ICOM-CC
18th Triennial Conference
2017 Copenhagen

EDUCATION AND TRAINING IN CONSERVATION

Science in the art conservation curriculum: Determining threshold concepts and strategies for teaching and learning

ALISON MURRAY*
Queen's University
Kingston ON, Canada
alison.murray@queensu.ca

AMANDINA ANASTASSIADES
Queen's University
Kingston ON, Canada
amandina.anastassiades@queensu.ca

ROSALEEN HILL
Queen's University
Kingston ON, Canada
hillr@queensu.ca

*Author for correspondence

KEYWORDS: threshold concepts, troublesome, transformative, education, science curriculum, course development, teaching strategies

ABSTRACT

What scientific areas do art conservation students find difficult to learn and apply? How can we prioritize key topics and make sure they are taught well? Other disciplines have used "threshold concepts" to identify topics that should be the focus of course development and renewal. According to Meyer and Land (2003), threshold concepts are troublesome, transformative, irreversible, integrative, and possibly bounded (delineating conceptual areas). The conservation community recognizes the general body of knowledge and scientific core competencies needed by art conservators, but identifying what content students find challenging and what teaching strategies will help still requires in-depth research. As a first step, authors surveyed science educators in North American conservation programs and held discussions with conservation professionals at a conference on conservation science and education. The results have guided art conservation professors at Queen's University in developing workshops that integrate science theory and lab practice to overcome curriculum challenges.

INTRODUCTION

Chemistry and materials science are integral to the applied field of art conservation. Some conservation students who come from the humanities, including art history, archaeology, anthropology, and studio art programs, find certain science topics theoretically demanding and challenging to integrate into their practice. The aim of this work is to determine which topics in the conservation science curriculum are difficult to learn but are also crucial in the development of conservation professionals. To facilitate the research, we are using the idea of threshold concepts, first brought into prominence by Meyer and Land (2003), and since then applied in many disciplines to assist with curriculum redesign.

Threshold concepts have been identified as being (Townsend, Brunetti, and Hofer 2011):

- troublesome – often counter-intuitive, the place where students get stuck;
- transformative – cause the learner to experience a shift in perspective;
- integrative – bring together separate concepts (often identified as learning objectives or competencies) into a unified whole;
- irreversible – once grasped, cannot be un-grasped; and
- bounded – may help to define the boundaries of a particular discipline and are perhaps unique to the discipline.

Threshold concepts are seen as more than competencies or learning outcomes. They can open new ways of understanding, thinking, and practising, often integrating several concepts. Over the duration of a program, a student may move from being a novice to an expert and can therefore engage with the discipline's community of professionals. Identifying threshold concepts can help prioritize curriculum topics while stimulating improved teaching strategies and curriculum renewal (Baradelli and Peseta 1999, Irvine and Carmichael 2009, Walker 2013).

This paper presents the first results of research to identify specific threshold concepts or topics within the science curriculum in art conservation programs. This enables a focus on developing strategies for teaching and learning these threshold concepts effectively, thereby enhancing the science curriculum for conservators and improving student achievement of science-related learning outcomes.

Science in the art conservation curriculum

"The fundamental role of the conservation professional is to preserve and to restore, as appropriate, cultural property for present and future generations" (CAC and CAPC 2000). At Queen's University, which offers Canada's only master's degree program in art conservation, students learn to conserve paintings, objects, works of art on paper, photographs, and new media. Science is fundamental to such treatments and therefore is critical in the education of conservators. The science pre-requisites for this master's level program include three term-length courses in chemistry. As students come in with undergraduate degrees in the humanities and only sometimes chemistry, their proficiency and comfort level in science varies widely. Applied conservation science is taught throughout the two years of the program.

The conservation literature identifies the science information that conservators need to learn. Course specifics have been outlined for scientific topics including analytical chemistry (Ford 1987), scientific research (Sandner and Schramm 1984), and physics (Jarjis 1997). Professional organizations have detailed the general competencies needed to satisfy the scientific aspect of conservation training and the levels required by practitioners, partly in response to discussions on accreditation (AIC 2003, ENCoRE 2001, ENCoRE 2011). Programs, such as the Queen's Art Conservation Program, publish degree level expectations that include learning outcomes, indicators of achievement, academic requirements, and transferable skills (Queen's University 2015).

A few papers offer detailed discussion of specific methods of teaching conservation students chemistry (Timár-Balázsy 1984), mechanical properties of materials (Fuster-López and Andersen 2014, Wei 2014), and the scientific analysis applied to easel paintings (Burnstock 1997). According to Timár-Balázsy (1984, 84.21.20), the goals for teaching science to conservation students are to "educate them to be able to form their questions to the chemists, to work together with scientists, to follow the chemical backgrounds of conservation methods written in special literature". She gives specific examples of the links she makes between science lectures and conservation treatment labs, and underlines that the sequence and grouping of topics are critical when linking the science theory to conservation practice.

So far, however, the literature has made no mention of threshold concepts, which could enable conservation programs to prioritize important scientific concepts and address the appropriate learning scenarios. Integrating the scientific and conservation treatment curricula is critical (Delcroix 1986); however, courses in programs often operate as silos, where instructors can find it difficult to collaborate due to busy schedules and ever-expanding curricula. At the meeting of the Association of North American Graduate Programs in Conservation (ANAGPIC) in 2002, conservation science educators gave overviews of their science curricula, presented the conservation science material covered, described their facilities and support, and discussed potential collaborative ventures. One of the three possible topics listed for future meetings was "how to improve the integration of conservation science classes with other coursework".

To address the need for integration in the Art Conservation Program at Queen's, a series of introductory workshops is being developed in which the theoretical science and the treatment curricula can be brought together. These workshops include lectures, discussions, and demonstrations and are in addition to the treatment lab time. The topics covered in these workshops were identified through this research on threshold concepts in the art conservation science curriculum.

METHODS OF STUDY

To identify threshold concepts for art conservation, information was gathered in two ways: conservation science professors in North American art conservation programs were asked to respond to a written survey; and participants in a session of the 2016 interim meeting of the International Council of Museums-Committee for Conservation (ICOM-CC) entitled "Conservation Science and Education" engaged in a reported discussion.

A total of 18 surveys were sent to 14 conservation science professors in North America and to 4 conservation scientists who recently taught in a North American art conservation program but now work in museums; 12 surveys were completed. The conservation programs are part of ANAGPIC and included the Art Conservation Program, Queen's University; the Art Conservation Department, Buffalo State College; the Conservation Center, Institute of Fine Arts, New York University; Winterthur/University of Delaware Program in Art Conservation; and the UCLA/Getty Program in the Conservation of Archaeological and Ethnographic Materials. An invitation to participate in an online survey was sent by email to all the above conservation science professors, with a follow-up phone call to non-respondents. The survey was not anonymous because awareness of the unique context of each institution was necessary to interpret the data. The question in the survey reported on here was: "What three scientific concepts or topics have you found difficult to teach in the conservation science curriculum?"

Participants in the discussion were attending a session at the joint interim meeting "Conservation Science and Education" hosted in April 13–14, 2016 by Harvard Art Museums and the ICOM-CC working groups Scientific Research, and Education, and Training in Conservation (21 people in total). Participants included conservation science professors and conservation scientists in museums as well as professional conservators; all were primarily from North American institutions, but some European institutions were also represented. The topic of threshold concepts was introduced in a lecture by the first author and the discussion session was held later the same day. All participants in the discussion session agreed to have their comments recorded on flip charts and their names and institutions included in the data. Participants, divided into four groups, were given an outline of the components of threshold concepts and asked to complete the following tasks:

- List the concepts and topics you find difficult to teach and choose the top five.
- Discuss why you have concluded that the five concepts or topics are difficult to teach.
- List the topics that you believe are transformative; that is, they changed your students' approach to conservation.

RESULTS AND DISCUSSION

Concepts difficult to teach

The survey asked professors to identify up to three topics they found difficult to teach. Topics listed more than once included analytical techniques (six mentions), mechanical properties (three mentions), solubility (three mentions), and phase diagrams (three mentions).

Topics identified as being difficult to teach by participants in the discussion group are shown in Table 1. The responses from the two groups had some overlap, but differences may in part exist because the discussion comments were generated in groups rather than individually. Additionally, the discussion group had been introduced to threshold concepts in the first author's conference paper earlier that afternoon, so their responses may have included aspects of threshold concepts, including the transformative aspect. Table 2 shows results identified by both the survey and the discussion groups. In both tables, topics were arranged according to teaching categories used at Queen's.

Table 1. Concepts identified as difficult to teach by four groups in the discussion session

Teaching categories	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Big picture		Learning to look, interpreting	Abstract to concrete (math/graphing to practice/example)	
		Explaining science to non-scientists		
Concepts	Solubility and selecting appropriate solvent		Solubility	Thermodynamics (solubility, viscosity)
	pH and equilibrium (logarithms)			
Instrumental analysis		Integrating results of analysis	Instrumentation, details, advances	Translating detection limits
Materials: structure, properties, and degradation	Forces and bonding		Rates of degradation	Invisible degradation process
				Link between polymerization and degradation products
				Material properties related to history of technology
Research	Scientific report writing	Constraining a research project (variables)	Evaluating scientific literature	Bad data or unanticipated findings
	Statistical significance	Statistical analysis		

Table 2. Difficult concepts to teach: combined results from survey and discussion initiatives

Big picture	– learning to look, interpreting – abstract to concrete – critical thinking – lack of math and physics – explaining science to non-scientists
Concepts	– solubility – viscosity – logarithms – equilibrium – pH – buffers – volatility – phase change – capillary action – osmotic effects – rheology and gels
Instrumental analysis	– integrating results of analysis and managing expectations – instrumentation details and advances – different detection limits for various instrumental limits – issues with specific techniques
Materials: structure, properties, and degradation	– mechanical properties, forces, and bonding between materials – phase diagrams – chemistry and properties of organic, inorganic, and polymer materials (ex. paint and finishes, natural organic mixtures) – material properties related to history of technology – redox chemistry – polymerization – polymers surface science and secondary forces – link between polymerization and degradation products – invisible degradation process – rates of degradation – kinetics, isotherms, isoperms – photophysical and photochemical properties of materials – accelerated aging
Environment	– pollutants in the museum environment – transportation issues (e.g. vibration damage)
Research	– statistics and significance – scientific report writing – choosing variables and constraining a research project – bad data or unanticipated findings (are teachable moments) – evaluating and navigating scientific literature

Why topics are difficult to teach

Participants in the discussion session were asked to suggest reasons why certain topics, including pH, solubility, and mechanical forces, were difficult to teach. Reasons given included:

- The concept of pH is not intuitive and it is difficult to find analogies.
- Solubility can be difficult to visualize as well as being theoretical and mathematical. Teas charts are taught with the caveat that they don't always work or that there is a lack of confidence in using them; students need to have case studies for when Teas charts are relevant and not.
- Mechanical forces and bonding are not intuitive. For example, in mechanical testing, samples are pulled apart and stretched, but the results are linked to the build-up of forces. The bulk material reacts in one way but there are also reactions on a molecular level. The information retrieved from testing can be complex to interpret when there are multiple components.

One solution to these learning challenges would be to assess gaps in the curriculum and develop educational materials, such as case studies, to fill them.

Scientific analysis and statistics were discussed as general topics that were difficult to teach. Reasons given were:

- Students can find it difficult to integrate results so as to understand the implications of analysis. The many details of instrumentation, combined with technical advances in the field, can represent an overwhelming amount of information. Familiarity with the fundamental limitations of the various methods, procedures, and the object (for example, the detection limits of various instruments) is essential. The students' sometimes unrealistic expectations of scientific analysis (perhaps based on popular TV programs like CSI) need to be managed.
- Not only may statistics be a new language for students, but working on statistics is time consuming; it can be difficult to determine if the results are significant and to select the calculation options. Also, when working on cultural objects, there may be too few samples to be statistically valid.

Such concepts need to be taught in conservation programs to give a basic understanding, but with the appreciation that collaboration with scientists is always necessary in practice. Participants reported that that unanticipated findings or bad data in scientific analysis can actually create teachable moments.

Undertaking scientific research (for example, limiting variables and report writing) presents challenges as do the requirements related to being an applied field, where much information needs to be brought together. Scientists and engineers come to understand such concepts over time by following degree programs. Participants commented on the scarcity of time for explaining science to non-scientists and conveying the importance of learning, looking, and interpreting. Reasons for why these topics are difficult are listed below:

- Students, with their enthusiasm and inexperience, find it difficult to constrain the variables in a research project.
- Report writing requires a specific structure, as well as a new and concise language.
- Going from the abstract to the concrete (for example, math/graphing to practice/example) is challenging and takes time, but is key in this applied field.
- The rates of degradation involve mathematics and can be abstract, with the end results sometimes being invisible. Polymerization is linked with degradation products, yet they are usually thought of as opposites.
- Relating material properties to the history of technology requires integrating disparate teaching entities (overcoming silo-structures).

Investigating other applied fields might provide some examples of appropriate teaching strategies.

Why topics are transformative

In the survey, professors were asked only about difficulties in teaching, whereas the discussion format allowed time to examine the transformative aspects of topics, one component of threshold concepts. The following are results that emerged from the discussion session.

- Students who have a eureka moment (e.g., about pH, solubility, or mechanical forces) experience a change in the way they think about and understand the concepts.
- Students with a better understanding of the requirements and realities of instrumental techniques can calibrate their expectations for analysis. Students need to know the limits of the method or object, how to integrate the results of analysis, and how to work with unanticipated results.
- Students who can relate the material properties of an object to the history of technology have a better appreciation for the condition of the object.
- Various aspects of research can have a transformative effect. For example, students who understand the need to constrain variables can carry this understanding into other projects. Understanding statistics can enable students to know whether their results are significant. Students who can write scientific reports have acquired a methodology that helps them to organize and digest their material quickly.

Workshops at Queen's University

At Queen's, faculty have developed three half-day introductory workshops that integrate science theory with applied conservation treatment practice, in order to give students more context. The survey and discussion results on difficult topics enabled professors to identify parts of the curriculum that workshops would benefit. The subjects of cleaning, solubility, and adhesion covered many of the topics listed in both the survey and the discussion results. Those attending the workshops were first-year students in their first term, who had already been streamed into their treatment option (paintings, objects, paper conservation, photographic materials and new media).

All professors subsequently confirmed that the workshops had been very useful in showing how other professors taught the same concepts, especially in the language and terms used. Attending these collaborative workshops gave all students a common language and understanding of core areas, with effective demonstrations. Overall, devoting three half-days to these workshops, with all professors in attendance, was deemed to be worthwhile in a busy curriculum. The ideal timing for introducing these workshops within the students' first term and the appropriate content and level of material presented are issues still being explored.

CONCLUSION AND FUTURE WORK

This research stimulated lively discussions about the science curriculum in art conservation, indicating a real possibility for advances in the educational methods as a result of awareness of threshold concepts. Responses to the challenges might include developing educational materials, recommending increased collaboration with scientists or statisticians in future projects, explaining to students that some aspects of the curriculum take time to learn, and investigating other applied fields for possible teaching strategies. Future work will include in-depth discussions with conservation science educators and students to focus on why some concepts are difficult to teach and learn, and to gather more specifics about successful teaching methods.

Future discussions should determine which topics comply with all five qualities of threshold concepts set out by Meyer and Land; that is, whether the challenging and transformative concepts are also integrative, irreversible, and bounded. At this time, however, the authors agree that assessing the difficulty and the transformative nature of concepts has been critical in deciding the focus of new teaching strategies, such as the recent workshops at Queen's.

As a result of this work, it is hoped that better teaching methods for integrating the teaching of science and conservation practice can be researched and developed to the benefit of both students and teachers in this field. It is also hoped that this research will encourage collaborations amongst professionals committed to improving conservation education.

ACKNOWLEDGEMENTS

The authors would like to thank the Centre for Teaching and Learning (CTL), Queen's University, for the Educational Research Grant for this research. Discussions with Dr. Corinne Laverty and Dr. Klodiana Kolomitro from the CTL have been key in the development of the project. The authors would also like to thank Heidi Sobol and Michael O'Malley for their delivery of the paintings component of the workshops on cleaning, solubility, and adhesion, Christine O'Keefe for her 2015 talk on threshold concepts in gross anatomy at the Showcase of Teaching & Learning 2015, Queen's University, and colleagues at the Preventive Conservation meetings held with ANAGPIC and the Getty Conservation Institute.

REFERENCES

AMERICAN INSTITUTE FOR CONSERVATION (AIC). 2003. Defining the conservator: Essential competencies. http://www.conservation-us.org/docs/default-source/governance/defining-the-conservator-essential-competencies.pdf?sfvrsn=1 (accessed November 16 2016).

BARRADELL S. and T. PESETA. 2014. Promise and challenge of identifying threshold concepts: A cautionary account of using transactional curriculum inquiry. *Journal of Further and Higher Education* 40(2): 262–75 (http://dx.doi.org/10.1080/0309877X.2014.971105).

BURNSTOCK, A. 1997. Scientific examination and the restoration of easel paintings at the Courtauld Institute of Art: Selected case studies. In *The interface between science and conservation,* British Museum Occasional Papers series, no. 116, ed. S. Bradley, 47–54. London: British Museum.

CANADIAN ASSOCIATION FOR CONSERVATION OF CULTURAL PROPERTY (CAC) and CANADIAN ASSOCIATION OF PROFESSIONAL CONSERVATORS (CAPC). 2000. *Code of ethics and guidance for practice of the CAC and of the CAPC*, 3rd ed. Ottawa: CAC and CAPC.

DELCROIX, G. 1986. Teaching science in conservation. Why? What? How? In *ICOM-CC Interim Meeting on the Role of Science in Conservation Training, Working Group on Training in Conservation and Restoration, British Museum, London, 6–10 October 1986*, ed. F. Smith, 31–8. London: ICOM.

ENCoRE. 2001. Clarification of conservation/restoration education at university level or recognised equivalent, ENCoRE 3rd General Assembly, Munich, 19–22 June 2001. http://www.encore-edu.org/ENCoRE-documents/cp.pdf (accessed 17 November 2016).

EUROPEAN NETWORK FOR CONSERVATION-RESTORATION EDUCATION (ENCoRE). 2011. Competences for access to the conservation-restoration profession, 2nd ed. http://www.ecco-eu.org/fileadmin/assets/documents/publications/ECCO_Competences_EN.pdf (accessed 16 November 2016).

FORD, B. Analytical chemistry for conservation students. In *ICOM-CC 8th Triennial Meeting Preprints, Sidney, 6–11 September 1987*, ed. K. Grimstad, vol. 2, 1027–32. Paris: International Council of Museums.

FUSTER-LÓPEZ, L. and C.K. ANDERSEN. 2014. Understanding structural conservation through materials science: Strategies and didactics. In *CeROArt*, ed. W. Baatz. http://ceroart.revues.org/4380 (accessed 18 November 2016).

IRVINE, N. and P. CARMICHAEL. 2009. Threshold concepts. A point of focus for practitioner research. *Active Learning in Higher Education* 10(2): 103–19.

JARJIS, R. 1997. The significance of physics in conservation research and education. In *The interface between science and conservation*. British Museum Occasional Papers series, no. 116, ed. S. Bradley, 39–46. London: British Museum.

MEYER, J. and R. LAND. 2003. Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines. Occasional Report 4, ETL Project – Enhancing Teaching-Learning Environments in Undergraduate Courses, May 2003. Edinburgh: ETL Project, Universities of Edinburgh, Coventry and Durham.

QUEEN'S UNIVERSITY. 2015. Degree Level Expectations – MAC. http://www.queensu.ca/sgs/sites/webpublish.queensu.ca.sgswww/files/files/Program%20DLEs/Art%20Conservation%20June%202015.pdf (accessed 16 November 2016).

SANDNER, I. and H.-P. SCHRAMM. 1984. Research and development as an integral part of teaching. In *ICOM-CC 7th Triennial Meeting Preprints, Copenhagen, 10–14 September 1984*, ed. D. de Froment, 84.21.12–13. Paris: The International Council of Museums, in association with the J. Paul Getty Trust.

TIMÁR-BALÁZSY, A. 1984. The teaching of organic chemistry and chemistry of plastics at the Faculty of Object Restoration of the Hungarian Academy of Fine Arts. In *ICOM-CC 7th Triennial Meeting Preprints, Copenhagen, 10–14 September 1984*, ed. D. de Froment, 84.21.20–22. Paris: The International Council of Museums, in association with the J. Paul Getty Trust.

TOWNSEND, L., K. BRUNETTI, and A.R. HOFER. 2011. Threshold concepts and information literacy. *Libraries and the Academy* 11(3): 853–69.

WALKER, G. 2013. A cognitive approach to threshold concepts. *Higher Education* 65: 247–63.

WEI. W. 2014. Teaching the concepts of the mechanical properties of materials in conservation. In *CeROArt*, ed. W. Baatz. http://ceroart.revues.org/4215 (accessed 18 November 2016).

How to cite this article:
Murray, A., A. Anastassiades, and R. Hill. 2017. Science in the art conservation curriculum: Determining threshold concepts and strategies for teaching and learning. In *ICOM-CC 18th Triennial Conference Preprints, Copenhagen, 4–8 September 2017*, ed. J. Bridgland, art. 0307. Paris: International Council of Museums.