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Going All the Way: Achieving the Full Potential of Collaboration between Conservators and Scientists to Produce Information, Products, and Processes of Demonstrated Use at the Bench

ABSTRACT

Heritage Science for Conservation at Johns Hopkins University was established in 2009 through a generous grant from The Andrew W. Mellon Foundation. Its purpose is to bring scientists into a closer working relationship with conservators. Bringing scientists into the conservation laboratory of an academic library fosters deep research collaborations relating to book and paper conservation. This alliance of scientist and conservator in a common laboratory also serves as a model for how the next generation of book and paper conservation science laboratories might be structured. The Heritage Science for Conservation model addresses the need for a stable locus for science and engineering dedicated to the ongoing needs of the book and paper conservator. In Heritage Science for Conservation, scientists and engineers design research projects and develop agendas in collaboration with conservators and carry out the work in the same physical space. Following this collaborative work, research is disseminated to a wide but targeted audience of conservators, engineers, scientists, librarians, curators, industrialists, students, and the general community.

During its pilot phase, 2009–2012, Heritage Science for Conservation was successful in achieving its programmatic milestones: (1) to conduct research into the fundamental causes of heritage materials degradation and the fundamental applicability of conservation technologies; (2) to expand the tools and techniques of conservation science; and (3) to produce information, products, and processes of demonstrated use at the conservator's bench. In this paper, the authors introduce the Heritage Science for Conservation model, which facilitates both ongoing research on behalf of book and paper conservation and the development of new technologies that can serve the conservation scientist and the practicing conservator. The authors present evidence of the model's success by describing three technologies developed at Heritage Science for Conservation, one for each milestone. The authors also suggest that establishing regional Heritage Science for Conservation centers at academic institutions with strong science programs and robust conservation programs will move the field toward a national conservation research agenda and strategy by capitalizing on institutional strengths and providing sustainable collaborative research, while avoiding redundant or disparate research efforts.

Presented at the Book and Paper Group Session, AIC's 40th Annual Meeting, May 8–11, 2012, Albuquerque, New Mexico.

INTRODUCTION

Heritage Science for Conservation (HSC) is a part of the Department of Conservation and Preservation in the Sheridan Libraries and Museums of Johns Hopkins University. Sonja K. Jordan-Mowery is the Joseph Ruzicka and Marie Ruzicka Feldman Director for Conservation and Preservation, the principle investigator of HSC, and co-author of this article. The Sheridan Libraries and Museums is home to one of the oldest ongoing library conservation and preservation departments in the United States that included in its original mandate the training of book and paper conservators. Established in 1974 by John Dean and modeled on the City and Guilds of London Institute, the conservation program has, for more than three decades, served as the only apprenticeship program for book and paper conservation education in an academic library.

The other co-author of this article, John W. Baty, is Assistant Research Professor and HSC Scientist—hereafter, ARP/HSC Scientist—and is jointly appointed to the Johns Hopkins Department of Materials Science and Engineering (DMSE), Whiting School of Engineering. DMSE has a record of conservation science research on diverse cultural heritage materials, with masters and PhD graduates who are active members of the conservation science community. From the mid-1980s until the early 1990s, DMSE also had a PhD program in conservation science. As an engineering department, DMSE has a focus on products and processes not present in a core-discipline physical science department, adding an important dimension to its partnership with the conservation and preservation department. Johns Hopkins University has exemplified a long-standing commitment to collaborative initiatives and partnerships between the sciences and conservation efforts.

HSC is the direct result of a two-day workshop held at Johns Hopkins University on April 28–29, 2008. Funded by The Andrew W. Mellon Foundation, the workshop brought scientists, conservators, industry partners, institutional managers, and funding agencies together to discuss how to develop a national conservation science research agenda to address the pressing conservation needs for book and paper collections in our nation's cultural institutions. The workshop produced a comprehensive report that identified the research needs for book and paper collections (Jordan-Mowery and Olson 2008), including (1) the need for change in the educational model for book and paper conservators and (2) the need to foster an environment for stronger and more sustained working relationships between conservators and scientists. Conservators and scientists needed more direct access to one another and more long-lasting collaborations: a new paradigm for book and paper conservation and conservation science.

In *The Structure of Scientific Revolutions*, Kuhn (1996) defines a paradigm as a set of practices that defines a scientific discipline at any particular period of time. He notes that a paradigm provides model problems and solutions for a community of researchers. As conservators and scientists engage in research collaborations, they often observe that some of the conventional research models and questions do not satisfy the research needs of heritage materials. The close proximity of the scientist, conservator, and cultural materials yields a better understanding of the materials' complexities. This, in turn, enables the scientist to provide better technologies and methodologies for the nuances of the materials and the conditions of their storage and use.

Conservation science contributes directly to the long-term preservation of physical collections in a number of ways: (1) by enabling an ongoing dialogue between conservator and scientist in exploring the effects of current materials and treatments; (2) by developing effective materials, equipment, and techniques for conservators; and (3) by enabling quantifiable long-term research and investigation. The interpretation and dissemination of scientific findings should be at the heart of preservation activities, as a bridge of communication between disciplines. The integration of new technologies with the knowledge, skills, and expertise of conservators enables the revision of current theories. This, in turn, informs decision-making and improves treatments. In HSC, scientists and conservators work collaboratively with no distinctions in rank: all contributions are equally valued. Conservators and scientists alike learn to communicate without jargon. Working in a shared laboratory with a diversity of expertise enables scientists and conservators to develop practical treatment solutions and a common research agenda.

Because it is located in the conservation department of an academic library and its scientific faculty are also appointed to the science and engineering departments of the institution, HSC can foster deep collaborations between scientists and book and paper conservators. In order to be successful, such a laboratory must create the expectation that—whatever the current issues are, and whatever key evaluations or reevaluations need to be made—conservators have a role in guiding scientific research. The elements that keep the science and engineering practice trained on book and paper conservation are (1) the collaborative design of research agendas with conservators; (2) the execution of those agendas in the same collaborative environment; and (3) the dissemination of results to a diverse audience, including conservators, engineers, scientists, librarians, curators, industrialists, students, and the general community.

Science and Engineering Dedicated to the Needs of Book and Paper Conservators

To ensure that scientific and engineering activities meet the needs of book and paper conservation, the HSC laboratory reports to the Director of Conservation and Preservation. The ARP/HSC Scientist, in addition to supervising the postdoctoral fellows and maintaining the laboratory, maintains a research agenda that reflects the interests and expertise of staff conservators and the wider conservation community. He also draws on the resources of partnering laboratories at Johns Hopkins, as well as collaborating heritage science, industrial, and academic laboratories in the region.

The application process for the postdoctoral fellowships contains several features to ensure their relevance to book and paper conservation. The call for proposals invites applications in specific areas that reflect the facilities, expertise, and momentum of the department. The 2012–14 call encouraged proposals targeting paper strengthening and the copper-catalyzed degradation of paper. The proposals are extensive and require a timeline and budget. They also require a narrative describing how the proposed research will serve conservation needs. After the postdoctoral fellows arrive on campus, they discuss their proposals with conservators for collaborative modification. The research is then carried out in the fully equipped conservation science laboratory adjacent to the book and paper conservation laboratories in the new Brody Learning Commons of the Milton S. Eisenhower Library. This close physical proximity keeps the work of the science team focused on the needs of the conservators and promotes the transparency conservators expect in the development of conservation science technologies. Scientists are also integrated into the daily work of the conservators, thereby gaining a richer understanding of materials and treatments. The ARP/HSC Scientist and postdoctoral fellows thus develop an enhanced understanding of the motivation for their research and the limits of treatment, enabling the generation of meaningful and relevant ideas for future work.

Communication is also a central component of the HSC laboratory, and it is not limited to the dissemination of research results or the demonstration of developed technologies. Oral and written presentations begin early on in the postdoctoral fellowships, and the entire science team is dedicated to getting ever better at communicating with conservators, scientists, business people, and local communities. To date, communication vehicles have included conservation and scientific publications, conference presentations, classroom lectures, brown bag lunches, library talks, and YouTube videos. Effective communication is the bridge that connects conservators and scientists.

MILESTONES OF THE SCIENTISTS' WORK: INCREASING APPLICATION AT THE CONSERVATOR'S BENCH

The image of a bridge has been a part of HSC's visual identity since its beginning and symbolizes the solid connection between conservators and scientists. This prompts the question, how do you know the bridge has been successfully crossed? To answer the question and to make sure HSC addresses its central obligation to serve the needs of the bench conservator, HSC has identified three milestones: (1) to conduct research into the fundamental causes of heritage materials degradation and the fundamental applicability of conservation technologies; (2) to expand the tools and techniques of conservation science; and (3) to produce information, products, and processes of demonstrated use at the conservator's bench.

Successes for each of these three milestones roughly correspond to the first three years of HSC's existence (2009–12) and to presentations at the AIC Annual Meetings. At the 2010 meeting in Milwaukee, the authors presented results on the fundamental degradation chemistry of papers containing papermaker's alum (Baty et al. 2010). In two presentations in 2011 in Philadelphia—the first exploring the role of polyester film encapsulation on paper aging (Minter 2011) and the second examining the role of metal salts in sizes, pigments, and ink (Baty 2011)—the authors discussed several technologies to improve accelerated-aging studies of paper and text blocks. These included improved long-term, low-temperature aging with passive control of relative humidity and ways to control ionic strength, pH, and the rates of oxidative versus hydrolytic degradation. In 2012 in Albuquerque, HSC first presented the three technologies described below (Baty 2012). All of these technologies are designed to be useful to conservators working in their own laboratories, whether they have immediate access to physical science laboratories or not. All the technologies have been developed to the point of provisional applications for patent, but have differing needs for partnership and further work to achieve their full potential. The authors welcome comments and suggestions, as well as inquiries about partnership in the development of these technologies. The authors are pleased to partner with Johns Hopkins Technology Transfer for the intellectual protection, marketing, and distribution of these technologies.

Milestone 1: Conduct Fundamental Research on Conservation Problems and Technologies

The need for a rigorous physical-science foundation for conservation technologies is recognized throughout the field, and HSC's commitment to it is not at all unique. A powerful illustration of this need can be found in the development of nondestructive techniques for artifact analysis. Here, if a conservator is to rely on an apparatus or protocol to reveal an important criterion for treatment, the technology must be supported with rigor and transparency.

Conservators and scientists have expressed some uncertainty about the amount of materials research that has already been done and that may be transferred from other, larger fields. Scouting other disciplines for relevant data and results is a mark of any good research laboratory, but this need is especially keen in conservation science due to its comparative lack of practitioners. There are many pertinent research areas from which to draw. For example, the conversion of cellulose into biomass-based fuels and feeds shares many common features with the degradation of cellulose in paper. However, this seeming gold mine of information has its limitations, since the goal in fuel production is to degrade the cellulose quickly, using liquid water and high heat, pressure, and acidity if needed. These conditions contrast markedly with the relatively mild ambient conditions and much longer timeframes in which paper degrades in the library, museum, or archive. Hence, scientists need to study the underlying causes of materials deterioration—and the fundamental applications of conservation technologies—under conditions pertinent to heritage collections.

As the HSC laboratory has conducted fundamental research, it has received two requests from conservators, both aimed at obtaining the greatest return for the invested effort: that the research be relevant and that the precision reported be meaningful. The close collaboration between conservators and scientists in HSC's shared workspace ensures that discussions about physical science take place on a regular basis, with the goal of maximizing research benefits for conservators. As a result, HSC scientists have learned to which decimal place they need to measure, and to avoid elucidating subtle differences—such as those between reaction mechanisms—when such differences do not change treatment protocols.

As a representative technology, HSC has developed common-ion buffers to maintain paper pH during aging. The

HSC laboratory has successfully applied this technology in paper-degradation research (Baty et al. 2011) and is currently exploring its application in conservation practice.

Whereas in conservation and paper science the word "buffer" usually implies an alkaline reserve, in other fields the term implies utilizing the common-ion effect to maintain pH. In a common-ion buffer, an alkaline species and its conjugate acid are in an equilibrium that resists change in pH when either an acid or a base is added. Common-ion buffers have appeared in the conservation literature in several contexts, although not yet as a means of controlling paper pH during aging. Researchers have used the precise pH control afforded by common-ion buffers to improve enzyme treatments, as in the removal of linseed oil (Blüher et al. 1997). Also, the pH-buffering ability of gelatin sizing, which contains both acidic and basic side chains, has been demonstrated in historically relevant samples (Baty and Barrett 2007). Perhaps the most familiar use of common-ion buffers is in calibrating pH electrodes in conservation laboratories.

The types of papers in which precise control of pH is needed—both in conservation research and in practice—are papers containing metal ions such as aluminumIII, copperII, and ironII, which are present in sizes, pigments, and inks, and are known to promote paper degradation. All these metal ions exist in compounds known as coordination complexes, whether they originate from the initial manufacture of the artifact (like the copperII acetate in verdigris) or from a conservation treatment (like the ironIII phytate produced in the treatment of iron-gall ink). The compositions and orientations of these complexes—and properties such as reactivity and color—are highly pH dependent, hence the motivation for precise control of pH in conservation treatment.

The HSC laboratory has inaugurated the use of two types of common-ion buffers—the first made up of acetate/acetic acid and the second of monobasic/dibasic phosphate—and has used them to find the pH dependence of aluminumIII-catalyzed paper degradation. The results of these studies, which targeted aluminumIII in papermaker's alum, show that paper deterioration in the presence of aluminumIII is greater than what might be expected due to acidity alone, but that increasing the pH consistently slows all degradation. Therefore, an alkaline reserve is sufficient to treat papers threatened by papermaker's alum, and common-ion buffers offer no advantage. HSC continues to study degradation catalyzed by copper and iron ions, where the same conclusion may not hold. In papers containing copper and iron ions, the pH should not become too low or acid-catalyzed hydrolysis of the cellulose will result. Nor should it become too high, due to the twin threats of increased oxidative degradation and discoloration of the pigment or ink. Here, the use of a common-ion buffer in treatment may indeed prove useful in obtaining the optimum pH.

Milestone 2: Expand the Capabilities of Conservation Science

There are good reasons why core-discipline physical-science laboratories might investigate a few select conservation problems. For example, an investigator with great understanding of her specialization might disentangle the science at the heart of a vexing conservation problem. Heritage science might also seize the interest of student workers who have not yet settled on the course of their future studies. However, for both analysis and research, the conservation field needs dedicated laboratories. Such laboratories provide a critical context: Conservation science provides an expertise and a suite of tools that help answer conservators' questions. Unless it is performing analyses by rote, a conservation science laboratory will seek to expand that expertise and those tools, enabling more conservators' questions to be answered with greater certainty and greater safety of persons and artifacts. To fulfill this goal, HSC developed one technology during its pilot period that promises to be very helpful in the study of materials aging: a new aging vessel.

Among the requests the HSC laboratory has received from conservators, the primary one has been for added transparency. In order to consider information useful, procedures deployable, or products trustworthy, conservators need to hear the challenges that were overcome in their development. While discussions on the efficacy of accelerated aging are present in the literature (Porck 2000), the problems of finding a suitable accelerated-aging vessel are not. In the wake of the ASTM study on accelerated aging (Shahani et al. 2001), there appears to be a preference in the field for aging samples in sealed vessels rather than in humid ovens for a better approximation of long-term natural aging. The chemical composition of papers following sealed-vessel aging mimics that of papers in the library, museum, and archive more closely. The difficulty lies in knowing and maintaining the conditions inside the vessel throughout aging. The HSC laboratory has found that many vessels fail during exposure to accelerated-aging conditions. One vessel identified by part number in the ASTM standard (ASTM 2007) emerged from the chamber with fractures in the top of the screw cap and moisture loss from the interior. Other vessels that had lost moisture did not exhibit visual evidence of failure, and it is suspected that previous accelerated-aging studies may have been inadvertently compromised for that reason.

The HSC laboratory has looked for solutions to two other criticisms of sealed-vessel aging. The criticism leveled by scientists and technologists is that the relative humidity inside the vessel during aging at higher temperatures is not that to which the paper was equilibrated when the vessel was sealed. (This is the primary reason for aging in humid ovens.) The criticism from conservators is that the vessel's gaskets, which are lined with a fluoropolymer such as Teflon, may off-gas and affect sample aging. Even if the user is satisfied that fluoropolymer-lined gaskets are chemically inert, there may be practical reasons for avoiding them. Specifically, the HSC laboratory has observed that fluoropolymer-lined gaskets can shrink at the temperatures specified for accelerated paper aging, exposing the headspace—and, therefore, the sample—to the other side of the gasket and the screw cap itself.

A new accelerated-aging vessel designed at HSC is capable of withstanding the temperatures specified in the accelerated aging standards (ASTM 2007), and the corresponding pressures inside the vessel, without failure. It eliminates exposure to polymers through a reusable glass-on-glass seal that requires no grease. It also controls the relative humidity through the use of a saturated salt charge in each vessel that is capable of buffering the air to a known relative humidity. At this time, the HSC laboratory is actively seeking a partner with analytical-glassware-manufacturing capabilities to carry this technology forward.

Milestone 3: Produce Information, Processes, and Products of Demonstrated Use at the Bench

In order to achieve the full potential of collaboration between conservators and scientists, a laboratory must develop information, products, and processes of demonstrated use to conservators at the bench. HSC seeks to develop discrete technologies that can be produced and deployed in conservation studios that may not have adjoining technical analysis laboratories. The accomplishment of this goal is rare among conservation science laboratories today, and is possible for HSC only through the physical proximity of conservators and scientists in day-to-day work. This collaboration allows scientists to develop a vital understanding of the context of conservation, and to identify technologies—whether they are developed in the laboratory itself or are already used in the physical sciences—that may be of possible use in conservation treatment.

The technology presented here is a calibration kit consisting of a series of paper targets of historically relevant manufacture with known concentrations of specific compounds deposited on them. Conservators can use these targets to calibrate x-ray fluorescence, near-infrared, or UV-Vis spectrometers for the nondestructive analysis of atoms or compounds in heritage papers in their own laboratories. The technology that underlies the manufacture of these targets originated with the need to deposit specific compound concentrations for paper-degradation research studies. Among the technologies the HSC laboratory developed for this purpose was the use of capillary action to deposit compounds onto paper, as in paper chromatography. This technique produces great uniformity in concentration of the compound perpendicular to the direction of solvent migration (i.e., horizontally, or in the x dimension), but not vertically. Therefore, this technology consists of fabricating the paper target and taking several readings across a horizontal line, using a rigorous, destructive quantification method—such as inductively coupled plasma-optical emission spectroscopy—to calculate the uncertainty in composition. The end user is then shown the precise locations on the calibration target to read with her nondestructive technique: locations alternating with the site of previous destructive analysis. Once again, the authors welcome comments and suggestions, as well as inquiries about partnership in the development of this technology.

CONCLUSION

Heritage Science for Conservation at Johns Hopkins University was established as a model book-and-paper conservation-science laboratory. This model addresses the need for a stable locus for science and engineering dedicated to the ongoing needs of the book and paper conservator. In this model, scientists and engineers design research projects and develop agendas in collaboration with conservators and carry out the work in the same physical space. When complete, they disseminate the results to a broad but targeted audience of conservators, engineers, scientists, librarians, curators, industrialists, students, and the general community. HSC has been successful in achieving its programmatic milestones, which are (1) to conduct research into the fundamental causes of heritage materials degradation and the fundamental applicability of conservation technologies; (2) to expand the tools and techniques of conservation science; and (3) to produce information, products, and processes of demonstrated use at the conservator's bench. Perhaps the best evidence of this success is the technologies HSC has developed during its 2009–2012 pilot phase.

The Johns Hopkins HSC model has been very successful because of strong institutional traditions and resources, as well as a long-standing, ongoing commitment to innovation and cross-disciplinary collaboration. Nonetheless, the HSC model can serve as an exemplar to other academic institutions across the United States, although it will be more viable in certain institutions than in others. Requirements for success include (1) the ability to stage interdisciplinary collaboration, understood as meaningful cooperation between team members with diverse training and experience; (2) an attitude of openness and support for discovery; and (3) the opportunity for the team members to undertake a serious effort to communicate science and engineering through diverse media to diverse audiences.

Establishing regional HSC satellites would form the foundation for a national conservation research agenda and research strategy. Such a system of HSC satellites would yield enormous benefits by supporting the conservation science needed to preserve our cultural heritage collections. The establishment of these regional HSC centers would avoid costly duplication of laboratories and effort while ensuring a coordinated response to research needs.

ACKNOWLEDGMENTS

We thank The Andrew W. Mellon Foundation for funding this work. We also thank William Minter, conservator in private practice, for his contributions to our laboratory and the development of the technologies described in this article. We acknowledge the support of Miriam Centeno, Jonah Erlebacher, Crystal Maitland, Ann Koch, and Lani Hummel of Johns Hopkins University; and Jamaal Davenport of P. H. Glatfelter Company. Finally, we thank the AIC Book and Paper Group, including Jamye Jamison of the program committee and Renée Wolcott of the *Book and Paper Group Annual*.

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