared understanding and application of spatial and spectral documentation*. (Boochs et al. 2013; Boochs et al. 2014, 713; emphasis added)

We, the authors, a scientist and an art historian, both academic scholars with years of experience of collaborative research, were elected to Chair and Vice-Chair COSCH. In a typical research project its team and skills are defined prior to the award of funding. Participation in COSCH was voluntary, however, and, with the exception of a core group of original proposers, could not have been predicted, impacting on our ability to plan and deliver the work in accordance with the original objectives. We expected the active participation of as many relevant disciplines involved in the study and documentation of cultural heritage as possible. The biographies of COSCH participants are representative of the extraordinarily diverse backgrounds (see p. 263 and *COSCH Who's Who* 2012–16). The participation in COSCH was augmented from 137 researchers from twenty-five countries (by July 2013) to 237 researchers from twenty-eight European countries by November 2016. It was assumed that, prior to joining, each new participant had familiarized him- or herself with the principles of COST Actions, and with the COSCH objectives and organization of work, laid out in the Memorandum of Understanding (COSCH MoU 2012).

The process of achieving the desired outcomes through the collaborative effort involved several stages. It started with the assumption that the complexity of the desired tasks might be reduced by restricting the number of technological specialisms and by clearly defining their scope—spectral and spatial applications, algorithms and data processing, alongside material surface analyses and data visualization—with the expectation of transferability of the scientific insights gained to different disciplines. However, the discussions revealed an enormous complexity of subjects and variations in individual understanding of technology even within a single discipline. The extent of disciplinary complexity obscured the broader picture and what we had assumed was a clear chosen path. The importance and characteristics of technological research were assessed in different

ways. At the next stage, the strongly interdisciplinary groups started to establish the connections between technology and fields of application, but without fully understanding how they operate. The significance of theoretical work, that underpins all research, could not be ignored. Finally, through practical work and more discussions, the group began to develop a shared view of problems and solutions.

COST Actions are open to new members in the course of their running, subject to eligibility (COST Vademecum 2016). A new researcher joining the group was seen an indication of the recognition of COSCH's work and purpose. In accordance with the COST emphasis on wide participation, COSCH was open to researchers from any field, at any stage of their career, from universities, research centres, public and private organizations, and commercial companies in any of thirty-six eligible countries. What such a wide and varied membership means in terms of the diversity of tongues and minds is not difficult to fathom. Not only the otherness of science and technology from the arts and humanities was apparent, but also differences between individual disciplines, and within their various fields, and between the individual researchers representing the same field. The heterogeneity of COSCH researchers was manifest in their individual experience and degree of specialization, education (even the impact of different schools within a discipline), diversity of cultural backgrounds, and personal interests. The interdisciplinary engagement in COSCH was therefore challenging on many levels. The contributors to this volume state, explicitly or indirectly, the intellectual differences encountered when dealing with another research culture. COSCH debates saw different ways of constructing an argument, different reasoning and different conceptualization. Drawing different conclusions from the same facts or scenarios, depending on one's background, was not unusual. "This experience showed that the ways humanities and engineering researchers approach a problem vary profoundly. Cultural differences, not connected to nationality, but to the field of work, represented both an asset for the project and a challenge at the same time" (chapter 7, p. 138).

For many involved in a collaboration such as COSCH a leap of faith is required to embrace another, often unfamiliar discipline, and sometimes not one, but a number of fields. An open mind and a great deal of new learning were required. Arts and humanities scholars who decided to get involved in a COST Action in the area of material science and physics have certainly demonstrated open-mindedness. However, not many archaeologists, art historians, museum curators are capable of fully understanding the scientific and technological complexity of 3D sensing, spectral imaging, algorithms, and data processing. Arts and humanities are more approachable to a non-specialist, but only to a point. One is often unable to help one's own superficial knowledge or ignorance when faced with an unfamiliar area of scholarly research. This ignorance is plain to see by a specialist. Optical technologies, such as laser scanning or structured light scanning, are praised for

their unprecedented accuracy of spatial recording. Why do they involve decimation of raw data? Is less data better than more data? Why is a manual repair of the resulting point cloud necessary? Why does imaging of a material object through RTI require the reconstruction of *the object*, with "reasonable reconstruction" considered a good result? (MacDonald et al. 2016, 76). Christos Stentoumis is linguistically more precise, when he writes about multiple view stereo vision (see p. 225) as "the process of reconstructing *the 3D model of an object* or scene [emphasis added] from a set of digital images." In archaeology, art and architectural history and in conservation, the notions of the object, its representation, and reconstruction are very different from scientific research. Each field would probably argue for being more nuanced. In conservation, reconstruction is considered and classified in relation to renovation, restoration, anastylosis, and restitution—depending on the extent of alteration of the original fabric, type of materials used (original v. non-original) and the final result. Reassembling parts of a broken ancient Greek vase (chapter 2) constitutes reconstruction when the missing parts are substituted, or restoration when no such an attempt is made (ICOM-CC Resolution 2008, 2). The same Resolution stipulates that restoration of a single object aims "at facilitating its appreciation, understanding and use. . . . These actions are only carried out when the item has lost part of its significance or function through past alteration or deterioration. They are based on respect for the original material. Most often such actions modify the appearance of the item" (ICOM-CC Resolution 2008, 2). Digital scholarship adds to this complexity by blurring the distinctions between physical and virtual processes. Training in such physical disciplines as archaeology, art and architectural history, the conservation and restoration of cultural heritage naturally prepares one for the extension of practice into the digital realm. This, for example, can be illustrated through a definition of virtual anastylosis in archaeology as "the reordering of available remains digitally to virtually reassemble something that existed in the past. This process makes a 3D model assembling surveyed fragments, present in the excavation site, with elements philologically reconstructed on the basis of historical knowledge and documentation' (AAT 1988–, ID: 300389891).

As COSCH discussions have shown (chapter 1) there is by no means a consensus as to the terminological variations in use. Transparent definitions of terms, in the context of a particular research project or task, are essential. Terms express ideas, decisions, and solutions. No understanding should be assumed, each use must be expressed unambiguously. Another good example can be found in chapter 4 (p. 79): "two snapshots of a detail of a thistle rendered using the Polynomial Texture Mapping (PTM) reconstruction method from an H-RTI recording," dispelling any potential ambiguity, in this particular case, between the object, its representation, and the subject of reconstruction. Far too often mental shortcuts

and the convenience of professional jargon confuse the message. The challenge in the interdisciplinary debate is to acknowledge that PTM reconstruction (through digital "stitching" of multiple images of an object to form a single visual representation) and philological reconstruction may have equal cognitive benefits and be not entirely disconnected. An excursion into a modern theory of the image complicates the matter further, while supporting some of the above claims. Elaborating on the linguistics, the code, and meaning of photographic representation, Roland Barthes saw it as a repetition rather than transformation of the source subject matter: "the image is re-presentation, which is to say ultimately resurrection, and, as we know, the intelligible is reputed antipathetic to lived experience" (Barthes 1964, 152).

Clarity of the terms and context of research is conditional to effective communication. As far as interdisciplinary terminology is concerned, Miller (2011, 8) believes that the problem of "translation" is superficial, as any researcher should be able to learn how terms are used in another discipline and use them appropriately. The experience of the COSCH Action was not that simple, however, confirming that to understand the specialist terminology one needs to understand the research culture and practice expressed. Therefore "the problems that interdisciplinary research faces stem [not from terminological issues and miscommunication, but] instead primarily from methodological issues, and in particular from the nature of the answers that different sorts of disciplines are looking for and the different sort of questions that are being asked" (Miller 2011, 9). The awareness of that difference is the first step towards identifying its nature.

Conclusions from COSCH

We would argue that successful interdisciplinary collaboration does not require reconciliation of disciplinary differences, which should be respected. A forum for their articulation and discussion, as provided by COSCH, is beneficial to collaboration. Research thrives on complementary coexistence of disciplines. The biological symbiosis of dissimilar organisms that need each other to function and develop may serve as an analogy. Interdisciplinarity is at risk when attempts are made to convert one field into another, or when a valid expression of knowledge or critique is lost through suppression by another. The topical debate of the observed undisciplining of knowledge through interdisciplinarity (Graff 2015) must respect the equality of varied cognitive positions. The eminent convergence of disciplines through interdisciplinary research, observed by Graff and others, was not experienced within COSCH. A greater coherence of modern methods of investigation, or the cross-disciplinary unimethods, seems more likely, but only after a considerable and prolonged collaborative effort.

Facilitators of Interdisciplinary Communication

COSCH approached the challenge of interdisciplinary communication through different forms of collaboration and discussion, training, internal and external dissemination—this book provides ample examples. "Collaborations are intense, not superficial, relationships," states a report by the US National Research Council of the National Academies, differentiating collaborations from "communication (the sharing of information), and cooperation (in which participants influence the decisions of other participants in a common effort). . . . What they share is the intention of creating something larger than the sum of their parts" (Mitchell et al. 2003, 40–41). The COSCH work towards the formal representation of knowledge relevant to applications of spatial and spectral optical surveying methods in the COSCH^{KR} represented such an intention.

Communication beyond the COSCH network and interaction with a wider community of practice was another objective. COST support was available for a one-off participation in COSCH conferences of experts from countries outside Europe, if and when beneficial to COSCH proceedings. For example, Fenella G. France, Chief of the Preservation Research and Testing Division at the Library of Congress, presented her Division's work on non-invasive hyperspectral imaging of Thomas Jefferson's 1776 draft of the Declaration of Independence and other historic manuscripts in the Library collections (France 2013). Other American experts contributed academic papers and served as peer reviewers to the *COSCH e-Bulletin*, an online journal set up by the network. The COST Trans-domain Action scheme is manifestly conducive to cross-disciplinary collaboration and recognizes its benefits, but does not directly support research. Funding is for networking activities (including travel and subsistence; excluding conference fees). Research is expected to be funded nationally and embedded in the activities of participating institutions. COSCH researchers, particularly those in the early stage of their careers, benefited from the COST effective support of study visits to foreign research establishments. Fifty-six of these, so-called Short-Term Scientific Missions (STSMs), were conducted (COSCH STSM Reports 2013–16), some of which contributed to the case studies described in this book. This kind of facilitation of interdisciplinary research should be encouraged. It enables individuals to conduct research according to their particular interests, in an institution they consider to be leading the field, under the supervision of their choice and scrupulous formal peer review. For COSCH researchers the contacts forged through these exchanges were overwhelmingly positive, enjoyable, and led to planning new collaborative projects. The same can be said about the nature of interaction within the network in general.

As a prerequisite to the technical enhancement of optical digital recording tools and methods, and their potential, wider adoption, COSCH's work was to

respond to *actual needs*. The needs had to be identified first and the COSCH case studies were designed to this end. The providers of technological solutions (some engaged in the cultural heritage research practice, therefore "users") reached out to other professionals and scholars. Custodians of museum collections, archaeologists, conservators, and heritage scientists working in museums identified the objects and sites suitable for COSCH research, and facilitated access. Technical examination and reliable methods of monitoring the condition of historic objects were amongst the top conservation needs, alongside other research questions. The study of fragments of the Karabournaki kantharos (chapter 2) investigated how this vase might have looked originally, and what are the benefits and limitations of a hypothetical, 3D virtual reconstruction. The study of medieval wall paintings in the Château de Germolles (chapter 4) was an investigation into the original artist's materials, the composition and meaning of the decoration—all important for deciding upon the most suitable conservation and presentation of the murals. Digitization of selected objects in the Romanian Museum of National History, for online access to virtual surrogates (chapter 6), aimed at alleviating the prolonged closure of the museum to the public, while also introducing the relevant know-how to practitioners in the local museum. The Roman coin case study (chapter 3) tested a wide range of optical recording and visualization techniques and engaged in discussions with numismatists and metal conservators about their evaluation and wider adoption. The number of identified scientific, technological, organizational and societal questions that are yet to be resolved to the satisfaction of the stakeholders will inform the ongoing research and development of the next generation of instruments and procedures.

Live demonstrations of professional practice—organized in the very places where research is conducted, with the possibility of asking questions, by specialists from the same field and the uninitiated alike—were amongst the most effective means of interdisciplinary, scholarly and professional communication of the latest science and technology applied to cultural heritage research. Demonstrations were part of many COSCH meetings. Numerous visits to scientific laboratories included demonstrations of an array of multispectral instruments in action at the SIB Laboratories of the School of Computing, University of Eastern Finland in Joensuu; an interesting application of the LAbScan imaging with VNIR PFD (400–1000 nm) to detect fake banknotes; and a process of automated digitization of botanical specimens from the herbarium of the Finnish Natural History Museum (Digitarium 2010–). At the Institute of Measurement Science of the Slovak Academy of Sciences in Bratislava, a phoenix nanotom® was demonstrated. The system is used in computed tomography (microCT and nanoCT) and 3D metrology. It was used in the elemental analysis of the denarii of Faustina the Elder, and to provide, with varying degrees of success, the ground

truth 3D data against which other measurements of the same coins could be compared (described in chapter 3). In addition to the lab demonstrations, visits to museums, conservation departments, and tours of heritage sites, guided by their scientists and curators were organized. They offered opportunities to understand issues in optical recording methods in the context of actual requirements, dictated by the nature of collections, local environment and the condition of the object. This is how we learned first-hand about particular challenges in the conservation of modern art by artists experimenting with materials that have not aged well. We looked at the artworks in question, housed in the Museum of Modern Art in St Etienne, France, where we also found out from their restorers about conservation treatments and discussed how technology may support this practice. In Mainz, Germany, we visited the laboratories of the Institute for Spatial Information and Surveying Technology (i3Mainz) of the University of Applied Science (the COSCH leading institution), as well as the laboratories of the Römisch-Germanisches Zentralmuseum (RGZM). At this archaeological museum we were introduced to digitization projects, such as the periodic recording in 3D of waterlogged historic wood, to monitor possible deformation (see chapter 9). Alongside the discussion of the role of technology in museum conservation practice, we were also able to appreciate the extent of traditional, manual, highly skilled artistic work involved in making material copies of ancient artefacts, ongoing at RGZM for scholarly and educational purposes.

The organization and funding of interdisciplinary work were frequent topics of COSCH discussions. An exemplary model of cooperation would be the RGZM's solution to employ an engineer specializing in geo-information and heritage science, based at the i3mainz university. He teaches students 3D scanning, and other subjects in applied technology, using the museum's artefacts that can be safely moved to the university. The objects and all involved benefit from this collaborative provision of specialist digitization solutions and education at the same time.

A new breed of professional intermediaries, including academic editors, is required to ensure that interdisciplinary research is adequately communicated to expert researchers and students alike. Scholarly communication must satisfy the highest standards of each contributing field, and without potentially compromising any of the contributing knowledge. Scientific papers on technology applied to cultural heritage often lack information about the cultural heritage in question (even as basic as the name, date, and location of the object); whereas humanities papers tend to ignore scientific research into the subject. COSCH authors were sometimes prompted to restore the interdisciplinary balance of the content. Academic publishers have traditionally separated scientific work from cultural subjects. Springer Verlag has an established reputation of publishing science and technology applied to cultural heritage; their outreach to readers within arts and

humanities however is limited. It may come as a surprise that this book, with considerable technical content, is published by Arc Humanities Press, renowned for titles in medieval and global history scholarship. The preoccupation of COSCH researchers with science, technology, and cultural heritage provided the desired connections that appealed to this humanities press, which "publishes research that fosters better public engagement in, and understanding of, the past and of the ways in which the contemporary world is linked to the premodern world. Arc Humanities Press is the publishing arm of the Carmen Worldwide Medieval Network, and reflects this learned society's particular interest in international collaborative research, global history, cross-faculty research, and applied research" (source: https://mip-archumanitiespress.org/series/arc/). This kind of openness to interdisciplinary research is needed to encourage the trend.

> The growing role of intermediaries is not simply that of the one-way dissemination of research outputs; it must foster a two-way or multi faceted dialogue between the various stakeholders and support the whole research cycle. (Carter and Paulus 2010, 84).

Training and Learning

In the elaborated version of his critique of two cultures, C. P. Snow (1963) argued that the solution to what is clearly a perennial problem of the widespread ignorance of science is through good and early education. Training and learning opportunities, at all levels, are essential for the future of the field in question. They guarantee direct exposure to interdisciplinary research and are conducive to critical reflection. As the i3mainz-RGZM cooperation shows, the learning environment necessitates the visibility of interdisciplinary research in the first place, and requires effective communication of its successes and failures. The role of specialist pedagogy in this process, both experiential and experimental, cannot be stressed enough. COSCH training schools, in small groups and led by inspiring teachers experienced in both theory and practice, were useful, rewarding to all involved and enjoyable, and therefore effective.

The validity of Snow's argument on two cultures was strengthened by the fact that he was both a molecular physicist and a prolific novelist. He not only spoke from an informed position, but also through personal experience of pursuing two very different disciplines alongside a high-ranking administrative career. A new generation of researchers is increasingly representative of the interdisciplinary trend, and offers a part solution to bridging the gap between discrete disciplines. A metrology scientist with a background in fine art, an astrophysicist examining historic wall paintings, an art historian applying pattern recognition to an iconographic study, or an archaeologist analysing a point cloud of an ancient

structure—to use the example of some of the careers represented in COSCH—are still in the minority, but no longer an oddity. Recent research into "the perceived gap between researchers and users of research, thought to be hindering effective collaboration and limiting the impact of research" found this observation "inaccurate, with a growing group of professionals identifying themselves as spanning both roles" (Bell et al. 2014). The COSCH experience confirms these findings.

Precision is as important in communication as it is in science and technology. Training in research methods should include interdisciplinary communication and academic writing skills, to minimize unintended factual errors due to insufficient command of language. Confident use of plain and correct language empowers communication and interaction in research-making processes. When the language is incorrect and imprecise, then ambiguity or even misunderstandings are likely. Quality research risks being lost through poor communication and presentation. Much of international interdisciplinary research, of which COSCH was an example, is being conducted and disseminated in English. This disadvantages many non-native English speakers. Those fluent in colloquial English seem sometimes to underestimate the importance of highly nuanced and precise academic communication. A distortion of the intended meaning results in misunderstandings and knowledge being altered or lost in translation. For example, a common misunderstanding amongst non-native English discussants of research into cultural heritage is the misuse of the term "science," often seen as a general term encompassing all learned disciplines of knowledge. Arts and humanities disciplines are often, incorrectly, being termed "scientific"; an academic humanities scholar is sometimes, wrongly, called a scientist; human sciences are confused with the humanities, whilst arts, which encompass many creative academic disciplines, are often narrowly understood as strictly fine art practice—the examples of the wrong choices of word are plentiful not only in speech, but also in scholarly literature. When unaware of this and similar misuse, native speakers of English misunderstand the nature of intellectual argument; the communicator is unaware of the miscommunication and both parties continue the dialogue based on false assumptions. It is therefore necessary to restate the obvious: good professional language skills and high standards in academic writing are essential for ensuring effective scholarly communication.

Standards and Guidelines

Arts and humanities thrive on critical disagreements. Can scientists and engineers disagree about the best optical method of recording cultural heritage? Many guidelines and technical standards exist to facilitate the answer, but we have learned in the course of COSCH that deciding which of the many standards available

is "best" depends on a number of factors and a particular research scenario. How to convey the measure of accuracy of colour registration or representation? The same goes for geometrical registration. What standards and procedures are likely to ensure the sustainability and long-term preservation of digital scholarship and its dissemination? These are key issues in the digitization of cultural heritage. The contributors to this book refer, independently, to VDI/VDE standards of the Association of German Engineers, and to ISO standards of the International Organization for Standardization. The revised image preservation technical guidelines of the Federal Agencies Digitization Guidelines Initiative (FADGI 2016) and Metamorfoze (van Dormolen 2012) were brought to the attention of COSCH by Olejnik-Krugły and Korytkowski (2017), when they presented solutions for colour-accurate archiving of images of paintings through spectrophotometry, at the COSCH final conference, held on 11 October 2016. The ISO image quality standards 19262, 19263, 19264 also concern archiving. For some researchers involved in cultural heritage, and using digital images extensively, even the basic calibration of devices used daily (computer screen and printer) are an obscure area, making them wonder, why, what they see on the screen differs in colour from a print of the same. The effort to learn the basics of colour resolution, display resolution, and print resolution may help with resolving the error (not a mystery) of bad colour representation. Art specialists, who have high visual literacy and sensitivity to perception and aesthetics of colour must not be shy in seeking advice on technical matters. The COSCH experience shows that the information will be generously provided by those in the know.

The lack of universally accepted standards, or too many standards, is an issue no research into applied science and technology can ignore. Universal standards are not in the commercial interest of the manufacturers and providers of proprietary solutions, but they are vital for the advance of science across disciplines.

The Future

According to Graff (2015, 1) the term "interdisciplinary" is so ubiquitous in today's scholarly writing that it is not unreasonable to assume that interdisciplinarity is becoming "the dominant form of scholarly work"; the critics are uncertain whether this phenomenon is positive or negative. Research described in this volume demonstrates the extent to which modern conservation and documentation of cultural heritage rely on different disciplinary components. Digital data, electronic tools, and computational methods cross-permeate academic disciplines making them potentially more contingent than ever before. The COSCH experience of interdisciplinary collaboration has been intellectually stimulating and has delivered a range of practical benefits to academic and professional advancement. Practitioners are

best qualified to articulate unresolved problems and admit that applying digital technologies to the study and preservation of cultural heritage is not all clear cut. It was argued in 2005 that "Currently, 3D modeling is too expensive, too time consuming, and not suited for conservation" (Eppich and Chabbi 2006, 11). This argument referred to the then developing regions, but many heritage institutions, even in relatively prosperous countries, particularly poorly funded provincial museums find themselves in this situation. Digital research cannot be viewed solely from the perspective of rich Western establishments; these should proactively contribute to the distribution of skills and resources to disadvantaged research communities worldwide. Researchers involved in COSCH participated in such international projects and have made most of the output of their work freely accessible worldwide.

COSCH activities evidenced the support available for interdisciplinary digital scholarship and its due prominence across the European Union and beyond. COSCH researchers fully support the recommendation "that funding extends over longer periods to grow and sustain partnerships between organisations committed to promoting collaborative heritage science research" (Bell et al. 2014). Networking opportunities similar to COSCH, and face-to-face communication in particular, should be encouraged and enabled. They provide a way forward for enhanced interdisciplinary communication, but alone cannot make a real difference in advancing research. Both a vision combined with adequate resources is needed to ensure that innovators are not trapped in conservative research environments that underuse their talents. Applying for research grants has become obligatory for academic positions, but is disproportionately time-consuming relative to the rate of success. Far too few grants are chased by too many applicants.

Owing to the complexity of the field and the speed with which technology develops, many unresolved questions remain, even for well-resourced establishments in leading economies. In our era of hyper-connectivity the ease of scholarly communication is unprecedented. With benefits come risks. We are prone to the overload and chaos of information, distraction, and superficial modes of critical engagement. Our times, lives, institutions, and work patterns have been defined as "liquid."[4] Research benefits from a global reach, but its efforts continue to be fragmented. Research funding is predominantly short-term and does not prioritize continuity. This situation is counterproductive to stable research environments, but may also be seen as conductive to new developments and ideas. Digital technology benefits research, while also making its digital outputs vulnerable to

4 *Cf.* A concept in critical sociology and analysis of modernity of Zygmunt Bauman, the author of, *inter alia*, *Liquid Modernity* (2000), *Liquid Life* (2005), and *Liquid Times* (2007), all from Cambridge: Polity.

improper preservation. Novel developments tend to supersede the future technologies of the past; important evidence of past visual and other non-text-based communication risks being lost. This book records a particular research perspective and practice of the 2010s. We hope that the critical discussion of COSCH's successes and failures will be instructive to those with an interest in this interdisciplinary field and the ability to take it forward.

To conclude the two cultures argument on a lighter note, a COSCH researcher may be quoted, saying "I'm not creative, I'm a scientist!" (COSCH ESR Think Tank, 20 October 2015). Indubitably wrong, this admission may be considered in the context of the artistic theory of Josef Albers (Fesci 1968): "the creative process is the same secret in science as it is in art. They are all the same absolutely. . . . art is concerned with human behavior. And science is concerned with the behavior of metal or energy. . . . It's the same soul behind it. The same soul, you see."