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Robert Potočnik* and Iztok Devetak

Pre-service teachers' views on chemistry of fine art materials of cultural heritage

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Abstract: The chemistry and cultural heritage can be integrated in an interdisciplinary way into teaching the Chemistry, from primary to secondary school and university, including learning about the specifics of works of art in the context of their preservation or care. The main purpose of this study is to determine the pre-service Chemistry, Primary school, and Fine art teachers' views about promoting an interest in the cultural heritage and Chemistry learning through materials of work of art from the chemistry perspective. The study revealed that pre-service teachers do not have sufficient knowledge and experience regarding cultural heritage from the point of view of chemistry (materials and techniques of fine art), and all groups show an interest in the mentioned contents. This integrated and interdisciplinary approach to teach Chemistry and cultural heritage is presented to the pre-service teachers as part of the general elective course that was developed on the basis of this preliminary research about pre-service teachers' views regarding these topics.

Keywords: and fine art teachers'view; cultural heritage; general elective course; materials of works of art; pre-service chemistry; primary school.

1 Introduction

The chemistry and cultural heritage can be integrated in an interdisciplinary way into teaching the Chemistry, from primary to secondary school and university, including learning about the specifics of works of art in the context of their preservation or care.

1.1 Culture heritage and awareness for its care

Organisations such as the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the International Centre for the Study of Conservation and Restoration of Cultural Property (ICCROM), and others are raising awareness among students about the importance of caring for cultural heritage through their programmes (Aslan & Ardemagni, 2006; Potočnik, 2017a). To encourage student participation and engagement, a general, comprehensive cultural heritage preservation education programme should be established, beginning with primary school students, and continuing through the university level (ICOMOS, 1987). The Slovenian National Cultural Heritage Strategy 2020-2023 (2019) states that culture heritage preservation content should be included in all levels of the educational system. Knowledge of the specifics of materials of cultural heritage and their chemical properties is important, as it forms the basis of an appropriate attitude towards cultural heritage care and the needs of artworks (De Troyer, 2005). Cultural heritage relates primarily to cultural landscape, architectural heritage, painting, and sculptural heritage (Potočnik, 2017b), but within our study, the emphasis is on painting heritage.

***Corresponding author: Robert Potočnik**, Faculty of Education, University of Ljubljana, Kardeljeva ploščad 16, 1000, Ljubljana, Slovenia, E-mail: robert.potocnik@pef.uni-lj.si
Iztok Devetak, Faculty of Education, University of Ljubljana, Kardeljeva ploščad 16, 1000, Ljubljana, Slovenia

1.2 Artwork as a tool for understanding the specifics of fine art materials and preservation care

Since the late 1970s, different reports suggest how to integrate cultural heritage into the Chemistry class that represents the cognitive features of the chemical contents of various fine art materials, fine art techniques, and other features of artwork (Deniao, 1979; Newman, 1972; Stamovlasis, 2003). The Chemistry education community has recognized that the examination of artwork is a valuable tool for teaching science to students at all stages of education (Uffelman, 2007). One of the aims of the general science and Chemistry curriculum is to make science and also Chemistry more relevant to pre-service teachers, including by relating art to Chemistry in interdisciplinary, individualized, and life-oriented approaches to learn the content of these subjects (Alcantara-Garcia & Ploeger, 2018; Matilainen et al., 2021).

Gaquere-Parker & Parker (2012) suggested that pre-service teachers from all backgrounds benefit from working with real-life applications of Chemistry and by keeping the students engaged with cross-disciplinary examples (such as fine art products). Using simple art concepts can assist non-science pre-service teachers in better appreciating the scientific facts related to Chemistry (Hemraj-Benny & Beckford, 2014). For the implementation in to school environments, practices dealing with fine art materials and techniques could be found, for example, in making paint (Potočnik, 2017a; Solomon et al., 2011) and exploring ancient and modern pigments (Orna, 2001), dyes and dying processes (Alves, Manhita, Barrocas Dias, Ferreira, 2014; Epp, 1995), glass, pottery, ceramics (Deniao, 1979; Kolb & Kolb, 2000), and archaeological artifacts (Huerta & Parr, 2021).

Furthermore, in the close observation of art objects, pre-service teachers can be introduced to a variety of modern analytical tools and tests designed to assess the composition, age, and condition of the art objects. Students learn to perform elemental analyses with a hand-held X-ray device, fluorescence (XRF) device. They collect infrared (IR) spectroscopic data on dyes and binders, use gas chromatographs and mass spectrometry (GC-MS) to analyse paint binding media, and use fluorescence microscopy for close observation of paint chip cross-section (Wells & Haaf, 2013). Some research (Burton, Horowitz & Abeles, 1999; Danipog & Ferido, 2011) in the last two decades has shown that high school students exposed to art-based Chemistry activities have significantly higher mean scores in chemistry achievement tests (e.g. they made connections between new and old information easily, they related the familiar with unfamiliar information, and integrated the new intellectual challenge into the existing mental structures) than the pre-service teachers exposed to non-art-based activities have.

Artworks could be an adequate tool for achieving stimulating situations among students for learning Chemistry, for example: finding hidden chemistry in Egyptian artefacts (e.g. arsenic, copper, lead substances in pigments and the degradation of its colour over time) (Gimenez, 2015), exploring different material components of artefacts in museum collections (Brown, Losoff & Hollis, 2014), or frescos found in Pompeii that contain mercury in the vermilion pigments (Gaquere-Parker & Parker, 2012). Some authors report that even younger students (in primary school) and parents were highly positive about the activities (for example, making and painting with a copper-based pigment); many parents requested ideas on how to perform similar experiments at home (Gaquere-Parker, Allie Doles & Parker, 2016).

1.3 The research problem and research questions

It can be summarised that more emphasis should be placed on developing the understanding of chemical and cultural heritage concepts due to the fact that Fine art and Chemistry can be interdisciplinarity connected in education, according to contemporary curricular guidelines (Potočnik & Devetak, 2018). The main purpose of this study is to determine the opinions of pre-service Chemistry, Primary school, and Fine art teachers, about promoting an interest in cultural heritage through materials of fine arts from the perspective of chemistry. In this study, we focused on the following research questions:

(1) What do pre-service teachers think about the specifics of cultural heritage from a chemistry perspective (materials of works of art)?

(2) What do pre-service teachers particularly point out in the context of learning the specifics of cultural heritage from the perspective of chemistry (materials of works of art)?

1.4 Methods

A cross-sectional exploratory, non-experimental, and descriptive research was conducted to determine pre-service teachers' views about chemistry in fine art cultural heritage.

1.5 Participants

Altogether, 118 pre-service teachers from the Faculty of Education, University of Ljubljana participated in the study; 21 (17.8%) of them were Fine art pre-service teachers, 25 (21.2%) pre-service Chemistry teachers, and 72 (61.0%) of the participants were pre-service Primary school teachers. There were only 14 males (11.9%), and the average age was 22.8 years (SD = 1.2 years). All students were in the fourth year of undergraduate study. To illuminate the participants' Fine art and Chemistry background, we emphasise that in the Slovenian primary and lower secondary school system, Chemistry and Fine art are obligatory subjects. However, in the upper secondary school system, some programs do not include Chemistry or Fine art subjects. In our research, four (3.4%) participants had not had upper secondary Chemistry, and two (1.7%) had not had Fine art. At the Faculty of Education, pre-service Chemistry teachers can participate in some general elective Fine art courses, and pre-service Fine art teachers can participate in science or more chemistry oriented general elective courses. Pre-service Primary school teachers participate in the obligatory science (comprised also from general chemistry topics) course during a 15-week period (30 h of lectures; 25 h of lab work and 5 h of field work) in the first year of undergraduate study and fine art course during a 15-week period (45 h of lectures and 30 h of practical work) in the third year of undergraduate study.

1.6 Instrument

A paper-pencil instrument was used to determine pre-service teachers' opinions. Participants were asked about their experience when solving the fine art materials and cultural heritage techniques questionnaire (fine art materials achievement test – FAMAT), the results of which we have published in two scientific articles (Potočnik & Devetak, 2018; Potočnik & Devetak, 2021). When solving the FAMAT questionnaire, we had them answer two open-ended questions, they were asked to express their thoughts and reflections on the topic of the questionnaire, which we present in Table 1.

1.7 Research design

The instrument was applied anonymously to groups of pre-service teachers. All the participants had the same conditions for completing the questionnaires.

Table 1: Open-ended questions within the framework of the FAMAT questionnaire.

1. How do you rate your knowledge of the specifics of cultural heritage (materials of works of art)?
2. To what extent are you interested in the specifics of cultural heritage (materials of works of art)?

For the analysis of the answers on the open question, a qualitative approach of data analysis with the determinations of codes and categories was used. Both authors conducted an analysis of the answers to the open questions data and codes were established. The codes were then discussed, and agreement was 96%. In cases where authors assigned different codes to specific data, the discussion led to agreement on how to assign a code for specific open question data. The data were included in a narrative description of the findings.

2 Results and discussion

Some research shows that teachers in practice are looking for information on cultural heritage to indirectly include in their didactic activities within the prescribed curriculum content (Kortam, Hugerat, Mamlok-Naaman, 2021; Potočnik, 2017a). Another research also indicates that more emphasis needs to be placed on developing an understanding of fine arts materials in terms of possibilities, limitations, and in the context of interdisciplinarity (science and visual arts/awareness of cultural heritage preservation) in accordance with fine arts education and science curriculum guidelines (Potočnik & Devetak, 2021). Knowledge of pre-service teachers (Chemistry, Fine Art, and Primary education) about the mentioned contents is low, therefore, additional inclusion of the mentioned contents is necessary, also in the form of a general elective course (Potočnik & Devetak, 2018).

The following is the first research question and the results obtained. *What do pre-service teachers think about understanding the specifics of cultural heritage from a chemistry perspective (materials of works of art)?*

Table 2 shows that all pre-service teachers in the study self-defined a low level of knowledge about the specifics of cultural heritage – art materials and art techniques – that the FAMAT questionnaire was designed to define.

Responses do not differ from pre-service teacher groups. All groups indicate that the content mentioned is challenging for them (low level of knowledge). Some pre-service teachers expressed that a certain content was understandable (moderate level of knowledge) but had doubts about their knowledge or the correct answers to the questionnaire. A high level of knowledge was not detected in the responses of pre-service teachers in any of the three groups.

Table 2: Category and codes from the pre-service teachers' open-ended question regarding their self-rating knowledge of the specifics of cultural heritage.

Category	**Knowledge of specifics of cultural heritage (materials of works of art)**		
	Illustrative pre-service teachers' comments		
Codes	**Chemistry**	**Fine art**	**Primary education**
Low level of knowledge	"I can't imagine what I'm giving answers about". *"I've no idea about it".* "I don't know certain terms at all, they all seem very similar to me".	"We didn't learn this in university, so the assignments are quite difficult". "My knowledge of chemistry is so low". "I lack knowledge in this field, even though I finished high school in fine arts".	"We don't have enough knowledge to answer these questions." "Chemistry isn't my strong point." "I don't know what the basic terms mean, so it's hard for me to answer".
Moderate level of knowledge	"I don't like to draw, sculpt, etc., but I understood most of it … I think … " "I mainly use modern synthetic adhesives and paints (for my hobby). Some things are the same? "	"I paint, draw (comics, drawings, portraits), graphics (experiments) … every week I have studio exercises in which I draw, paint, sculpt … I know some materials from practice that were presented, but I do not know what in detail …"	"I don't know what *gesso* preparation means, so I didn't really know how to solve the task, but I found the rest quite interesting, but I don't know if it's correct …"
High level of knowledge	No examples.	No examples.	No examples.

Research shows that the content (materials of works of art) is complex (Potočnik & Devetak, 2018; Potočnik & Devetak, 2021) and at the same time very important, especially for strengthening an appropriate and responsible attitude towards cultural heritage (Gesche Koning, 2008), the inimitability and authenticity of material cultural heritage (Stanley-Price & King, 2009), and the source of students' interest in the didactic activity (Potočnik & Devetak, 2018; Thornton, 2008).

In the second research question, we asked ourselves: *What do pre-service teachers particularly point out in the context of learning the specifics of cultural heritage from the perspective of chemistry (materials of works of art)?*

Table 3 shows that pre-service teachers in the study self-defined three main codes in the category of interest pre-service teachers in the peculiarities of cultural heritage.

Pre-service Chemistry teachers highlight content that emphasizes the importance of cultural heritage for people (they like to look at works of art, what is shown, also in what form of known techniques is the work of art, e.g. painting, drawing, graphics …). They are less interested in the materiality or composition of artwork. They

Table 3: Category and codes from pre-service teachers' open-ended question regarding their self-rating interested in the peculiarities of cultural heritage.

Category	**Interest in cultural heritage content (materials of works of art)**		
Codes	**Illustrative pre-service teachers' comments**		
	Chemistry	**Fine art**	**Primary education**
Interest in the content of cultural heritage, but less in its material	I'm interested in painting and drawing techniques, but not so much in materials." "I'm not interested in a material, that's not my field; I prefer to look at works of art". "I think the paintings are beautiful, but I've never wondered what they're made of." "I've no experience or training in this field, so I probably lack interest."	No examples.	"I look at works of art rather amateurishly, I like to look at them, I mainly wonder why a certain product was created (the story), but not so much about the materials of the art products." "I am more interested in what the artwork says and less in the material." "I usually don't wonder about the materials, but focus on the subject …"
Interest in the specifics of materials and techniques when used in fine art creation	No examples.	"I would find it good to know how materials work chemically, for example, how they react with the environment (water, air …)." "I am interested in how the materials were traditionally obtained." "I like to learn, although chemistry is not an area I excel in, I am curious and like to learn new things." "As an artist, I think this content related to chemistry must be of interest to at least a small level." "I am interested in the chemical creation of individual components or colours, but also how materials behave when they interact."	"I am mainly interested in art materials for drawing and painting because I know only the basic modern materials like tempera, watercolour, acrylic … and I do not know their peculiarities, their specificity." "Why do artists devote /create one type of material and less or not at all in another." "I am mainly interested in modern materials."

Table 3: (continued)

Category	Interest in cultural heritage content (materials of works of art)		
Codes	Illustrative pre-service teachers' comments		
	Chemistry	**Fine art**	**Primary education**
Interest in the sense of didactic application in class or explanation of content within the course at the faculty	No examples.	No examples.	"You could introduce these contents into a course at the faculty or organize a club for students." "I'm interested in everything, because you don't know much about it, or rather I didn't have the opportunity to learn anything more about it even at faculty." "I would like to know the materials better, e.g. during lessons with children, if I run out of any art materials, so that I know how to replace them with the most suitable one." "I'm interested in why the artist used a certain material in a certain period, how they obtained it and things like that." "I'm interested in both "modern" and "old" materials and how I can use them in lessons, in terms of art techniques." "I never thought about the materials, but I find them interesting … they are also important … "

also point out that they are not trained in this field or that they do not have experience. Similar responses were identified in the group of pre-service Primary school teachers, but less pronounced. No specific examples were identified among pre-service Fine art teachers. Pre-service Chemistry teachers could use cultural heritage as a source of information and stimulate students' interest (Horikoshi, 2021) for learning Chemistry and Science. A visual interpretation of the chemical content is important (Devetak, 2017), with an appropriate approach, e.g. incorporating basic visual arts concepts to make the chemical content more motivating to students who are challenged (Potočnik & Devetak, 2020), or whether the artistic content is of interest to them (Potočnik, 2017a), and vice versa (Wells & Haaf, 2013; Kafetzopoulos et al., 2006; Matilainen et al., 2021). Pre-service Chemistry teachers can learn this as part of additional training, most easily as part of an elective course (Potočnik & Devetak, 2018). Pre-service Fine art teachers are interested in knowing the specifics of cultural heritage materials in terms of their properties, response, and composition, especially in the process of artistic creation (creating a work of art). Pre-service Fine art teachers during their studies do not learn the specifics of the technology of materials used in art (Potočnik, 2017b). They do not know the composition of materials, material procurement, processing, and production of art materials (Hudoklin, 1958). In particular, they lack knowledge and experience about the compatibility of different materials, reversibility, or the actual process of assembling or combining materials that leads to the final form of an art material (e.g. oil paint, stretched canvas, wooden support, etc.) (Potočnik, 2017b; Potočnik & Devetak, 2018). The specifics of materials could be taught from the perspective of understanding the specifics of cultural heritage from the perspective of chemistry (visual arts materials and techniques) as part of the general elective course. Pre-service Primary school teachers directly express their interest in the creation of additional didactic training to the content, as they are aware, as future teachers of various subjects, of the importance of understanding both chemical (science) and fine art content in terms of interdisciplinary teaching (Aslan & Ardemagni, 2006). They are also interested in knowing the specifics of the materials, in the sense that

they can find an appropriate substitute without limiting the students' experience (real clay can be substituted by preparing cellulose pulp and similar) (Potočnik & Devetak, 2020).

3 Conclusions

From the results, it can be concluded that pre-service Chemistry, Primary education and Fine art teachers do not have sufficient knowledge and experience regarding cultural heritage from the point of view of chemistry (materials and techniques of fine art), and all groups show an interest in the mentioned contents. For this reason, the general elective course was developed.

The course includes 30 h of lectures, 15 h of seminars, and 15 h of laboratory work. Lectures include content on the fundamentals of the properties of materials used in the visual arts, cross-curricular integration (concepts of science and visual arts), and the care of material cultural heritage. During the lectures, pre-service teachers learn the characteristics of: canvas (structure, properties, types of textile fibres, decomposition of cellulose fibres, canvas and fine arts – impregnation, preparation, protection); metal (structure, metal as a carrier of art, as a material of art, corrosion, protection); pigments and dyes (properties, types, uses); binders (organic, inorganic, hydrophilic, hydrophobic, oil, resin); tempera (types, characteristics of protein binders); varnishes (oil, resin), solvents; resins (natural and synthetic); waxes (mineral, vegetable, animal, wax-like synthetic); adhesives (polymers, glues); gilding of works of art; frescoes (fresco buono, fresco secco); graffiti; encaustic; other materials (charcoal, chalk, pastel, watercolour, gouache, tempera, clay, plaster, etc.) and reconstruction, retouching, documentation with photography, etc. These topics may be explored in greater depth in the preservice teachers' individual work in seminars and laboratory work.

According to the number of hours of laboratory work, seven activities are designed (see Table 4).

The general elective course is in the initial phase of implementation. An evaluation of the course in the future is necessary, with the aim of optimization, adaptation to the needs of pre-service teachers, with the aim of promoting an interest in cultural heritage and chemistry learning through materials of fine art from the chemistry perspectives.

According to the results presented above, we expect that this general elective course will be selected mostly by pre-service Primary education teachers. This is predicted regarding the facts that pre-service Fine art teachers are exposed to similar courses during their university education through mostly practical work, without much fine art material theoretical background. On the other hand, pre-service Chemistry teachers do not find such

Table 4: Topics of seven lab work (adapted from Greenberg & Patterson, 2008).

No.	Topic	Short description of pre-service teachers' lab activity
1	Art conservation and restoration	Pre-service teachers distinguish between an "art forgery" and the "real" painting and discuss methods of detecting art forgeries. They make their own artwork and later detect "art forgery" through chemical (e.g. chromatography) and ultraviolet analyses.
2	Colours and paint	Pre-service teaches make paint and explore ancient and modern pigments, dyes and dying process.
3	Supports and grounds of artworks	Pre-service teachers prepare egg tempera paint and gesso ground. They also learn the specifics of handmade paper and collage painting.
4	Materials of sculptures	Pre-service teachers illuminate the specifics of materials in sculpture (e.g. cellulose pulp, starch pulp). They design a three-dimensional sculpture in different materials and apply the principles of good three-dimensional composition.
5	Metal art	Pre-service teachers learn the specifics of metal-working techniques. They design a piece of jewellery with wire liner. They learn about the properties of soldering and colouring (galvanization) of the metal.
6	Photography – a picture as artform	Pre-service teachers build a pinhole camera. They use light as a brush. They illuminate knowledge of light-sensitive chemicals and the ability to control those chemicals.
7	Chemical hazards in art	Pre-service teachers learn about alternatives to toxic chemicals that can be used in selected art disciplines. Using a collage technique, they design a poster on the proper use of chemical materials.

courses very interesting due to the fact that they are focused only on the chemical properties of the materials and not that much on the works of art in general. There are some limitations to this study. There were difficulties for pre-service teachers to answer the open-ended questions because the questionnaire was quite long. In addition, the artworks presented in the questionnaire were prints from photographs, and it was challenging for some individuals to transfer the presented image as material, such as fresco painting on the wall, woven tapestries, and the like.

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