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Conservation Science Education Online (CSEO) – A heritage science resource

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Abstract: Conservation Science Education Online (CSEO) is a new online resource that shares strategies for teaching science in art conservation and related cultural heritage fields. An overview will be given of how undergraduate chemistry curricula in the United States have used examples from cultural heritage. The field of art conservation will then be described with an emphasis on the science curricula taught in art conservation programs around the world. Challenges include relating theoretical learning to real-world applications and teaching scientific terminology and concepts to students who may have limited science backgrounds; as well,

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there is a lack of textbooks and resources with appropriate case studies. The newly launched CSEO online resource offers freely available, effective teaching methods in the form of modules developed by international educators in the field. The inaugural CSEO Conference 2022 served as an introduction to the online resource for a global audience and was the first dedicated conference to bring together heritage science educators to discuss challenges and teaching strategies with the goal of building such a resource. The conference facilitated discussions among participants about teaching strategies, with the intention that these topics would become modules for the online resource, available to all science educators.

Keywords: conservation science; cultural heritage; heritage science; online teaching resource; teaching strategies; threshold concepts

1 Introduction

This paper introduces the online resource Conservation Science Education Online (CSEO) (https://www.queensu.ca/art/art-conservation/conservation-science-education-online-cseo) and the launching conference held in June 2022, both of which are committed to sharing ideas and teaching strategies among science educators across the globe in the field of cultural heritage. These educators teach in various fields including programs in conservation, archaeological sciences and technical art history (which fall under the umbrella of "heritage science" or the science of cultural heritage), as well as undergraduate chemistry departments and high schools. Background will first be given on the teaching of chemistry in undergraduate courses using art and cultural heritage in the US from the 1970s to the present, and the teaching of science in the field of art conservation.

People are fascinated by stories about cultural heritage. Such narratives are the perfect hook for educators, who can teach various aspects of science through the lens of technical investigation of cultural heritage. The detection of fakes and forgeries of paintings and sculptures may rely upon knowing which pigments were available to artists in specific periods, understanding their potential degradation mechanisms and choosing the appropriate analytical techniques for identification. Establishing the effect of relative humidity and temperature on material properties of panel paintings explains why controlling and monitoring the environment in museums is critical to ensuring the longevity of these objects. Studying the composition of modern plastic materials and how constituents may contribute to degradation gives insight into long-term preservation of modern art collections. These cross-disciplinary examples, drawn from cultural heritage, could be of interest to the budding engineer or chemist, but also to the non-scientist.

2 The science of cultural heritage in the curriculum of US undergraduate science courses

The use of art and cultural heritage in teaching US undergraduate chemistry dates to at least as early as Sister Mary Virginia Orna's pioneering work in the late 1970s (and onwards) (Orna, 1978) and two 1980 and 1981 journal issues dedicated to chemistry in art (Sarquis, 1980; Sarquis, 1981). The development of these courses continued as an organized US national pedagogical movement originating in workshops funded by the National Science Foundation (NSF) in various forms between 1996 and 2017, initiated by Michael Henchman and Patricia Hill (Henchman, 1994; Hill & Hark, 2003; Henchman, 2008). The early history of these developments and the evolution of the workshops have been previously outlined (Hill & Simon, 2012; Hill et al., 2012). Later, advanced NSF undergraduate teaching workshops furthered US chemistry in art and archaeology pedagogical developments (Hill et al., 2011). Pioneering mentorship programs, like the Indianapolis Museum of Art's Project MUSE: MUseum Sabbatical Experiences for Faculty Teaching at the Arts-Science Interface, offer undergraduate chemistry faculty sabbatical and summer research opportunities in conservation science labs (Smith, 2019). Articles based on pedagogical research in art conservation graduate programs have been published in the *Journal of Chemical*

Education on topics including chromatography (Alcántara-García & Szelewski, 2016), polymers (Alcántara-García & Ploeger, 2018) and differential scanning calorimetry (Ploeger, 2018). This journal has published many articles on the chemistry of art (Del Federico et al., 2013; Duncan et al., 2010; Greenberg, 1988; Mabrouk, 2022; Marine, 2013; Nivens et al., 2010; Ogren & Bunge, 1971; Schrenk et al., 1993; Vyhnal et al., 2020; Wells & Haaf, 2013).

It was recognized at least as early as the mid-1990s that US students would benefit significantly from intentional incorporation of international practices and developments into the undergraduate pedagogy (Uffelman, 2007a; Uffelman, 2007b). Uffelman's work explicitly and deeply embedded study abroad and art conservation into these considerations, and expanded the range of topics in undergraduate "science in art" courses (Uffelman, 2011). Subsequent incorporation of portable instrumentation into the study-abroad programs fused scientific research and cultural heritage (Uffelman et al., 2014). These innovations became part of the introductory NSF workshops from 2006 until they ended in 2017. There have been many notable contributions to the interface of study abroad, research and pedagogy (Bradley & Mackie, 2021; Fieberg, 2010, 2021; Marine, 2013; Smieja et al., 2010) and these have influenced the NSF chemistry-in-art community of scholars in general.

The NSF-funded workshops generated numerous American Chemical Society (ACS) National and Regional Meeting symposia as well as similar sessions in meetings of the Biennial Conference on Chemical Education (BCCE), many yielding publications. Because this topic is not the focus of this paper, the reader is referred to two of the more substantial publications (and the references therein) that were engendered by the NSF workshop efforts and spinoffs: the ACS Symposium Series books published in 2012 (Lang & Armitage, 2012) and 2021 (Braun & Labby, 2021).

Given that over 20 years of US NSF funding generated a group in excess of 400 faculty dedicated to teaching chemistry and art and archaeology, the authors suggest that this paper and the accompanying resource will have interest well beyond the conservation community, and hope, in turn, that some of the work pioneered by undergraduate chemistry faculty will see use by the conservation pedagogy community. In particular, US undergraduate science faculty will benefit greatly from the significant expansion of international viewpoints and teaching resources made possible by the initiatives described in this paper.

3 Scientific topics taught in conservation programs

When students embark on a career in conservation, they may not be aware that caring for heritage requires significant knowledge of materials science. All materials come from something that was mined, synthesized or grown, and many materials are inherently unstable. A conservator's job is to study the impact of these natural processes on the objects being looked after and to assess and predict the effects of the materials being introduced during treatments. This is only possible if the chemical and physical processes at work are understood. For conservation students, and particularly those whose training is in the humanities, the scientific components that are part of conservation training can be daunting. In fact, many of those who consider applying for art conservation as a possible higher education option abandon the idea, fearing the science requirements. A student's inherent hesitancy can be overcome by introducing the scientific concepts in an applied fashion. Typically, conservation students tend to understand the world in a visual way. Providing the practical applications of scientific concepts develops the neural networks to link the theory to existing knowledge.

The following statement from the International Council of Museums – Committee for Conservation (ICOM-CC), the largest international organisation of conservator-restorers and conservation scientists, describes the activities of the conservator in this way (1984):

> The activity of the conservator-restorer (conservation) consists of technical examination, preservation, and conservation-restoration of cultural property: Examination is the preliminary procedure taken to determine the documentary significance of an artefact; original structure and materials; the extent of its deterioration, alteration, and loss; and the documentation of these findings. Preservation is action taken to retard or prevent deterioration of or damage to cultural properties by control of their environment and/or treatment of their structure in order to maintain them as nearly as possible in an unchanging state. Restoration is action taken to make a deteriorated or damaged artefact understandable, with minimal sacrifice of aesthetic and historic integrity.

To succeed in this endeavour, conservators must link hand skills and artistic abilities with ethical reflection and decision-making based on an understanding and appreciation of history, as well as being capable practitioners of science. The term “three-legged stool,” first applied by Harvard conservator George Stout to the field of art conservation to describe the collaboration among scientists, conservators, and art historians (Chase & Hill Stoner, 1975), is often used to refer to the diverse and over-arching qualities conservators need for success (Whitmore et al., 2005). Indeed, many conservation programs internationally are based on curricula involving science, conservation and art history. More and more conservators want to include local communities and the public in conservation decision-making, whereupon the stool becomes four-legged: conservators, scientists, art historians (or archaeologists), and the users.

Science is a central part of curricula internationally, even if the distribution and focus of pure and applied science courses vary widely. One of the pioneers of science education in conservation, Agnes Timár-Balázsy, wrote in 1986 that programs should “educate [students] to be able to form their questions to the chemists, to work together with scientists, [and] to follow the chemical backgrounds of conservation methods written in special literature … ” (Timár-Balázsy, 1986). Table 1 shows scientific topics that students need to learn, from both theoretical and hands-on points of view (Murray et al., 2017). During most formal conservation training for an MA degree, students study applied and theoretical science related to the analysis of materials, the solubility of adhesives and varnishes, and the degradation of materials. These topics also play an essential role in studio and field work, as does the application of science during final year dissertation projects. Within the European context, the European Network for Conservation-Restoration Education (ENCoRE) recognizes chemistry, physics, biology, earth sciences, processes of degradation, and environment (including climate, lighting, and security) as “essential to any conservation syllabus” (ENCoRE, 2001), without quantifying credits for curricula. This statement reflects the current education of conservators, even if this approach is also criticized by some (Muñoz Viñas, 2022). Muñoz Viñas puts forward the importance of the tacit skills, knowledge and intuition that conservators need when treating objects and feels this aspect has been overshadowed by conservation science.

As can be seen, many scientific areas relate to conservation practice and thus need to be taught and the list of such areas grows longer with advances in the field, for instance, digital imaging, scanning, and modelling. In addition, teaching scientific principles to conservators encompasses vast ranges of inorganic and organic materials, from ancient ores to modern polymers. Keeping up to date can be challenging to both educators and students. The time on these topics must also be balanced with the other critical components of art conservation programs such as decision making and hand skills development.

Table 1: Examples of scientific topics conservation students need to learn.

Scientific topics	Description
Concepts	Such as solubility, adhesion, and cohesion.
Materials	Including the structure, properties, and degradation of organic and inorganic materials that make up cultural heritage objects, as well as the materials used in conservation treatments. The proper use of terminology and the comprehension of the processes that describe the chemical, physical, biological and mechanical properties of materials are critical in education.
Analytical techniques	Including the scientific principles of the techniques and the capabilities, applications, and limitations of scientific instrumentation.
Environment	Such as relative humidity, temperature, light levels in buildings, museums, galleries, storage areas, and archives. Additionally, the role of pollutants and volatile organic compounds (VOCs) in the degradation of artwork and the migration of their effects is central to preservation.
Research skills	Enabling students to develop hypotheses they can test, comprehend the scientific literature, and improve critical thinking and problem solving. Students need to learn how to limit variables, determine sample size, suggest suitable analytical methods, including accelerated aging and long-term aging studies, document and process research outcomes, and understand the benefits and drawbacks of studies of model samples in comparison to historic materials.

4 Conservation programs and the science prerequisites

At this time, conservation is a discipline of higher education and includes the possible degree levels of bachelor's, master's, and PhD. Training in conservation internationally varies greatly. Much of Europe follows the Bologna model of a three-year undergraduate degree in conservation and a two-year specialization (https://encore-edu.org/), which is in line with the European Confederation of Conservator-Restorers Organisations (E.C.C.O.) recommendations, and establishes access to the profession with a master's or level 7 in the European Qualification Framework (https://www.ecco-eu.org/wp-content/uploads/2021/01/ECCO_Competences_EN.pdf).

Other countries also have undergraduate and master's programs; this is true for some countries in South America, such as Peru, Ecuador, and Argentina. Conservation programs in China (for example at Beijing University and Northwest University) are mostly four-year undergraduate degrees in conservation followed by a three-year master's degree in scientific research in conservation or in conservation practice. In contrast, conservation is mostly studied at the postgraduate master's level in the Netherlands, United Kingdom, India, South Africa, and North America. In these regions, most students who train as conservators already have undergraduate degrees in a wide range of fields including art history, studio art, archaeology, historical and heritage studies, curatorship, museum studies, tourism, sciences, or engineering.

The amount of chemistry required for entry into conservation programs around the world varies from no science, to pre-university level, to several university-level chemistry courses. Many of the students in the master's programs in China and India have a science background. In India, every student studies mathematics, physics, chemistry, and biology for up to 15 years of education, and therefore, while applicants to conservation courses may have pursued humanities at the undergraduate level, they are able to pick up the science they need with some guidance and revision of their school textbooks. While in the past basic science was taught as a module or part of diploma courses in the UK, another approach has recently been adopted at The Courtauld Institute of Art (Sperber and Burnstock, 2023); from 2022, students must pass an exam prior to enrollment demonstrating basic knowledge of general and organic chemistry (between European Qualifications Framework [EQF] level 4 and 5). A similar approach is used in Amsterdam, where students can enter the program only with an EQF level 4. Some US programs are altering their prerequisite requirements in order to increase diversity and access.

The Conservation Science Training and Research Program (CoSTAR), a collaboration between Lakshmi Mittal and Family South Asia Institute, Harvard University and CSMVS Museum Mumbai was developed over a pilot three-year period straddling the COVID-19 pandemic. The program engaged with over 150 professionals and created "student teams" comprising scientists, conservators, art historians, fine artists, curators, architects and others in order to achieve learning through peer engagement. One of the first exercises in this, suggested by Dr. Narayan Khandekar, Director of the Straus Center for Conservation and Technical Studies, Harvard University, was to "form the questions," not just in chemistry, but also in the humanities, thus breaking siloed thinking and providing practice for both students and educators.

5 The background and role of conservation science educators

Educators teaching conservation treatment and conservation science support conservation students as they learn the scientific aspects of the field. Conservation science educators come from a variety of academic backgrounds and have narrowed their area of research, for example to chemistry, material science, polymer science, analytical chemistry, conservation or archaeological science, in order to be qualified to teach in a conservation program. Often these educators have not been trained as conservators nor have they necessarily had direct experience working with art; they may never have conserved a painting or an archaeological object. The relevance of exchange and collaboration with scientists without a conservation background was evident in a series of conservation training programs conducted as part of the 2018–2023 phase of the Tata Trusts Art Conservation Initiative implemented in India. Along with experienced trainers, new experts were identified to increase the resource bank of conservation educators in India. Most of these expert scientists from premier material science institutions had never applied their learning to museum environments or art conservation applications, and as broad-minded educators they were fascinated by the new vista.

As teachers in conservation programs, scientists not only need to share their expertise in certain scientific areas but are required to understand, teach, and answer questions related to the practical application of science to conservation treatments. Moreover, there are very few dedicated textbooks or educational materials available to assist them. Another challenge for conservation science educators is that new students have a wide range of scientific backgrounds, and learning curves can be very varied and rather steep for some. The CSEO online resource was created to address these challenges in the field by building a community and facilitating learning from others.

6 Research into the challenges of teaching science to conservators

Foundational work for the CSEO online resource was accomplished using threshold concepts (Murray & Biggs, 2021; Murray & Biggs, 2023; Murray et al., 2017), a framework first proposed by Meyer and Land (2003) and applied successfully in many fields such as medicine, science, humanities and engineering. A number of articles have been written on threshold concepts in chemistry (Claus et al., 2023; Kaiser, 2018; Meltafina, 2019; Park & Light, 2009; Talanquer, 2015; Timofte, 2015; Ulfa, 2020; Wiji et.al., 2021; Wiji & Mulyani, 2018). Threshold concepts are defined as being challenging, transformative, integrative, irreversible, and “bounded” (i.e., delineating conceptual areas). Investigating threshold concepts can lead to an improved curriculum, helping to identify why certain topics are challenging, what teaching strategies work well and what new tools should be developed to tackle teaching challenges. Applying the framework of threshold concepts therefore helped to identify useful content for the CSEO resource.

Murray and her colleagues set up a research initiative to interview conservation science and conservation treatment educators, as well as conservators at various stages of their careers. In addition, conservators were surveyed at the annual conference of the Canadian Association for Conservation (CAC) in 2018. The interview and survey questions used the framework of threshold concepts. The interviews were analysed qualitatively using thematic analysis. Murray and Biggs (2023) give an overview of these research methods.

Figure 1 shows what scientific concepts the surveyed conservators found to be particularly difficult to learn but were also especially useful in their work as conservators. The threshold concepts as determined by the

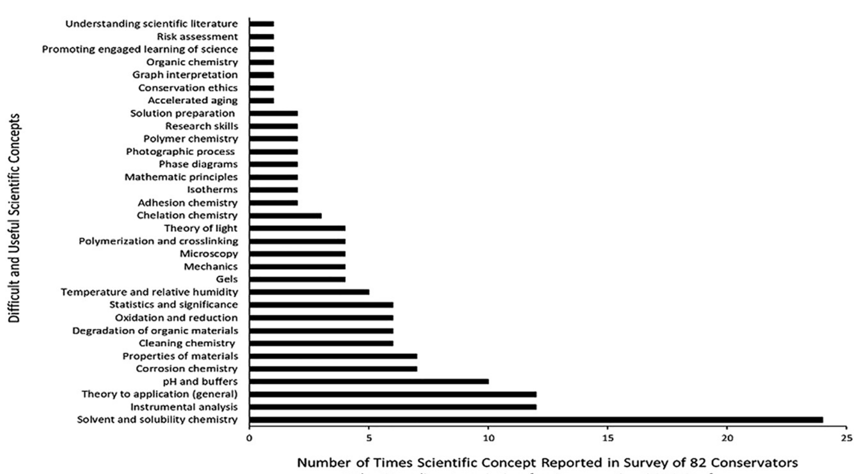

Figure 1: Difficult and useful scientific concepts for conservators based on a survey of 82 conservators at the Canadian Association for Conservation (CAC) 2018 Conference. These results were first published in a different format in Murray, A. & Biggs, K. (2021). Science in the Art Conservation Curriculum II: Views of Conservators. In *Transcending Boundaries: Integrated Approaches to Conservation. ICOM-CC 19th Triennial Conference Preprints, Beijing, China*. ed. J. Bridgland. Paris: International Council of Museums.

interviews and survey were found to be concentrated in four general areas: instrumental analysis, properties of materials, aspects of general chemistry, and solvents and solubility. The discussion and thematic analysis provided information regarding the specific challenges in teaching science to conservators. The first overarching theme was the "implications for students with limited science backgrounds "; this showed that the variety of prior scientific knowledge of conservation students in education programs could be a barrier to their learning. Many remain ill at ease with science throughout their careers. Some conservators had difficulties in interpreting equations and graphs, as well as in visualizing abstract chemical and physical concepts.

The second main theme arising from the interviews was the challenge of "bridging the gap between theory and treatment." Solubility was given as the number one most difficult but important topic in the CAC conference survey, reflecting what is well recognized in chemistry as one of the most difficult topics to teach and learn (Pinarbasi and Canpolat, 2003). One conservator understood the science part of solubility, "but it doesn't really click until you're working on it. Physically doing something makes understanding memorable and more enriching." This point is supported by Caple, who found that those choosing careers in conservation say they learn best through tactile experiences (Caple, 2012).

The third theme from the interviews was "learning to work with scientists," which was noted to be critical for conservators' understanding of analytical techniques and their limitations. This included learning to formulate questions that scientists can help answer and working with experts on interpretation. Also, the language of science had to be introduced to many conservation students, as, of course, the language of the arts has to be introduced to the science educators.

The fourth and final theme, "the realities of applying science in conservation," recognized the importance of understanding that simplified traditional scientific teaching models are not always easy to relate to the complexities of working on actual art objects.

7 Introduction to the resource "Conservation Science Education Online (CSEO)"

Some universal issues raised above illustrate the need for a mechanism to support educators: a resource that provides information to aid in teaching challenging scientific concepts that can be difficult for students to comprehend or for educators to communicate. The CSEO platform aims to offer such support. It consists of modules designed by educators who have already used them successfully. A module might be an application, a case study, a collection of infographics, or a problem-based learning method that shows how a certain concept or theory relates to the real-life scenarios a conservator may encounter. Another module could illustrate how a collaborative strategy can make a class or assignment more engaging. The resource is being designed collegially by educators with different experiences and backgrounds. CSEO will open new teaching avenues for educators, instead of each needing to devote time to reinventing teaching plans. Finding efficient and effective ways of teaching could also permit more time for students to be in the treatment lab, developing decision making and hand skills. This resource is accessible not only by conservation science and conservation treatment professors, but also by teachers in mainstream chemistry, physics, biology and engineering in high school, college or university. The main goals of CSEO are to offer education support and promote collaboration, outreach, and discussion with educators across the globe.

Modules within the online resource are broken down into sections that depend on the specific content of the module as shown in Table 2. The modules in this resource address specific topics and recognize different levels of education in conservation students from around the world. The modules highlight different resources and variables to promote adaptability. Modules will be updated according to their continuing evolution, based on the growing relevant literature, and discussion and feedback in the comments section. The resource is meant not only to recognize effective learning but also difficulties, challenges and even valuable failures and how to learn from them. Individual modules will include citation recommendations, ensuring that creators are recognized for their contributions. Modules are reviewed by an international editorial board before publication on the resource.

Table 2: Content of modules in the Conservation Science Education Online Resource.

Section	Content description
1. Title page	Title, purpose (for example, whether it is a plan of a lesson, teaching method, laboratory, course, or project), authors, affiliations, intended audience and abstract.
2. Introduction	Concept to be discussed with brief introduction and outline of the topic. This can be broken down into a hypothesis that will provide the key issue and reason for the unit, the main threshold concept(s) or task being presented and a list of the major goals and student learning outcomes.
3. References	Key resources that support the module; these may include academic papers, theses, images, videos, lab notes, exercises, infographics, data, websites, or case studies.
4. Images	Explanatory images, videos, or infographics that can be used to explain key concepts more clearly.
5. Plan of lesson, teaching method, laboratory, course, or project	Details of the plan are needed: procedure, process, case study, instrumentation, or outcome that addresses the hypothesis, concept, or key issue in cultural heritage science.
6. Methods for student engagement	Discussions, assessments (formative and summative), and challenges. This includes questions to promote student engagements and sub-topics that have been found to be challenging. Potentially also teaching strategies or class questions used for beginning students and ones for more advanced students.
7. Comments	This is an area open for comments and suggestions from others in the CSEO community as well as assessment of outcomes from implementing the module.

This platform and the related conference discussed in the next section are the first efforts in a very much needed re-direction of heritage science pedagogy, which has changed a great deal since the first conservation programs were established in the 1950s, 70 years ago. ICOM-CC continues to have a working group on Education and Training in Conservation as well as interim meetings on this topic. More art conservation conferences are starting to include themes of education in general.

8 Inaugural CSEO Conference 2022

In June 2022, a three-day online conference was held to promote the resource (https://www.queensu.ca/art/conservation-science-education-online-inaugural-conference). Before the conference, eight invited lecturers and 18 posters presenters from around the globe pre-recorded talks that were made available to attendees. The conference itself was devoted to moderated discussions among the speakers, facilitators, and conference attendees.

Many relevant topics were presented (Table 3), including teaching science using Indigenous philosophies and applications and employing social media to engage students in science learning. A portion of the conference was reserved for a breakout session where speakers and attendees could discuss their teaching challenges and share their own successful strategies. The goal of the conference was not only to draw attention to the CSEO platform, but also to help educators improve science curricula for conservation students around the world by creating a space to foster open discussion and share experiences and ideas, as well as incorporating some of the topics presented at the conference into future modules.

The 300 people registered to attend the conference spanned numerous professions and areas of interest, with 58 countries represented among speakers and attendees (Figure 2). The average attendance for each day of the conference was approximately 50 to 100 people. Most participants came from the conservation field, either as part of training programs (conservation science and treatment educators) or from cultural heritage institutions, but attendees also included collections managers and heritage site custodians. Others were chemistry teachers at universities and high schools with no official affiliation to cultural heritage other than a keen interest in using the topic in their teaching. Finally, some current students and recent graduates from conservation and science

Table 3: Session topics, speakers, and moderators of the Inaugural Conservation Science Education Online Conference, June 14–16, 2022.

Session 1 (invited talks): Learning Scientific Language through Examples with Meaning
Moderator: Laura Fuster López, Universitat Politècnica de València (Spain)

Teaching Fundamental Concepts to Understand and Predict the Microclimate in Packages, Showcases, Microclimate Vitrines and Backing Board Protected Paintings
Giovanna Di Pietro
Bern University of the Arts (Switzerland)
How to Overcome Conservation Students' Resistance to/Fear of Science by the Way the Syllabus is Taught from the Start
Maggi Loubser
University of Pretoria (South Africa)
Use of Indigenous Elements in Teaching Mathematics and Science
Arzu Sardarli & Jana Sasakamoose
First Nations University of Canada (Canada)
Considerations Regarding the Teaching of Reflectance Imaging Spectroscopy
Erich Uffelman
Washington and Lee University (USA)

Session 2 (posters): Finding Relatable Examples – Threshold Concepts, Teaching Methods, Research and Teaching to Non-Conservators
Moderator: Edgar Casanova-González, Universidad Nacional Autónoma de México (Mexico)

Complex Systems & Constructive Failures: Experimental Workshops with Dyes and Electrochemical Cleaning
Megan Creamer & Emy Kim
Queen's University (Canada)
Mastering the Microscope: Approaches in Polarizing Light Microscopy Instruction
Kirsten Moffitt
Colonial Williamsburg Foundation (USA)
It's a Material World: Bringing Material Science and Mechanical Engineering to a Laboratory Exercise
George Wheeler
Highbridge Materials Consulting (USA)
Instagram to Promote Motivation and Learning Environments in Higher Education: A Preliminary Study
Pilar Bosch-Roig, Lucía Bosch-Roig, Melani Lleonart-García, & José A. Madrid-García
Universitat Politècnica de València (Spain)
On-Site Assessment of the Status of Historical Libraries as Part of the Conservation Training Process
Yerko Quitral
National School of Applied Arts (Chile)
From Tomatoes to Chocolates: Teaching Conservation Students How to Take a Representative Sample
Sagita Mirjam Sunara
University of Split (Croatia)
Bringing Materials into Focus: Teaching Initiatives at the University of Chicago and the Art Institute of Chicago
Maria Kokkori, Francesca Casadio & Ken Sutherland
The Art Institute of Chicago (USA)
The Expansion of Conservation Science Student Research Projects
Catherine Matsen, Jocelyn Alcántara García & Rosie Grayburn
Winterthur/University of Delaware (USA)
Is the Message in the Media? Object-Based Learning and Brazilian Constructive Art
Corina Rogge
The Museum of Fine Arts Houston (USA)

Session 3 (invited talks): Theory to Practice – Engagement through Training
Moderator: Gregory Dale Smith, Indianapolis Museum of Art at Newfields (USA)

A Collaborative Project-Based Approach for Teaching Instrumental Analysis in a Cultural Heritage Context
Patricia Gonzales & Betty Galarreta
Pontificia Universidad Católica del Perú (Peru)
Teaching Solubility to Conservators: From Salt Solutions to Dissolving Varnish
Austin Nevin
Courtauld Institute of Art (United Kingdom)
Parallel Training Programs – A Network Approach
Anupam Sah
Formerly CSMVS Museum Art Conservation Centre (India)

Table 3: (continued)

The Identification of the Binding Agent Used in Turquoise-Inlayed Bronze Objects in Ancient China Shuya Wei University of Science and Technology (China)
Session 4 (posters): Shifts in Teaching and self-Reflection - social-media, Pandemic, E-learning and Teaching strategies ***Moderator: Maartje Stols-Witlox, University of Amsterdam, (The Netherlands)***
Flipped Learning: Strategies towards Improving Learning Outcomes in Applied Sciences in Conservation and Restoration of the Bachelor Degree at the Cologne Institute for Conservation Sciences Ester S. B. Ferreira Cologne University of Applied Sciences (Germany) *Organic Chemistry for Chemistry-Shy Emerging Conservators* Elizabeth Peacock & Gordon Turner-Walker Norwegian University of Science and Technology (NTNU) (Norway) *Coloring Science at UNAM, Mexico* Nora Ariadna Pérez-Castellanos & Yareli Jáidar-Benavides Universidad Nacional Autónoma de México (UNAM) (Mexico) *The Pigment Reference Set: A Resource for Technical Art History and Scientific Analysis* Abbie Vandivere (1) & Annelies van Loon (2) (1) University of Amsterdam (The Netherlands), (2) Rijksmuseum Amsterdam (The Netherlands) *Introductory Aspects to Discuss Transdisciplinarity in the Training of Conservators-Restorers* Daniele Baltz da Fonseca & André Alexandre Gasperi Universidade Federal de Pelotas (Brazil) *Integrating Expertise for Teaching Collaborations in Conservation Science* Susana França de Sá & Márcia Vilarigues NOVA University Lisbon (Portugal) *The CAPuS E-Learning Platform for the Conservation of Art in Public Spaces* Dominique Scalarone University of Torino (Italy) *Conservation Science Education Online in Difficult Moments* Johanna Maria Theile Bruhns Universidad de Chile (Chile)

programs were also included. By the end of the conference, the video recordings of the talks had been viewed a total of 3000 times. The conference concluded with remarks on the themes brought up during the conference and a call for new contributors and for international representatives to join the CSEO team and organize future conferences.

Figure 2: Global distribution of speakers and attendees of the Inaugural Conservation Science Education Online Conference, June 14-16, 2022.

9 Themes from the inaugural CSEO Conference 2022

Most educators agreed that some areas of knowledge are challenging to convey to students in a tangible way, as confirmed by the results from the interviews and survey discussed earlier. Many reported struggling to find how to engage students in learning theoretically challenging concepts. Most talks centred on applied and practical teaching strategies that involved students with hands-on lessons, making use of demonstrations, didactics and various media. Speakers concluded that such efforts led students to be more knowledgeable, confident, resilient and less fearful of science.

Building student confidence was often cited as a main goal of the educators. Because, as mentioned earlier, many students come from the humanities and have limited science education, educators at the conference brought up the importance of developing student assurance as a gateway to successful scientific education. These challenges are also found in teaching science in non-heritage fields. It is hoped that those in such fields will find the CSEO resource equally helpful.

Several larger themes became apparent from the discussions:

9.1 The need for scientific literacy and skills

Many remarked that scientific language can be difficult to understand and may alienate those entering the field, contributing to the lack of confidence observed by educators. Math and physics were cited as difficult, as were terminology and equations. The scientific method relies upon documentation, but conference speakers from many parts of the world mentioned that students were hesitant to record findings and instrumental parameters during their labs. Here it could be mentioned that some Indigenous students whose parents and grandparents suffered in Canadian residential schools think that science and mathematics curricula still contain attributes of colonialism. This concern is based on the many years of the negative experience of Indigenous people and needs to be studied not only as an academic or educational problem (Truth and Reconciliation Commission, 2015), which Sardarli also reports. It has to be noted that Canadian academic society is aware of this problem and educators, along with governmental institutions, are willing to improve the existing curricula of various levels based on holism principles.

The speakers suggested skills for students to be taught, including how to formulate a hypothesis and test it using experiments; becoming comfortable using scientific terminology when communicating with scientists; and the importance of reading scientific papers, even if students only partly understand the research. Scientific literacy could be encouraged by providing relevant examples and explaining concepts in layman's terms, using glossaries built by the community. The importance of developing common terminologies acceptable to communities was also emphasized. Simulations and animations were put forward as ways to make the science more accessible. Another presenter described having students carry out a survey and then apply the appropriate statistical method. Speakers also underlined the importance of managing expectations by, for example, explaining that scientists and engineers have spent years mastering the underlying theory which cannot necessarily be completely transferred to people coming from other fields. This reflects the need for collaboration between specialisms in conservation practice. The science content in a conservation course transfers the scientific terminology and concepts that enable conservators to understand the materials and treatments with which they work; a comprehensive understanding of the scientific topic may not be necessary. It is a privilege for educators to work with these students who welcome this introduction to science.

9.2 Benefits of using case studies and stories

Many speakers found that teaching with case studies or stories helped students (for example in conservation, art history, science or education) to connect theory to practice. Examples included giving the context or "discovery story" for unknown pigments in order to solidify ideas learnt in microscopy; developing an object-based course through collaboration between a museum and university; or using actual data sets from X-ray fluorescence spectroscopy of a painting to explain the technique. One presenter suggested starting a class with a conservation problem or application and only then giving the background scientific theory, grounding the scientific concept in its application to art or cultural objects.

9.3 Theory to practice and hand skills

The importance of hand skills in the scientific training of conservators was identified as a key theme. In order to learn, conservation students need hands-on experience. Observing materials through all their senses can help overcome any fear of science that students have. They also need to apply the theory learnt in class to their work on actual objects, and draw on their understanding of concepts such as solubility when removing varnish or applying adhesives. The possibility of being hands-on was missing from many programs during the COVID-19 pandemic. Though participating educators developed innovative strategies to deal with this challenge, the need to incorporate more hands-on experience within the science curriculum was emphasized.

9.4 The importance of open communication and collaboration

Presenters stressed that it was critical for students to communicate with each other, learn from each other through group work, and use peer-to-peer instruction and presentations. Teachers should be open about what they know and do not know. The desire for worldwide communication and collaboration between educators was a prevailing theme. Though coming from different cultural backgrounds, presenters had dynamic discussions. In spite of some common ground, there were also many differences in approaches. Presenters and participants were eager to explore these and to incorporate them into their own teaching. It was pointed out that Indigenous students consider artifacts not just as objects of study, but as part of their belief systems, which raises additional questions related to ethics and cultural sensitivity in the training of conservators or the presentation of conservation education to more general student audiences. Based on this, it is important to convey in teaching the skills to develop trust, respect, and open communication when collaborating with other communities. Similarly, it is important to convey that not all collaborations can be approached the same way or might not be possible: each community is sovereign in its own decisions. For example Sardali and his colleagues discussed this in conversations with Elders (Sardarli et al., 2022).

9.5 The impact of the COVID-19 pandemic on education

The ramifications of COVID-19 were central to many of the presentations and resulting discussions. Numerous speakers addressed the difficulties of teaching during the pandemic, specifically having to adopt a virtual education model where application-based learning in the laboratory was often near-impossible. From these difficulties, however, came innovative teaching strategies that not only conveyed the necessary information, but resulted in new ways of engaging students. Examples were the creation of interactive group-based literature studies as an alternative for carrying out a scientific study and another was incorporating social media in the lesson plan. CoSTAR decentralized its practical training by partnering with institutions across the Indian subcontinent through hybrid engagement. Other programs did the same in various regions. Educators were also challenged to find innovative ways to demonstrate practical science skills online, for instance by using handheld X-ray fluorescence (XRF) spectroscopy and recording this for students, giving them access to the software and the raw data, and then recapping the findings together. Students were said to become more self-directed and confident when working on their own. Losses from not being in the lab were replaced by in-depth classes that also had the advantage of online guest experts. However, a downside to the online and at-home instruction was a widely reported reduction in preparation among new students. Already shaky foundations in science and math were exacerbated by the pandemic and will require extra attention and repair in future.

10 Conclusions

Three hundred registrations were garnered for the inaugural CSEO conference, involving people with geographical and cultural distribution across 58 nations, and with over 3000 views of the conference talks. This illustrates that, first, the core group of heritage science educators is committed to finding answers to specific questions, and second, an interested group of stakeholders are looking forward to tangible education support, discussion, and collaboration with educators around the globe. Aspects such as the rising use of technology, the increasing scientific component in conservation practice, ethical concerns, and geographical and cultural trends are constantly evolving and education and training programs have to be always adapting. Opening a channel for educators through this resource will facilitate such organic processes. The CSEO exercise has precipitated a thoughtful revisit to the pedagogical systems at a time when the need for cooperative revitalization is becoming especially clear. If this is any indication, then the CSEO conference has successfully implemented an effective Training Needs Assessment that confirms the value of the new CSEO global forum of heritage science educators. This is not just a place to exchange strategies for successful teaching of various scientific concepts, but also to serve as a resource bank offering modules for reference by educators everywhere. If effectively implemented and sustained, this forum could serve as an exemplar for other science teaching communities who wish to initiate similar pedagogical initiatives.

Educators identified overarching themes such as the need for scientific literacy and skills, use of case studies, emphasis on hands-on transmission of knowledge linked to scientific theory, and breaking silos to achieve strength in collaboration. There is apparent consensus on a universal set of educational challenges that conservation science educators worldwide aim to overcome, allowing for diverse cultural perspectives.

While highlighting the importance of science to cultural heritage education, training, and practice, the CSEO initiative also places onus on the conservation science community to communicate effectively with non-science cultural heritage professionals. Science curricula for conservation science education are now being re-imagined and the opportunities presented by the CSEO initiative augur well for a groundbreaking future. The fact that the resources envisioned would be works in progress, democratic and adaptable, only adds to the appeal and relevance of the CSEO online resource, to which the authors of this article invite all interested parties to contribute.

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Abbreviations

ACS	American Chemical Society
BCCE	Biennial Conference on Chemical Education
CAC	Canadian Association for Conservation of Cultural Property
CSEO	Conservation Science Education Online
CoSTAR	Conservation Science Training and Research Program
E.C.C.O	European Confederation of Conservator-Restorers Organisations
ENCoRE	European Network for Conservation-Restoration Education
EQF	European Qualifications Framework
ICOM-CC	International Council of Museums – Committee for Conservation
NSF	National Science Foundation
VOCs	volatile organic compounds
XRF	X-ray fluorescence

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