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# Teaching Chemistry for Cultural Heritage in the Philippines: A Graduate Course for Non-Science Students

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## ABSTRACT

The Philippine government advocates cultural-based education to strengthen national pride by having culture as the core and foundation of development. Chemistry can significantly contribute by educating the populace on the need to have science-oriented thinking in safeguarding the country's tangible heritage materials. This paper describes a graduate lecture course introducing chemistry principles in studying cultural heritage materials intended for students or professionals with limited science education. Students learned to appreciate and understand the work of a chemist in providing fundamental knowledge on local materials through scientific research and inquiry. Guidelines successfully implemented in the graduate course, such as the suggested topics, learning objectives, teaching techniques, and assessment tools, are reported. Part of the goal of this paper is to revitalize discussions among chemistry educators in the Philippines on this topic and to inspire the conceptualization of similar courses in different learning institutions.

***Keywords:*** *chemistry education; cultural heritage education; heritage conservation; graduate course; heritage materials; analytical techniques*

## INTRODUCTION

Chemistry has the fundamental role of providing a means to understand and acquire more information on tangible materials that are of interest in the cultural heritage field (Badea, 2019). Since several heritage materials are either undocumented or poorly documented in the Philippines, chemical information can address the issues related to provenance, material composition, and manufacturing technology and techniques. This information profoundly impacts the material's degradation through time, which is aggravated by its interaction with the changing environment. Thus, the results of the chemist's scientific analysis contribute to aiding conservators, restorers, and other cultural heritage professionals in crafting a wholistic conservation methodology for the heritage materials (Melo et al., 2018; Mazzeo et al., 2011).

Even though to a certain extent, chemical analyses are routinely performed on conservation work in the Philippines through basic solubility tests and simple instrumental analysis, the increasing complexity of heritage materials merits the adoption of rigorous scientific research in obtaining more accurate information (Maronilla-Reyes, 2015b; Montilla, 2015). The lack of awareness in the local heritage community on the benefits of systematic chemistry research, especially to cultural workers with non-science backgrounds, has led to a gap in the proper integration of chemical concepts with actual conservation practice (Bonnet et al., 2018). One of the avenues to address these issues is through formal education, specifically as described in this paper, a graduate course entitled "*Chemistry of Cultural Heritage Materials*" designed for non-science graduate students. This 3-unit cognate course was offered for the first time during the 2$^{nd}$ Semester of Academic Year 2018-2019 under the Cultural Heritage Studies (CHS) Program of The Graduate School at the University of Santo Tomas (UST), Manila (UST, 2014). A total of 9 graduate school students were enrolled with undergraduate backgrounds in fine arts (3), education (1), information technology (1), interior design (1), literature (1), tourism and travel services management (1), and philosophy (1). The students have no college-level chemistry experience and are limited to general high school chemistry knowledge.

The "*Chemistry of Cultural Heritage Materials*" emphasizes the chemist's work of generating scientific knowledge and innovations in material analysis. Students were introduced to the different tools or analytical techniques chemists utilize for diagnosis, appreciate the information it provides, and have a basic understanding of interpreting results. Importance is also given to local heritage materials and scientific journal publications authored by Filipinos. This course complements an analogous graduate lecture class offered by the UST CHS Program entitled "*Introduction to Conservation and Restoration: Theories and Practice*," which was taught by a trained chemist-conservator (Maronilla-Reyes, 2015a). Even though the general chemistry concepts are tackled to a certain degree, its focus is on the actual application to a conservation problem. The course "*Chemistry of Cultural Heritage Materials*" was not meant to provide practical tips on conserving and restoring. Instead, it centers on the fundamental research aspect of conservation science, which most non-science cultural heritage workers in the Philippines might not be familiar with.

***Cultural Heritage Education in the Philippines.*** The Philippines, through the National Cultural Heritage Act of 2009 or Republic Act (RA) No. 10066, recognizes the importance of establishing nationwide teaching programs to highlight the protection, conservation, and preservation of cultural heritage properties, as well as to develop instructional materials on its significance (Article X, RA No. 10066) (NCCA, 2020; 2017). As a result of this law, the Philippine Cultural Education Program (PCEP) of the National Commission for Culture and Arts (NCCA), together with the Department of Education (DepEd), were tasked to produce a standardized curriculum for Diploma (24 units) and master's degree (45 units) related to cultural and arts education, which is designed to be implemented in various higher education institutions (HEI) in the country. Noteworthy of these government mandates is the creation of Graduate Diplomas in Cultural Education and in Teaching Arts. These diploma programs aim to equip elementary and high school teachers in the core subject areas (i.e., Science, Mathematics, Social Studies, and English and Filipino Languages) with the fundamental skills and knowledge to integrate culture-based information into their teaching professions (NCCA, 2021). Different HEIs partnered with the NCCA, such as Bicol University (Bicol U, 2014; 2009) and Cebu Normal University (CNU, 2017), has also begun offering a graduate program leading to a Master of Arts in Cultural Education. Graduates of this master's program would have the skill sets and extensive knowledge necessary to address critical issues in cultural heritage and conduct local non-science research. Furthermore, a framework for a Bachelor of Culture and Arts Education, including the core competencies and a prescribed curriculum, has been prepared by the Commission on Higher Education (CHED) to guide any HEI wanting to offer the undergraduate program. The bachelor's curriculum is aligned towards an outcomes-based educational approach and incorporates the changes brought about by the K to 12 programs (CHED, 2017).

Since these programs follow an education curriculum, most of the courses are undoubtedly related to the essential learning competencies needed for a teaching profession and its application to local cultural heritage studies. For the advanced graduate studies and the diploma programs, as an example, courses such as cultural mapping, cultural documentation, and cultural governance were added to enhance the integration of education with heritage-related issues. It was also observed from the available course offerings that all are related to the social sciences and humanities, but none, even for a 3-unit cognate course, were recommended for the field of heritage conservation science (NCCA, 2021; Bicol U, 2014). Its inclusion would have been a promising avenue for the natural sciences, specifically the chemistry discipline, to be highlighted for its importance in heritage discussions.

Another approach to heritage education is more multidisciplinary in scope, which is pioneered in the country by the UST Graduate School's Cultural Heritage Studies (CHS) Program. Through the program, UST began offering a 42-unit Master of Arts in Cultural Heritage Studies that trains and develops future heritage professionals adept in doing scholarly research, promoting policies and advocacy works, and crafting conservation assessments and management plans, among others. The CHS program has the advantage of having tie-ups with in-house support units from the UST Museum of Arts and Sciences and the UST Center for Conservation of Cultural Property and Environment in the Tropics (UST-CCCPET). Courses are more holistic in terms of their application, such as museum context, cultural tourism, conservation works (i.e., movable or immovable), and archaeological heritage (UST, 2020). The 3-unit cognate course (CHS 108 Seminar) also gives flexibility on particular topics of interest wherein the course described in this paper was included.

This article provides a model for teaching a gradute course in chemistry for cultural heritage, which can also be modified and integrated into an existing undergraduate or high school program in the Philippines. It can be adapted into a training program or as part of a continuing education course for heritage professionals. The potential topics presented in this paper, even though catered for a non-science major, can be leveled up to include advance analytical chemistry concepts for chemistry majors.

***Learning Outcomes.*** Designing experiments, obtaining chemical data, and accurately interpreting them are skill sets possessed by chemists obtained through training and years of chemistry education (Overton and McGarvey, 2017). Apparently, chemical intuition cannot be acquired in one semester, and it is not expected that non-science students of this course would be able to develop efficiently. Hence, the best approach would be to impart an appreciation and enough awareness of scientific concepts to enable the students to decide intelligently and when to seek science experts on a given conservation problem (Brokerhof, 2015).

To specify measurable and observable learning outcomes upon completion of the "*Chemistry of Cultural Heritage Materials*" course, the student is expected to be able to do the following:

1. Explain the importance of basic chemical research in cultural heritage studies.
2. Implement the scientific method while thinking about the "molecular-level" in viewing any material analysis.
3. Evaluate an analytical technique applicable for the type of heritage material to be analyzed.
4. Create intellectual discussions with science professionals to encourage open communications and collaboration.

Additional outcomes can be formulated depending on the needs of the students and their educational degree. To illustrate, since a Master of Arts in Cultural Education is being offered in the Philippines already, a suggested learning outcome would be for the students to create a teaching methodology that incorporates a specific heritage material in teaching a fundamental concept in chemistry. For example, the education students can look at capiz shells in old house windows to teach about spectroscopy and clay bricks to understand the concept of thermodynamics. These are also consistent with the cultural-based education policy of CHED.

***Overview of the "Chemistry of Cultural Heritage Materials" Graduate Course.*** Table 1 shows the possible topics for a cultural heritage chemistry course patterned after the graduate course on "*Chemistry of Cultural Heritage Materials*". The course content is designed to achieve the learning outcomes identified for a graduate school curriculum but can be customized depending on the intended degree program. Units 1 and 2 are essential in providing a groundwork for the rationale of chemistry research on built heritage materials. It attempts to instill the idea of how a chemist thinks and how evidence is gathered to solve problems. Emphasis is given to the scientific method to generate practical solutions or understand the material composition and its effects (Idelson, 2011). Since material composition problems are not readily visible, practicing "molecular-level thinking" will help students consider conservation protocols carefully before making any decisions that will damage the heritage object. Student misconceptions about chemistry as a field will also be addressed in these units (Ambag, 2018).

Unit 3 looks broadly at the two general classes of compounds that one will encounter in any heritage material (i.e., the organic and inorganic components), which may not be intuitive to a non-science major. It is a common belief for most Filipinos that organic compounds are mostly limited to plant-based sources and that inorganic compounds are generally metals, which is not always true. These classifications will stress that materials are not identical and have different behaviors, especially when they age. The general composition of common heritage materials and their manufacturing process will follow the discussion on the classification. For example, in the "*Chemistry of Cultural Heritage Materials*" course, the following materials were examined: bricks, lime mortars, paper, pottery, paints or pigments, and metals.

Due to the limitations of a person's five senses in observing the molecular level, analytical chemistry equipment is invented to "see" (surface and morphology), "know the arrangement" (structural analysis) and "know the composition" (elemental analysis) of an object. These techniques are introduced in Unit 4. The topic will associate the suitable equipment (i.e., destructive and non-destructive) to the material and the type of problem to be analyzed. Even though the theory and data interpretation for each piece of equipment is too tedious for non-science students, it would suffice for them to know the information generated and when to apply it. The standard techniques discussed in the "*Chemistry of Cultural Heritage Materials*" course are spectroscopy instruments, X-ray techniques, microscopy, and thermal techniques. The instructors can also decide to modify the number of analytical methods to include in the course.

**Table 1. *"Chemistry of Cultural Heritage Materials"* course overview and suggested topics.**

| Unit | Suggested topics |
|---|---|
| 1. Chemistry fundamentals | Scientific method, concepts of matter, classification of matter, physical and chemical changes, molecular level thinking |
| 2. Chemistry and cultural heritage | Approach to heritage conservation and chemistry research (Philippines), qualitative and quantitative measurements |
| 3. Composition of heritage materials | Organic and inorganic components, common heritage materials, manufacturing methods (Philippines), general chemical composition |
| 4. Analytical techniques for material characterization | Destructive and non-destructive (non-invasive) techniques, general overview of techniques, basic interpretation |

***Instructional strategy.*** Various teaching methods were employed in the "*Chemistry of Cultural Heritage Materials*" course. These include interactive lectures, class discussions, and the Socratic method and questioning. Interactive lectures engage the students to participate in instructor led demonstrations to explain different chemical concepts (Vinko et al., 2020). As an example, demonstrating the molecular nature of matter can be facilitated by using colored dyes dissolved in water at different concentrations and observing the light that diffuses. Class discussions may also include paper critiques and journal discussions, which also engages the Socratic method and questioning approach. These methods develop the student's logical and critical thinking skills, and science intuition (Olsson et al., 2015).

To supplement the concepts learned in class, guest speakers who are trained in chemistry and cultural heritage research were invited to talk about their research. The invited experts include a painting conservation chemist from the National Historical Commission of the Philippines and an archaeological chemist from the Science and Society Program, College of Science, University of the Philippines, Diliman. Each gave a one-period class lecture on their chemistry backgrounds and research interests while highlighting the use of analytical techniques to understand the heritage material's behavior. The talk was followed by fun activities such as making paints and using them to make artwork for the paint chemistry session and food tasting on clay pots for the archaeological chemistry session.

Another suggested activity for the class is to organize a field trip in an actual conservation laboratory. This activity was planned for the graduate course but did not take place due to conflicts in schedules. Suggested places to visits are the Materials Research Division of the National Historical Commission of the Philippines, UST Museum and Archives, and Roberto M. Lopez Conservation Center in the Lopez Memorial Museum and Library, to name a few. A real-life chemistry instrumentation laboratory should also be part of the site visits to appreciate better the analytical techniques discussed in class. All the equipment mentioned in class is readily available in the Philippines, either in the Department of Science and Technology (DOST) or in major universities in Metro Manila. It is up to the instructor to explore these possibilities and coordinate with these institutions.

Focus on homegrown capacity and journal publications on local heritage materials run through the entire theme of the course. This approach will also reinforce the policies in the National Cultural Heritage Act of 2009. Most of the examples and case studies mentioned in class, as much as possible, were all local. The challenge of this course is the lack of available scientific journal articles on local heritage materials. Most are from bricks and lime mortars, as shown from the suggested readings in Table 2. Also indicated in the table are the different analytical techniques used in each study. Reading these journals will keep the students be updated on the latest local chemistry research on heritage objects and deepen their appreciation that these types of research are being done and possible in the Philippine setting. The instructor can choose among these suggested lists of journal articles on what to discuss and expound on.

**Table 2. Suggested journal readings and the analytical chemistry techniques employed.**

| Heritage material and the journal title | Analytical techniques * |
|---|---|
| *1. Brick masonry* | |
| Spanish colonial period bricks from churches in Laguna, Philippines: A preliminary chemical characterization using X-ray diffraction, energy dispersive X-ray fluorescence and Fourier transform infrared. (Cayme et al., 2021) | EDXRF, FTIR, XRD |
| Analytical chemistry methods of estimating the original firing temperature of bricks form a 19$^{th}$ century convent in the Philippines. (Cayme, 2021) | EDXRF, FTIR, SEM-EDX |

| | |
|---|---|
| Chemical characterization of historical brickwork of the church convent in Pagsanjan, Laguna. (Cayme et al., 2016) | AAS, FTIR, SEM-EDX, TGA |
| Extraction methods for quantifying iron, calcium and magnesium in a historic brickwork produced during the Spanish Colonial Period in the Philippines. (Cayme and Asor Jr, 2015) | AAS, EDX, FTIR |
| *2. Lime mortar* | |
| Chemistry of lime mortared rubble masonry in Bohol, Philippines. (Cayme, 2021) | EDXRF, FTIR, TGA, XRD |
| The restoration of the church of Our Lady of the Assumption, Dauis, Bohol, Philippines. (Kalaw and Naguit Jr, 2019) | XRF |
| Assessing the composition of 19th century lime mortars from a mission chapel in the former *Hacienda de San Isidro de Mariquina* Philippines. (Cayme et al., 2018). | FTIR |
| Characterization of mortar from church ruins in Barangay Budiao, Daraga, Albay. (Mangay et al., 2018). | AAS, FTIR, TGA |
| Petrographic and thermal characterization of mortar from a church ruin in Cagsawa, Albay, Philippines. (Laplana et al., 2018). | TGA |
| Calcium content of lime mortars from 19th century church ruins in the Philippines using volumetric analysis. (Cayme and Asor Jr, 2017). | AAS, FTIR |
| Characterization of historical lime mortar from the Spanish Colonial Period in the Philippines. (Cayme and Asor Jr, 2016). | AAS, FTIR, SEM-EDX, TGA |
| *3. Paint and pigments* | |
| Decision making, materiality and digitisation: Esteban Villanueva's *Basi* Revolt paintings of Ilocos. (Tse et al., 2018). | SR-μFTIR, XRF |
| Scientific analysis of pigments in 20th century paintings for selected historical churches of the Bohol, Philippines. (Roxas et al., 2017) | GC-MS, SEM-EDX, XRD |
| Artistic practices of the Bohol school of painting: An analytical and archival study of nineteenth-century panel paintings in the Philippines. (Tse, 2005). | FTIR, GC-MS, RS, SEM-EDX |
| *4. Pottery* | |
| Archaeomaterial characterization of historical-cultural pottery from *el Noble Villa de Pila* (Laguna, Philippines). (Asor Jr et al., 2019) | EDXRF, FTIR |
| Rice pots or not? Exploring ancient Ifugao foodways through organic residue analysis and paleoethnobotany. (Eusebio et al., 2015). | MS |

* AAS – Atomic Absorption Spectroscopy, FTIR – Fourier Transform Infrared, EDXF – Energy Dispersive X-ray Fluorescence, MS – Mass Spectroscopy, RS – Raman Spectroscopy, SEM-EDX – Scanning Electron Microscopy with Energy Dispersive X-ray, SR-μFTIR – Synchrotron Radiation Fourier Transform Infrared Microspectroscopy, TGA – Thermogravimetric Analyzer, XRF – X-ray Fluorescence, XRD – X-ray Diffraction

***Assessment Tool.*** The assessment should represent the learning objectives determined for the course. Since the *"Chemistry of Cultural Heritage Materials"* course was offered in graduate school, the targeted cognitive skills should go beyond the knowledge and comprehension level according to Bloom's Taxonomy. Hence, assessment tools are designed for the students to develop skills of applying, analyzing, synthesizing, and evaluating the concepts learned in class (Anderson et al., 2001). Essays, journal discussions and critics, and reflection papers are the chosen modes of evaluation for the students. As a summative assessment, the students were tasked to present an individual oral report in class and successfully answer queries raised by a panel of heritage chemists. The report is about a simple project proposal applying the chemistry concepts and analytical techniques taught in class on a specific local cultural heritage material that the student wants to conserve or study.

Even though there will always be limitations on the chemistry knowledge to scientifically evaluate a cultural heritage problem, the student's exposure to what chemists or scientists do in general will provide a deeper understanding when faced with complex heritage issues. This mindset would better harmonize the efforts of science experts with those having a non-science background. Depending on the target educational level (i.e., high school, bachelors, or masters) or training needs, the assessment tools can be varied accordingly, and group works can be applied rather than individual projects. If there is a need to strengthen the lower-level skills, especially if the course is adapted to the high school level, quizzes, exams, or other interactive activities can also be employed with the other assessment tools mentioned (Orbe et al., 2018).

## CONCLUSIONS

The course *"Chemistry of Cultural Heritage Materials"* has demonstrated the feasibility of introducing the study of chemistry on tangible heritage materials in the Philippines. Though this course was taught for only one semester and at the graduate school level, informal feedback from the students without chemistry backgrounds has been satisfactory. The notion of science is only for the specialists and the select few, which the public cannot understand, is still prominent in the thinking of most Filipinos. Educating non-science persons is one way to inform the public that combining chemistry knowledge with culture is possible.

The course still needs to be developed further with more practical integration with existing local heritage issues. Scientists working on local heritage materials should also produce more published research to increase valuable resources for future discussions. The framework and suggestions introduced in this paper can serve as a pioneering model of developing an educational platform for a chemistry approach to cultural heritage for the graduate school program and other degree levels.

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