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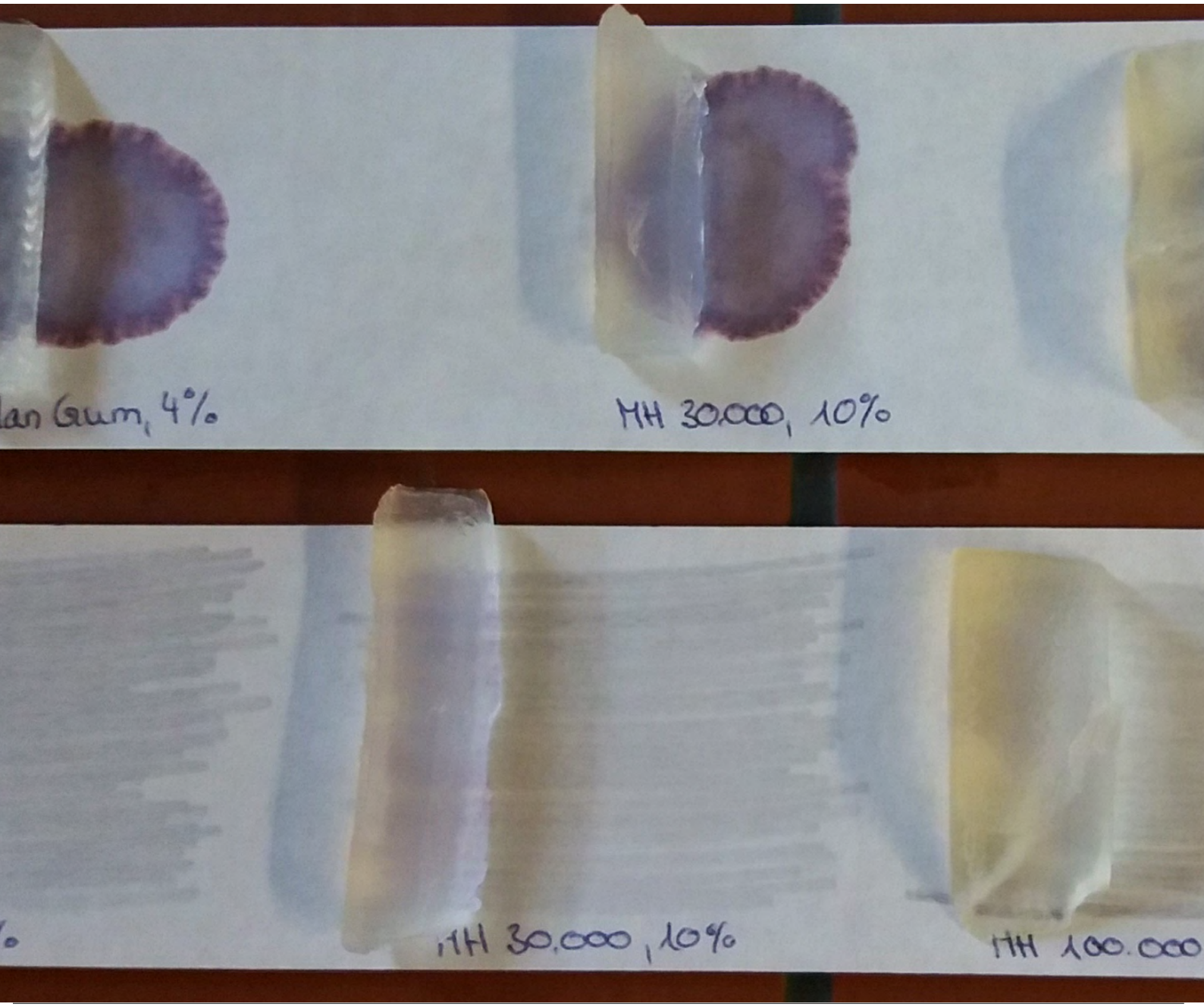

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Content

Foreword

Dear reader,

We have the pleasure of introducing the first issue of 2026, dedicated to ***"Gels in Paper Conservation"***, with a focus on their application in conservation treatments. The issue addresses the chemical and physical properties of gels, as well as their behaviour and interaction with different substrates.

The article by Dr Andrea Pataki-Hundt, **"How to Teach the Use of Gels and Thickeners in Paper Conservation,"** This article presents a teaching approach to the use of gels and thickeners in paper conservation, combining theoretical knowledge with practical experimentation. It highlights the importance of direct engagement with materials in order to understand their behaviour and evaluate their application in conservation contexts. The study demonstrates how a structured teaching methodology can support the development of technical understanding, critical observation, and practical skills. Overall, it provides an effective framework for introducing key concepts and methodologies in the use of gels and thickeners within conservation practice.

We would like to give special credits to our peer-reviewers who offered their specialised knowledge to maintain the high-quality standards of our publication. We also thank the ERC board and national representatives, as well as webmaster Emanuel Wenger and social media administrator Penny Banou, for their support in the dissemination of the periodical.

Our thanks also go to our proofreaders Katarina Kelsey, Mathilde Renauld, and Charlotte Wilkinson, and to Anja Props for the final layout. We are especially grateful to Patricia Engel for her dedication and guidance throughout the publication process. Our final acknowledgement goes to the readers, as well as all the people who offer their services voluntarily, which form the periodical Conservation Update.

Finally, we would like to acknowledge our readers and all those who contribute their time and effort on a voluntary basis, making Conservation Update possible, the periodical of the European Research Centre for Book and Paper Conservation-Restoration.

Our next issue, the second to be published in 2026, will be dedicated to ***"Emergency Response for Paper Collections".*** In the context of ongoing climate change and increasing global conflicts, emergency preparedness and response have become

essential for the protection of library and archival collections. For this issue of Conservation Update, we invite submissions that present case studies of emergency response, including events such as floods, fires, and earthquakes, as well as contributions addressing the work of conservators in conflict-affected regions and their efforts to safeguard paper-based collections.

Submissions must be sent by May 20, 2026.

We wish our readers all the best

Marta **Soliva-Sanchez** and Manto **Sotiropoulou**

We would like to share with you some words about how we chose this topic, *"Gels in Paper Conservation"*:

Gels have been used in conservation practice for many years, in various applications, however, the full length of their interesting properties is not yet fully comprehensive. In education, gels are not taught as part of standard conservation courses, but mostly as advanced classes or specialised research projects. This paper is important, as it examines the necessary educational methodology so that the subject of gels may be introduced in the academic field in an organised manner. Bringing the subject of gels to the core conservation studies will allow their future development and extend their possibilities for paper conservation.

Manto **Sotiropoulou**

This contribution highlights the importance of combining theoretical knowledge with practical experimentation in the teaching of paper conservation. From our perspective, direct engagement with materials such as gels and thickeners is essential, as it allows students to develop not only technical understanding but also the critical observation skills needed for their future professional practice. We hope you, reader, enjoy this issue

Marta **Soliva-Sanchez**

How to Teach the Use of Gels and Thickeners in Paper Conservation

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DOI: 10.48341/fp71-gh70

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Keywords:
Flipped classroom,
Blended learning,
Didactic,
Gels,
Video tutorial,
Thickener.

ABSTRACT

This article presents a teaching concept for the application of gels and thickeners in paper conservation, implemented at the Technical University of Applied Sciences Cologne within a four-day course module. The course targets primarily bachelor's level students, aiming to convey theoretical foundations alongside hands-on experience with various gels and thickeners. During the course, students prepare eight different materials—including cellulose ethers, gellan gum, laponite®, agarose, xanthan®, and advanced commercial products such as Nanorestore Gel® Peggy—and test them on water-sensitive substrates. Three kinds of coloured stamp ink and a copy pencil serve as a water sensitive media. Key parameters such as water absorption, moisture release, and residue formation are examined and documented. All recipes are given to prepare the gels and thickeners. The curriculum combines theoretical lectures, video tutorials in a flipped classroom format, and practical lab work, fostering active learning and technical confidence. Student evaluations include written and visual documentation of their observations as well as oral feedback. Results align with established literature, confirming distinct material behaviors and providing a comprehensive overview for students. The course also promotes technical, methodological, and social skills through collaborative group work and guided practice. By integrating blended learning elements that maximise both contact time and independent study, the program offers an effective and modern educational approach. This teaching model contributes significantly to the professional training of future paper conservators by equipping them with essential knowledge and skills for the practical application of gels and thickeners in conservation interventions.

Introduction

Teaching conservation practices[1] is a fundamental cornerstone of the conservation and restoration of written documents, archives, and library materials, alongside all other disciplines of conservation sciences. Since there are hardly any explicit standard textbooks on the subject of paper conservation, the disclosure of the didactic approach and structure is a fundamental building block. The textbook Paper and Water[2] is one of the few well-founded standard works in the field of paper conservation. In addition to the editors, various experts shed light on the material paper and compile the various methods for examination, interaction with water, and conservation work. On the subject of gels and thickeners, there is an anthology[3] and overview publications[4], publications on individual applications[5] and on new developments[6]. The work is based partially on master's theses or doctoral dissertations and flows into the scientific community in the form of scientific publications. The transfer to conservation issues is highly successful[7] and demonstrates the application-oriented focus. This article aims to present the methods and principles of teaching the application of gels and thickeners in paper conservation as an introductory course. This includes the formulated learning outcomes, the didactic methods, sample preparation, the evaluation tools, and the evaluation of the students on behaviour of gels and their use.

1 Di Pietro (2024)
2 (Banik et al., 2011)
3 (Angelova et al., 2017)
4 (Khaksar-Baghan et al., 2024)
5 (Delattre et al., 2023) and (Henniges et al., 2024)
6 (Richard et al., 2024) and Giordano/Cremonesi (2021)
7 Totten (2003)

The learning outcome encompasses the following objectives: students learn about different gels and thickeners, making them, apply them, and document the properties of the gels visually and photographically by testing their functionality and experimenting with them using test specimens. This enables them to transfer and apply their knowledge to original objects at a later stage. There is also the opportunity to further develop their skills in working with the materials.

The learning outcome is the common thread in a teaching unit that is offered as an introductory module in the bachelor's program and also as an advanced course in the master's program. A course with this content lasts four full days (BA program) and consists of theoretical and practical parts.

Experimental

A variety of gels and thickeners were produced for experimentation (Tab. 1). In the following, cellulose ethers are named thickener, because this is the main industrial application. All other tested materials are called gels even though they can be rigid or soft. Students are provided with work instructions in German and English in sealed plastic sleeves, which they use to produce the gels and thickeners in the laboratory after receiving safety instructions, using tools such as magnetic stirrers, beakers, stirring rods, and microwaves. All recipes can be found under the heading "recipes". Silicone trays measuring 10 × 15 × 5 cm are provided for the gels and thickeners (Fig. 1). All gels and thickeners, despite of Nevek® and Nanorestore Gel® Peggy, are prepared in demineralised water (conductivity between 5-7µS). The percentage for a 4 % solution is calculated: 4g of solid to 96 ml of deminer-

alised water. Since the walls of the silicone trays are smooth, gels and thickeners with smooth surfaces are produced. As a variation, the gels and thickeners can also be poured onto a textile or textured plastic sheet placed in the silicone trays to obtain gels with a textured surface.

Table 1
The various gels and thickeners with concentration specifications that are to be produced by students or are already commercially available.

Gel/Thickener	Concentration [%]
Methylhydroxyethylcellulose, MH 3.000 (Tylose®)	20
Methylhydroxyethylcellulose, MH 30.000 (Tylose®)	20
Methylhydroxyethylcellulose, MH 100.000 (Tylose®)	10
Gellan Gum Low Acyl (LA)	4
Gellan Gum High Acyl (HA)	2
Laponite®	10
Agarose	4
Xanthan®	15
Nevek®	Pre-prepared
Nanorestore Gel® Peggy	Pre-prepared

The prepared and dried gels and thickeners (Fig. 2) are tested in contact with water-sensitive media. Red and green commercial stamp ink, a methyl violet stamp, and a copy pen are applied to filter paper in various graphic shapes. The coloured stamps and swatches should be particularly water-sensitive in order to observe the properties of the gels and thickeners. It is important that the gels and thickeners are only applied to half of

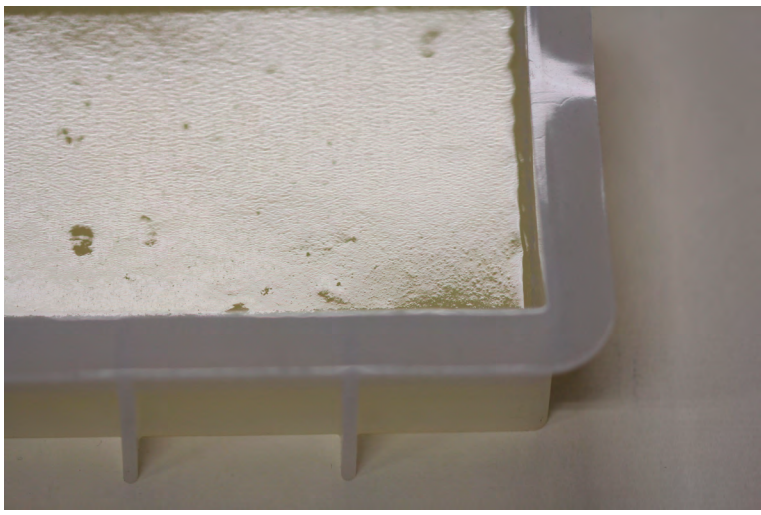

Fig. 1: *Silicone tray, 10 x 15 x 5 cm, to prepare the gels and thickener. Silicone provides a smooth and non-adhesive surface.*

the sensitive medium so that the untreated reference is always visible (Fig. 3). The length of time the gels and thickeners are left on the substrate is initially tested at around one hour. Variations are also possible, from very short exposure times to several hours.

The gels and thickeners differ in concentration, water absorption capacity, water retention capacity, and stickiness or residue left behind. Water absorption capacity describes the ability to absorb liquids into the gel or thickener and act like a sponge. Water retention capacity refers to the ability to release moisture or water from the gel or thickener into the substrate. This is particularly interesting if the gel is to be used as a moisturiser, for example to delaminate an adhesive bond. Stickiness describes the adhesion to the substrate, i.e., how well the gel or thickener can be removed after a certain period of time. These are the main parameters of gels and thickeners that are used as comparison criteria in the bachelor's program. The students are asked to check these phenomena visually and by taking pictures. The parameters pH value, concentration, and stiffness are not

yet the focus of the investigation in the bachelor's program[8]. The shape of the course in the master's program is not described here. Other parameters such as the influence of different concentrations, different substrates (textiles, paper, stone, etc), length of application, or influence of water quality and pH values describes the profile for a masters' course.

This results in a table with various parameters to be observed, which are recorded by the students (Tab. 2). The observations are scaled from + to +++ to represent a poor result (+) or a very successful application of the gel on the substrate (+++).

Table 2

The parameters of the gels and thickeners (Tab. 1) are compared with the sample sets and the observations are recorded visually. The rating ranges from +++ = very good to + = unsatisfactory. Such a table is created for each gel and thickener by the students.

	Red stamp ink	Green stamp ink	Methyl violet stamp	Copy pencil
water absorption capacity				
water retention capacity				
stickiness/residue				

Fig. 2: *The prepared and dried gels and thickeners in silicone forms as well as in petri disches.*

8 Giordano/Cremonesi (2021)

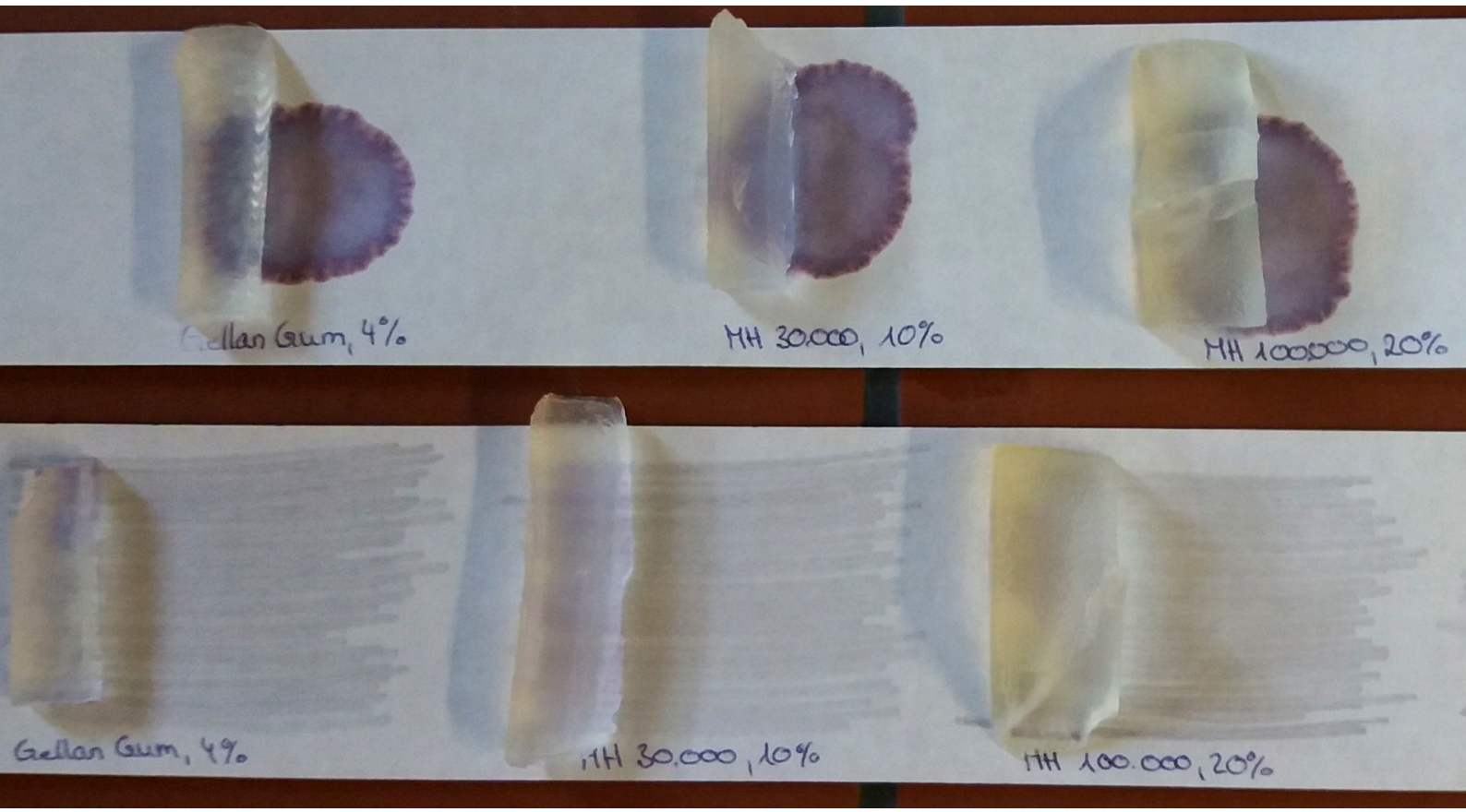

Fig. 3: *The gels and thickeners should be applied only to half of the sensitive medium so that the untreated reference is always visible.*

Methods

The teaching of the topic of gels and thickeners is divided into a theoretical introductory session in class in the form of a PowerPoint presentation ahead of the hands-on workshop to give students the necessary time to assimilate the contents. The various gels and thickeners are presented, the distinction between rigid and soft gels is explained, the risks of change of the substrate are highlighted, and the chemical structures are presented. The literature and application examples are presented for all gels and thickeners. The theoretical input enables students to engage with the topic for the first time. The next step is to discuss the individual practical elements of the course days. With a group size of around 10 students, up to 4 groups are formed to prepare the samples, prepare the gels and thickeners, evaluate the interaction between gels and thickeners and the substrate, and study the specialist literature. The course content is made available digitally on ILU, the learning platform of the Technical University of Applied Sciences, Cologne. It includes the PowerPoint presentation, a collection of about 20 scientific articles, and various web links.

The flipped classroom[9] serves as the next methodological model. In this model[10], the traditional learning space is inverted and students are brought to a higher level of knowledge before and during the actual learning unit (Fig. 4). This is achieved, for example, by giving students time before and during the course to familiarise themselves

9 Hattie (2023) and (Hernàndez-Sabaté et al., 2024)
10 Bernstein/Ng (2025)

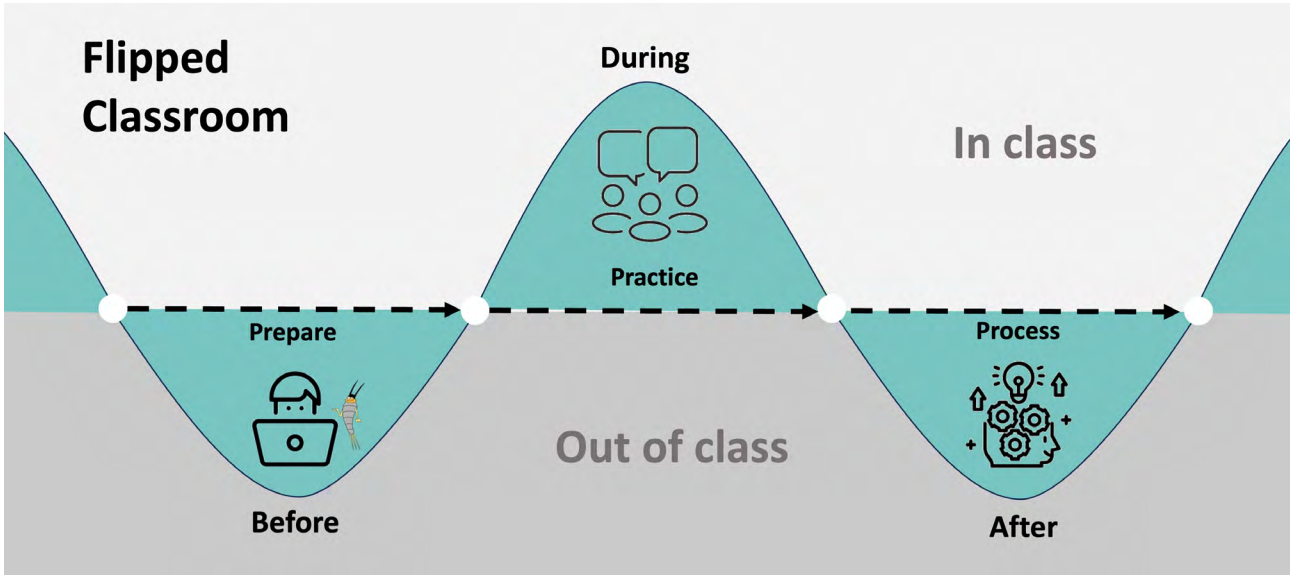

Fig. 4: *Diagram of the Flipped classroom model, © Marlen Börngen*

with the content through video tutorials in German and English. The mixture of analog and virtual learning strategies is also described as blended learning[11]. At the Cologne Institute of Conservation Sciences (CICS), around 30 professional video tutorials were created as part of a research project and posted on YouTube[12]. In this research project, which was supported by the Foundation for Innovation in Higher Education (STiL), teaching units for the subject of paper restoration were filmed as a supporting pillar of teaching and fulfill the idea of blended learning. In that model, students choose when to watch the tutorials and prepare for a class. The self-study or contact-free time is included in the ECTS system (European Credit Transfer and Accumulation System) along with contact hours when lecturers are in the classroom. Students always have both contact and contact-free time to deal with content and topics and achieve their ECTS credits.

The practical units of this course demonstrate practical applicability and the link between theory and practice. Manual work or laboratory activities give students self-confidence and methodological competence. Since the learning units are carried out in groups, social skills are also enhanced. The practical observations are drawn visually, discussed in the working groups and presented on the fourth day to the whole group. The fact that students carry out observations individually also teaches them the aptitude to observe in real time the effect of treatment: this skill is important to develop and it provides basic understanding of the material studied.

The acquisition of technical, methodological, cognitive, and social skills is presented in taxonomy levels in order to record the gradual acquisition of skills. In teaching, taxonomy levels are stored as a learning curve in order to classify different skill expansions[13]. There are six taxonomy levels, with level one being the lowest and taxonomy level six being the highest[14]. The levels one to six can be described as cognitive competences and de-

11 Berkian, N., Rajab, A. (2025) and (Lambert et al., 2017)
12 Jigsaw Teaching in paper conservation, Poultices-Gels https://www.youtube.com/channel/UCs2E5FgbtAuIKuPbbEL__BA (10.12.2025)

13 Hendersen 2016
14 Pataki (2019)

scribe the degree of learning steps. They can be defined as remember, understand, apply, analyse, evaluate and create (from one to six). The bachelor's course "gels and thickeners" would aim to reach the remember, understand, and apply levels as a minimum expectation.

As an additional learning unit, students are provided with specialist articles on gels and thickeners. An interim task is for each student to summarise an article and present it orally to the group in 3-5 minutes on the fourth and final day. The articles cover topics such as making the gels, description of case studies, scientific research approaches to comparison of different gels and thickeners. The goal is for students to learn about a wide range of topics from each other's presentation. Additionally, students are asked to read scientific literature with specific vocabulary and structure, and to present it in a few minutes. This testing represents one possible approach, but there are many other ways to interact with the students' knowledge such as making short movies, set-up a multiple choice play or gaming structure[15].

Results

Based on the introductory theoretical input, video tutorials, and the distribution of recipes, the students were able to produce the gels and thickeners under the supervision of a lecturer and apply them to the sensitive substrates. The observations were recorded in writing and with illustrations by the students. Each student filled out the data sheet (see Table 2) and exchanged the observation with their study colleagues.

On the first day, eight gels and thickeners were prepared by the ten students, as shown in Table 1. The concentrations were varied at least once, resulting in a total of 16 gels and two finished products. These 18 gels and thickeners were cut into small pieces, approximately 0.5 x 0.5 cm, and applied to the four water-sensitive media. This gave each student approximately 72 samples to observe and evaluate on day two and three. In this first step, all gels and thickeners were left on the media for the same length of time, approximately one hour. In this article, the observations from the paper conservation students are described - not of the colleagues from the painting and textile conservation disciplines who prepared a different set-up of samples.

The following main conclusions could be drawn: The cellulose ethers MH 10.000, 30.000, and 100.000 release moisture well at these concentrations, their water retention capacity is rather low, they are only slightly sticky, with stickiness decreasing as chain length increases, and they have a medium water absorption capacity. The thickeners can be cut, but are still quite soft.

Gellan gum gels LA, on the other hand, are rather firm and rigid at a concentration of 4 %. Their water retention capacity is significantly higher than that of cellulose ethers, as is their water absorption capacity. Their stickiness is very low.

Laponite® behaves differently again. Its water retention capacity is very low, meaning it releases a lot of moisture, and its water absorption capacity is also low. However, it is highly sticky, which means that residues can remain on the substrate.

Xanthan® behaves similarly to Laponite®. It has a low water retention capacity, a low water absorption capacity and it is very sticky.

15 Pataki/Börngen (2024)

Agarose has a medium water retention capacity, very good water absorption capacity, and low stickiness.

Nevek® is comparable to Laponite® and Xanthan®, it has low water retention capacity and relatively high stickiness. There is a strong smell of alcohol, which is probably due to the additives[16].

The hydrogel Nanorestore Gel® Peggy is comparable to Gellan Gum gels, type HA, which is high acyl- white and flexible.

Clear differences were observed between the individual gels and thickeners in this test setup, providing a diverse impression of their application. By preparing and observing the gels themselves, the students gained an increased level of technical and methodological competence. As this course is offered to both prospective paper conservators and textile and painting conservators, an interdisciplinary exchange was ensured. The literature review underpins the examination of the gels and thickeners and covers not only paper conservation topics, but also textile applications[17]. Finally, the students presented about the goals reached and the lessons learned. Because of the small learning group the feedback was performed in person on the final fourth day.

Discussion

The gels and thickeners presented here can be divided into five groups based on their chemical structure[18] (see table 1). Cellulose ethers (group 1), the two variants of gellan gum (LA, HA) (group 2), the layered silicate Laponite® (group 3), the polysaccharide forms such as agarose, Xanthan®, and Nevek® (group 4), and the hydrogel Nanorestore Gel® Peggy (group 5). There is already a great deal of variety and diversity here alone. The concentrations of cellulose ethers, gellan gums, agarose, and Xanthan® can be varied. Further variations include the dwell time on the substrate and whether an interlayer paper is used between the gels and thickeners and the substrate. The parameters of concentration and barrier layers[19] were not taken into account in this experimental setup. The possibility of doping the gels and thickeners with solvents[20] or, for example, enzymes[21] or complexing agents[22] go beyond the scope of this course and are topics in the MA years.

The observations are consistent with the experiences reported in literature, such as the fact that residues can remain on the substrate, as Totten has already demonstrated in the case of Laponite®[23], where residues can be seen directly. Henniges et al. also detected minimal residues on the substrate in the case of gellan gums[24]. These tiny amounts of residues are invisible to the naked eye. They investigated the residues by means of nalytical measurements. For the students it is important to reflect and keep this information in mind even though they do not handle the necessary analytical equipment.

The description of the experimental setup shows how many possible variations there are and that not everything can be covered in a four-day course. The aim of the course is to provide an overview of the most

16 Nevek® is ready-made, derived from a seaweed, it comes from food additives (E406) and it is classiefied as sustainable and it containes 1-10% ethanol (data from the product and safety data sheet).
17 Perenteau, A. (2013)
18 (Khaksar-Baghan et al., 2024)
19 Da Silveira (2013)
20 (Richard et al., 2024)
21 (Delattre et al., 2023)
22 Bazemore (2017)
23 Totten (2003)
24 (Henniges et al., 2024)

important components and possible variations according to the learning outcome. The transfer of this knowledge to an original object has not yet taken place within the scope of this course and represents a significantly higher level of taxonomy. It is also clear that this teaching unit is designed for students. If this course is conducted for professional conservators, the lecturers can build on their experience and previous expertise. This also means that the structure of a course for students and for professionals differs significantly. An example of a different approach for professionals would be the handling of literature. Students are used to reading and summarising literature in a very short time. Professionals usually need more time for this. On the other hand, thanks to their often many years of experience, professionals are better able to put restoration techniques into practice or to visualise and design this transfer. These different skills must be taken into account and adapted when setting up a course.

Conclusions

The science of teaching how to use gels and thickeners is another building block in the field of conservation practice. It expands the spectrum of publications on materiality, on investigations into the interaction between gels and thickeners and the substrate, and on the variety of possible applications. Student learning is the basis of scientific practice. The learning methods used are the flipped classroom and blended learning models, in which the material to be taught is made available in the form of video tutorials, a theoretical unit marks the start of the course, and students produce the gels and thickeners and test them on samples. A total of eight gels and thickeners were prepared according to the recipes provided, and two ready-made gels were used. These gels and thickeners were applied in equal parts to four different water-sensitive media. The students recorded their observations in words and pictures. During the course, the concentrations of the gels and thickeners were partially changed so that the students had 72 samples to test. The video tutorials, literature provided, theoretical introduction, and the practical implementation meet the criteria of blended learning and the flipped classroom model. The students' observations correspond to the descriptions in the literature. The learning outcome goals have been achieved.

Recipes

Gel/Thickener Tradename source of supply	Description of preparation
Methylhydroxyethylcellulose, MH 3.000 (Tylose®) Kremer Pigmente Hauptstraße 41 88317 Aichstetten https://www.kremer-pigmente.com/	The cellulose ether will be prepared in a concentration of 20 %. Mix 20 g of powder and 80 ml of demineralised water and heat it up until boiling. After boiling, pour it in a heat-resistant flat tray, let cool down and use it the next morning. The gel is supposed to be translucent and still quite soft. It can be stored for several weeks wrapped in a cling film in the refrigerator.

Gel/Thickener Tradename source of supply	Description of preparation
Methylhydroxyethylcellulose, MH 30.000/100.000 (Tylose®) Kremer Pigmente Hauptstraße 41 88317 Aichstetten https://www.kremer-pigmente.com/	The cellulose ether 30.000 will be prepared in a concentration of 20 %. The cellulose ether 100.000 will be prepared in a concentration of 10 %. Therefore, mix 20/10 g respectively of the powder and 80/90 ml of demineralised water and pour it in a flat tray. It can be stored in the refrigerator until a gel is formed overnight. The gel is ready for use the next morning. The gel is supposed to be translucent and rigid. It can be stored for several weeks wrapped in a cling film in the refrigerator.
Gellan Gum Low Acyl/High Acyl (LA/HA) Gaby Kleindorfer Aster Straße 9 84186 Vielsheim https://gmw-shop.de/	The gel is prepared in an alkaline salt solution. It is mandatory for LA but not for HA. Add 0.2 g calcium acetate to 0,5 litre of demineralised water. Concentration for LA is 4 % and for HA 2 %. 20 g of gellan gum (LA) or 10 g (HA) powder are added to the solution. The mixture is heated in the microwave at 700 watts for approx. 9 minutes and boiled until a clear solution (LA) is formed and bubbles rise to the top of the glass. Gellan gum HA stays opaque even after boiling. A sufficiently large beaker and a cover prevent the gellan solution from foaming over and overflowing. Pour the hot solution into a heat-resistant container so that no bubbles form. Then allow the gel to cool down without shaking. The gellan gum LA is supposed to be translucent and rigid. The gellan gum HA is supposed to be opaque and soft. It can be stored for 1-2 days in cling filmIn the refrigerator. Clean, unused leftovers can be reheated and poured out again.
Laponite® Kremer Pigmente Hauptstraße 41 88317 Aichstetten https://www.kremer-pigmente.com/	Laponite® will be prepared in a concentration of 10 %. Therefore, mix 10 g of powder and 90 ml of demineralised water and heat it up until boiling once. After boiling, pour it in a heat-resistant flat tray, let it cool down and use it the next morning. The gel is supposed to be translucent and soft. It can be stored for several weeks in the refrigerator.
Agarose Deffner & Johann Mühläckerstraße 13 97520 Röthlein https://deffner-johann.de/de/agar-agar-100-g.html	To prepare a 4 % solution, 4 g agarose powder is mixed with 96 ml water and boiled once on a plate or a microwave. The mixture is then poured in a heat-resistant flat tray or Petri dish. After cooling down a rigid gel is formed. It can be stored for several days wrapped in a cling film in the refrigerator
Xanthan® Amazon business	Xanthan® will be prepared in a concentration of 15 %. Therefore, mix 15 g of powder and 85 ml of demineralised water and boil it once on a plate or a microwave. After boiling, pour it in a heat-resistant flat tray, let cool down and use it the next morning. The gel is supposed to be slightly yellow, opaque and soft. It can be stored for several weeks in the refrigerator.

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