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Science in the art conservation curriculum II: Views of conservators

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Abstract
In 1959, C.P. Snow, the scientist and novelist, first used the phrase "the two cultures" to describe the division between the sciences and humanities. In this field, however, conservators must work with professionals from both these two cultures to form the three-legged stool referred to by George Stout. Conservators' need to be well grounded in the science of conservation is undeniable; the question is how to deliver the highest quality science curriculum possible within a graduate training program. For this research, conservation graduates were invited, through a survey and interviews, to identify the concepts they found difficult to learn and that proved important in their career development. This paper reports on conservators' comments on training and suggests how to implement them in classroom practice.

INTRODUCTION

Conservation educators recognize that the scientific component of training programs can be intimidating, especially to students whose backgrounds are not scientific. This study identifies scientific concepts that are challenging to learn and effective strategies for teaching them.

Teaching science to conservation students is under-researched; only a few papers on effective approaches exist (Delcroix 1986, Tímár-Balázsy 1986, Burnstock 1997, Fuster-López and Andersen 2014, Wei 2014, Alcántara-García and Szelewski 2015, Murray et al. 2017, Alcántara-García and Ploeger 2018, Lambert et al. 2018, Ploeger 2018). Instructors from a wide range of science backgrounds are eager for such strategies. Conservation students in this multidisciplinary field must learn to apply judgment through handling and treating objects (Caple 2000) and to use conservation methodology (Appelbaum 2007). Science instructors without conservation training need insight into the challenges presented by the science curriculum to both students and teachers and consequently need to develop effective teaching strategies.

At the 18th ICOM-CC triennial conference in 2017, results were presented from a questionnaire completed by North American conservation science professors and from group discussions with participants at the ICOM-CC 2016 joint interim meeting, "Conservation Science and Education," held in Cambridge, Massachusetts (Murray et al. 2017). Participants identified important scientific concepts they found difficult to teach. At the Canadian Association for Conservation of Cultural Property (CAC) conference held in 2018, conservators completed a survey identifying scientific concepts they had found challenging to learn; subsequently, some conservators were interviewed on this topic. This paper presents the results from the CAC survey and a thematic analysis of the interviews.

METHODS OF STUDY

Conservators completed a survey at CAC's 2018 conference at which the first author of this paper gave a presentation on threshold concepts (see next paragraph) used in teaching science to conservators. Conservators were asked: "What was a particularly difficult scientific concept for you to learn that has also been especially useful to you as a conservator?" These questions were distributed in paper copy to the attendees. Eighty-two conservators replied, resulting in 142 concepts. Conservators were also asked to state their specialties and their years of experience. The largest specialties were objects, paper (including books and photographs), and paintings. Years of experience were classified into three ranges: 0 to 5 years (students and early-career conservators), 6 to 15 years (mid-career conservators), and over 15 years (late-career conservators).

Twelve conservators expressed interest in being interviewed, including one who was not present at the conference. The nine who responded from the perspective of learners rather than educators were included for this paper; they were trained in six different conservation programs and each had between 4 and 32 years of experience. The framework of "threshold concepts" is used extensively in the educational field and guided the interview questions. Threshold concepts (Meyer and Land 2003) are challenging, transformative, integrative, irreversible, and "bounded" (i.e., delineating conceptual areas). The terms were defined for the interviewees during the CAC presentation and in the follow-up email for scheduling the interview. A comprehensive list of concepts covered in the science curriculum at Queen's was also included in the email. A semi-structured interview protocol was followed. Interviews were 40 minutes to an hour long and were recorded using Audio Hijack. They were then transcribed and coded using the qualitative analysis software NVivo.

The interviews were studied qualitatively using thematic analysis where "Patterns are identified through a rigorous process of data familiarisation, data coding, and theme development and revision" (Braun and Clarke 2006). This paper examined the predominant and important topics or ideas, across all the nine interviews. Inductive thematic analysis was used, with latent themes determined from the data, through coding or identifying parts of the interviews, rather than from specific research questions or preconceptions. Themes were identified on a semantic or explicit level by taking the surface meaning of the data and then organizing results to show patterns, where the significance and implications are discussed considering the experiences and situation of the participants.

SURVEY RESULTS AND DISCUSSION

Figure 1 lists concepts that conservators identified as challenging to learn but crucial in practice, as well as the number of times each concept was recorded in answer to the open-ended question. Conservators most often listed *solvent and solubility chemistry* (24 times out of 82 responses), which appeared twice as many times as the next-mentioned concepts, *theory to application (general)* and *instrumental analysis* (including theory and analysis). Other concepts mentioned included *cleaning* and topics related to the properties and degradation of materials.

Figure 2 shows the survey results analysed by specialty (paintings, objects, and paper). The concepts reported were associated with the needs of specific conservation specializations. Paintings conservators' answers related to the most common treatments; for example, *solvent and solubility chemistry* and *cleaning chemistry* can apply to varnish removal and cleaning. Objects conservators, who often work on materials requiring more varied instrumentation and a broader understanding of material properties, listed

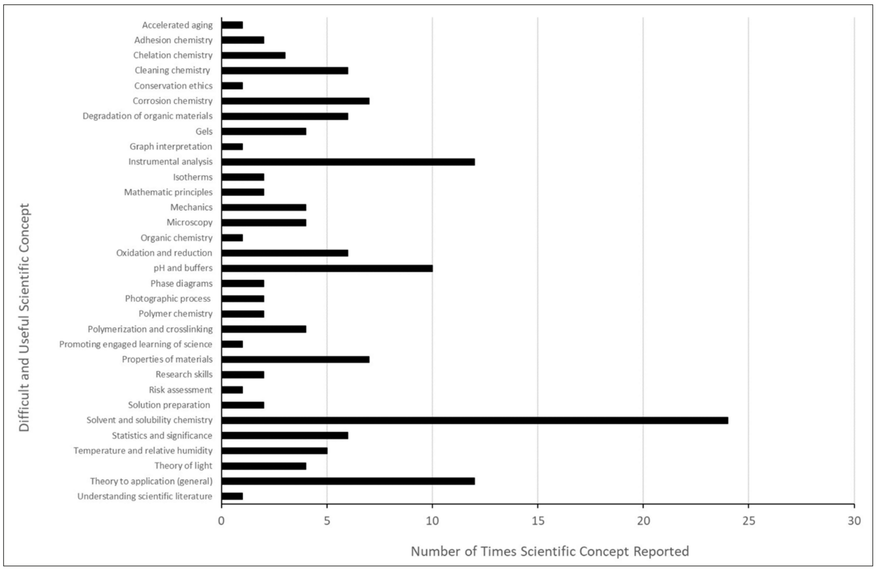

Figure 1. Difficult and useful scientific concepts for conservators

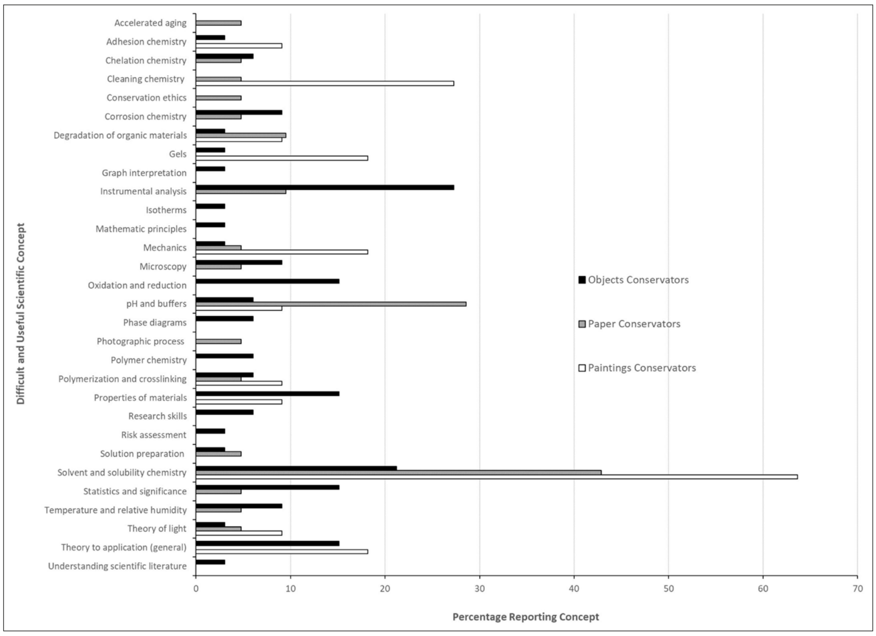

Figure 2. Difficult and useful scientific concepts for paintings, paper, and objects conservators

instrumental analysis and concepts linked to material properties. Paper conservators registered *solvent and solubility chemistry* as well as *pH and buffers*, all often required in paper treatments.

The results were reported by respondents' years of experience (Figure 3). Students and early-career conservators, for whom the study of materials was new, reported concepts related to materials and degradation. Going from *theory to application (general)*, a skill learned over time, was listed by both early- and mid-career conservators. Mid-career conservators most often recorded *solvent and solubility chemistry* and *cleaning chemistry*, which are important in complex treatments; *properties of materials* were still significant, challenging topics. Finally, *instrumental analysis* was listed twice as often by late-career conservators, perhaps because newer analytical techniques have become available since they trained and because they may be involved with more complex projects requiring instrumental analysis. Other topics listed by late-career conservators were *gels*, *pH*

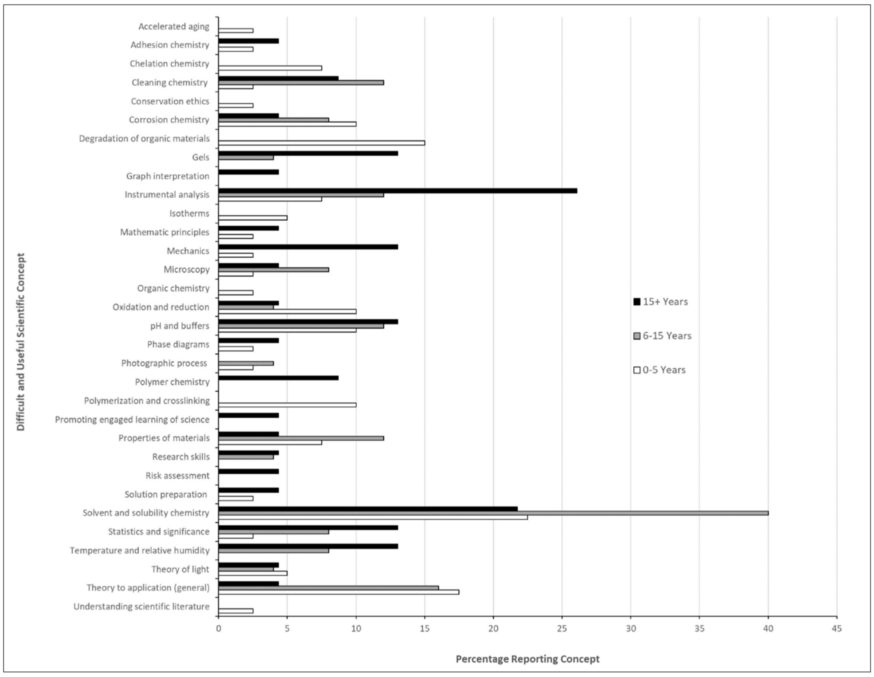

Figure 3. Difficult and useful scientific concepts for early-, mid-, and late-career conservators

and buffers, and *mechanics*, all components of more recent conservation approaches in the field.

INTERVIEW RESULTS

Themes emerging from the interviews were: consequences for non-scientists applying science to conservation practice; bridging the gap between theory and treatment; learning to work with scientists; and the overall philosophy and strategies that conservators reported promote learning.

Theme 1: Implications for non-scientists

Some conservators said their fear of science led to feeling intimidated and less confident. Others commented on barriers erected by unfamiliar scientific terminology and equipment. Some felt frustrated because applying science to a specific situation did not always work as expected.

Six conservators reported a lack of ease with science. One described solubility as "intimidating" [P6], and another said the same about the Canadian x-ray fluorescence (XRF) certification manual [P7]. A third conservator said her brain was "not wired for science," with regard to understanding concepts such as solutions or solvents. Also, science was "scary" and not fully incorporated into conservation [P3]. Another responder said she never felt "super confident in … [her] science abilities" and thought conservators in general were "a little science-phobic." She felt "unprepared" to understand graphs, charts, and scientific results, such as those from Fourier transform infrared (FTIR) spectroscopy analysis or to speak with scientists [P5]. One conservator thought that with more confidence in science she would have done more of it [P4]. It was suggested that the complex, detailed, and dense aspects of science made it hard to learn [P9].

Three conservators reported finding equations and graphs intimidating. One [P5] jokingly said that, when confronted with an equation, she "sees a white light and my ear starts ringing and my knees go weak," while the other [P1] responded with "Aahh! I don't know what this is." Another conservator struggled with graphs such as isoperms and asked herself "What is this actually telling me?" She believed some students found it difficult to extract knowledge from graphs, such as isoperms, to make decisions on specific environmental management issues [P4].

Conservators emphasized that visualizing concepts and materials was vital. One found science too abstract; she could only trust the theory of cleaning or molecular reactions when she saw the results. "I need to visualize things and there's a lot of things that you cannot visualize" [P3]. Another conservator suggested her materials class was more effective because it was easier to visualize materials than instruments [P9]. A third conservator said she needed "illustrations with thoughtful use of colour" [P1]. A fourth conservator stated:

> ... Once I accepted that I couldn't see a mole or a reversible reaction, but just had to [accept it] kicking and screaming … [I enjoyed] making that leap from general chemistry and the principles to the practical application, whether it was washing or solubility. I could manage much better with the specific topics because I could visualize adhesion, or I could visualize solubility and how it works. [P4]

The new terminology used in instrumental analysis and metallurgy was challenging to one conservator. Unfamiliar analytical techniques made it "difficult to understand the applications" [P7]. Because these techniques were "so specialised" and "borrowed from other fields" like geology, one conservator found that they were too removed from conservation [P6]. The theory of techniques was difficult to "reconcile" with the application, so she did not attempt to apply various analytical methods in a research project. Only when working at an institution did she see "the capabilities and how great it is when science and conservation are … accessible to each other."

Three conservators believed that following strict scientific rules might not yield the best results since actual treatments are more ambiguous. Examples included using the PEG calculator, cold storage [P2], maintaining environmental conditions over the course of an exhibition, and treating one enamel piece that did not behave like others [P8]. One conservator said she had to "jettison some of this theoretical baggage" and rely instead on her conservation methodology and experience [P8].

Theme 2: Theory to practice

Conservators wanted theory joined to practical applications, with a hands-on, sensory component. Subthemes included understanding solubility and other conservation concepts, applying instrumental techniques, learning about materials, and being equipped to make decisions about microscopy and preventive conservation.

Solubility and other concepts

Conservation treatments such as solubilization, cleaning, adhesion, and consolidation have theoretical and practical components. Conservators found that bridging the two is difficult, particularly for solubility; the survey results confirmed this. Three conservators found this concept to be important and challenging. One found it difficult to choose the right solvent, use it safely, and choose an ideal application. She felt that: "Solubility and solvents just got lost in a non-applicable way in the classroom" but being in the lab made it clearer. She suggested applying the theory of solubility "in a controlled laboratory setting where there are desired outcomes" [P6]. Another interviewee reported not finding the actual theory difficult, but rather the application: "… how to take this theoretical knowledge and … apply it to remove this adhesive or to figure out the right solvents" [P5]. Often cited was the sensory aspect of learning. One conservator said she lacked a tactile understanding of solubility while she was learning only the theory [P6]. Another felt she understood the science part of solubility "but it doesn't really click until you're working on it." She said, "Physically doing something" makes understanding "memorable … and … more enriching" [P9].

Conservators appreciated the alignment of science content across different courses so that concepts were reinforced over the program [P6]. One said, "I really need things to be organized sequentially or organized with what I'm doing at the time" [P9]. Two others emphasized that theory and application should be as close as possible in time for effective learning [P1 and P9]. One said theory should be put into practice "quickly and to not have a lag period in between … The same day … is great" [P9].

Analytical techniques

Three conservators commented on learning analytical techniques and applications. One found it important to visit the instruments and observe analysis of an object [P6]. Another valued access to instrumental techniques more than memorizing details without context. She believed access should include participating in the entire process (from running samples to seeing possible applications) and working with experts on interpretation [P7]. Another conservator had to see the equipment being used, "… otherwise it's this abstract concept that you … shelve … in the back of your mind … that you can look up later" [P9].

Two conservators understood an analytical technique only after completing the instrumental course. When one conservator was performing colour monitoring with microfade testing during a summer internship, she realized how she could interpret the results and understand future applications [P6]. Another conservator was working with a conservation scientist, analyzing pesticide residues, when she began to appreciate features of x-ray fluorescence spectroscopy, including its non-destructive aspect and health and safety concerns [P7].

Material properties

Conservators consider the integrity and degradation of an object, as well as the material properties of products used in a conservation treatment. Three conservators said that understanding the material properties was important both theoretically and practically. One described an effective approach to learning about plastics that included an overview of various types as well as their history and manufacturing; identifying the materials and their degradation with spot testing and analytical techniques; and practical workshops [P7]. Only after graduating did another conservator start to "question everything" and understand why specific materials were chosen for treatments. She found it critical to have links to the conservation of actual objects when studying the properties of materials (for example, animal skins) [P9]. Another conservator understood the implications of damage to an object once she had "… read about it, … heard people talk about it, … seen it in real objects and in a real situation, [and had] to actually apply the knowledge" [P1]. One conservator described transformative moments when finally comprehending material properties such as glass transition temperature and mechanics [P3].

Microscopy

Three conservators stated they needed to practise microscopy to develop judgment and understand features like contamination and birefringence [P9]. One, who had taken mid-career microscopy workshops, felt she would need more microscopy experience to be able to work independently [P5]. Another was glowing about her polarized light microscopy course:

> … One of my most memorable courses was our microscopy course… and I loved it, it was fun. I was playing with my microscope all day and drawing, which is something that I like to do. We … looked at sample slides for hours on end and drew the structures that we saw, we used Becke lines and polarized light … It was learning through hands-on experience and practical application. [P7]

Preventive conservation

Preventive conservation requires using scientific information to make decisions. One conservator found this meant envisioning the big picture (for example, looking beyond minor relative humidity fluctuations) or having to compromise. She valued "being armed with a good base of information." The concept of light was difficult for her because light is very complex and recommendations depend on numerous factors. Also, as ultraviolet light cannot be seen, it is hard to relate on a sensory level to make decisions [P1].

Theme 3: Working with scientists

Conservators said they appreciated visits to analytical labs and seeing samples from objects analyzed. Overall, four conservators mentioned the need to learn how to work with scientists, with their expertise in analytical equipment and interpretation. Two conservators enjoyed hearing the questions asked, learning about the potential of analysis, and following complex interpretations. The first of these conservators had mistakenly imagined as a student that she would be required to operate the scientific equipment [P6]. The second conservator had initially had "this idea that you point and shoot, and it tells you what you have. What I've learned over time is that there are experts who can interpret this" [P7]. Two other conservators said it was critical to know the right questions. One felt present training programs pressure students to be "quasi-scientists", although she believed that knowing the right questions should be enough [P8]. The second conservator wondered if, though her conservation program taught them how to interpret spectra, this gave students "just enough tools to get [them] into some trouble" [P2].

Challenges emerged when courses were taught by science educators from outside conservation. One conservator found her metallurgy course difficult because the professor misjudged the students' backgrounds [P7]. Another conservator reported that students did not know the questions to ask; the science teachers tried to adapt the course to conservation, but the subject matter was very general; many concepts were covered but not in depth [P5].

Theme 4: Student philosophies and strategies

Five of the nine conservators interviewed each spoke about one of the following subjects: the value of curiosity and imagination, developing judgment, being open to science, and learning from others. One stated:

> ... I think the key in teaching science in those one to two years is just to ignite curiosity and the students can take it from there … It can be really exciting, but it just takes time. [P4]

She also said "… This isn't about recipes … Any time … something is cross-disciplinary, it's really hard … If it were easy then we wouldn't be having this discussion." Another conservator advised that when looking at an object, she thought of:

> … all the things that could've affected it … If it was in someone's basement and got mouldy, what is this water line here for, why is this particular type of blooming happening, to really let your imagination engage with what you understand of the science …" [P2]

Two conservators found that focusing on the treatment helped them to make decisions.

> When I started, I always struggled with how much I needed to know to be able to interpret the literature or to make a reasonable judgment. But having that science and practical conservation application helped me to understand how it worked. [P4]

Conservation programs expose students to new areas of study, and the science can be especially overwhelming. "What was really transformational for me [was] when I realized that the equations were just a different language to … express the same idea" [P1]. Another comment was "I think that's what microscopy does too … It's just showing you that this is an option for you" [P9]. A third conservator realized that "so many things make up the science skillset of what we're doing." She felt she had strengths in certain aspects (evaluating the condition of an object) but not in others (making solutions) [P8].

One conservator highlighted learning from others. She would have liked to have had a scientist actually in the treatment lab, discussing various phenomena or specific damage on an object. A colleague's use of techniques had prompted her to use analytical methods in her own treatments. She would have liked time for more discussion among students about their individual research [P9]. Another conservator mentioned the value of looking to other disciplines (for example, forensics) and trusting their scientific findings [P4].

DISCUSSION: IMPLICATIONS FOR TEACHING

Concepts discussed by conservators in both the survey and interviews were similar to those mentioned by educators at the last ICOM-CC triennial meeting (Murray et al. 2017). This paper discusses the perspective of conservators, examining the relative importance of the concepts in the survey and the overarching themes from the interviews.

The results showed the challenges for non-scientists studying conservation: some conservators are apprehensive about the science curriculum and this feeling can persist throughout their career. Scientific terminology and tools used by scientists, such as equations and graphs, must be demystified and clearly explained, with examples. A valuable initiative would be to develop images to help students visualize concepts. Educators should attempt to clarify the complexity of science and its possible limitations when applied in conservation (Muñoz Viñas 2004).

Conservators stated that students needed to see strong links between theory and practice, for example when solubilizing materials. According to Caple (2000), judgment is learned through experience; those choosing careers in conservation say they learn best through tactile experiences. Practical education in the treatment laboratory must be integrated with the theory learned in the classroom. Workshops on solubility, cleaning, and adhesion, with theory and lab components, have proved effective at Queen's University; in the lab sessions, students are eager to apply concepts to their specialty (paper, paintings, or artifacts) immediately. Other ways have been found for aligning theory and treatment. Two programs use co-teaching: in labs at the Winterthur/University of Delaware Program in Art Conservation (Norris 2019) and in lectures at the Conservation-Restoration Programme, University of the Arts Bern (Di Pietro 2017). With the collaboration of treatment professors, hands-on demonstrations, visual aids, and examples from ongoing treatments should be incorporated into the science classes.

Visiting analytical labs with samples from cultural heritage objects and with hands-on opportunities proved effective in bringing theory and application together. Having an in-depth understanding of objects from many perspectives was critical (including history, manufacture, material properties, and degradation). Various methods to use case studies have been introduced successfully in science classes (Herreid 2013). Specifically in conservation, case studies and problem-based learning have been found valuable in teaching mechanics (Fuster-López and Andersen 2014). Learning to make decisions requires opportunities for practice; for example, microscopy requires time with the microscope. Preventive conservation is best learned from site visits, but case studies can also be helpful. Opportunities to work with scientists were said to be critical, especially for learning technical analysis. Students initially discouraged in the classroom need to know that eureka moments often happen when formal learning is over.

Most exciting was hearing about the philosophies and strategies that students find illuminating; these include exercising curiosity and imagination, being open to science, and learning from others. Students should be encouraged to develop these approaches and to recognize their value as intriguing areas appear and can be explored throughout one's career.

CONCLUSION

Conservators were canvassed to identify scientific concepts that are difficult to learn but crucial in practice. Thematic analysis was applied to interviews with conservators to establish overarching themes that educators should consider. Conservation is a very hands-on discipline in which students learn by experiencing direct links between materials and concepts. Guided by conservation treatment professors, students in the labs refer to their knowledge of material properties and techniques to decide upon actual treatments. This paper describes strategies by which conservation scientists can reinforce this experience. Interviews were also held with conservation science professors as they expressed great interest in sharing their own teaching experiences. These results and discussions of threshold concepts will be the basis of future research papers.

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