2023

Virtual Microscopy
Histology and Histopathology

MAPPING RESEARCH

ON SETTING UP THE EU CURRICULA ON HISTOLOGY AND HISTOPATHOLOGY FOR THE VIRTUAL MICROSCOPY DIGITAL TRANSFORMATION

OVERVIEW REPORT OF WP2

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DIGITAL TRANSFORMATION OF HISTOLOGY AND HISTOPATHOLOGY BY VIRTUAL MICROSCOPY (VM) FOR AN INNOVATIVE MEDICAL SCHOOL CURRICULUM

ERASMUS+ PROJECT, REF.NO. 2022-1-RO01-KA220-HED-000089017

AUTHORS
José Luis Girela López[1], Noemí Martínez Ruiz[1], Rosa María Pérez Cañaveras[2] and Flores Vizcaya Moreno[2].
[1] Biotechnology Department and [2] Nursing Department, University of Alicante, Alicante Spain.

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1. Introduction.

1.1. Histology and histopathology in Medical studies

Medical doctor is a regulated profession under the directive **Directive 2005/36/EC of the European Parliament and of the Council of Europe**[1]**.** From the administrative point of view, the studies are recognised in the Medical Universities of different European countries to access the benefits of such professional conditions. To standardise the study programmes around Europe, a consortium of European institutions was created under the Tuning programme. In particular, for Medical studies, the work was developed by **European Thematic Network Project MEDINE and The Tuning Project (Medicine) under its auspice [MEDINE]** from 2004 to 2007, and the **Thematic Network in Medical Education in Europe [MEDINE2]**[2]**.** As a result of the work of these projects, the learning outcomes for primary medical degree qualifications in Europe were set.

Histology is a core discipline in Medical Studies. It is present in the structure of the degrees in Medicine all over Europe and in the rest of the world as a basic subject to be taken in the first or second year of the Medicine Degree. Histology allows medical students to study the microscopic structure of tissues and organs. It provides a foundation for understanding the normal organization and function of cells, tissues, and organs in the human body. This knowledge is essential for accurately diagnosing diseases and interpreting clinical findings. Histology bridges the gap between gross anatomy (study of macroscopic structures) and cellular-level structures. It helps students correlate the anatomical features they learn in gross anatomy with the cellular composition and organization of tissues. This integrated understanding is essential for comprehending the functional aspects of organs and systems. Moreover, Histology

[1] **Directive 2005/36/EC of the European Parliament and of the Council of 7 September 2005 on the recognition of professional qualifications.** http://data.europa.eu/eli/dir/2005/36/oj
[2] **MEDINE – MEDICINE (2004-2007 & 2009-2013)** https://tuningacademy.org/countries/czech-republic/medine-medicine/

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serves as a basis for research in various medical fields. It enables scientists to investigate the cellular and molecular mechanisms underlying diseases, develop new treatment modalities, and advance medical knowledge. Histological techniques, including immunohistochemistry and molecular histology, are vital tools in biomedical research.

Regarding Histopathology, it usually is present as a mandatory subject on the third or fourth year of the Medicine degree. Histopathology is instrumental in recognizing and diagnosing various diseases. By studying abnormal tissue structures, such as cellular changes, inflammation, or tumor formation, medical students can identify pathological conditions and understand the underlying mechanisms. This knowledge is crucial for diagnosing diseases and planning appropriate treatment strategies.

1.2. Virtual Microscopy in Histology and Histopathology teaching

Virtual microscopy in histology teaching refers to the use of digital technology to replicate the experience of using a traditional microscope for educational purposes. It involves capturing high-resolution images of histological slides and making them accessible through a computer or other digital devices.

With virtual microscopy, students can view and explore histological slides at their convenience without the need for physical microscopes or glass slides. These digital slides can be accessed through specialized software or online platforms designed for histology education.

Virtual microscopy offers several benefits in histology teaching. Here are a few advantages:

Accessibility: Virtual microscopy allows students to access a wide range of histological slides from anywhere and at any time, as long as they have an

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internet connection. It eliminates the need for physical slides and microscopes, making it more convenient for both students and educators.

Enhanced learning experience: Digital slides offer high-resolution images that can be zoomed in or out, providing students with detailed views of cellular structures. This enhances their ability to identify and understand histological features, improving their overall learning experience.

Interactivity: Virtual microscopy platforms often provide interactive features such as annotations, labels, and pointers that help students focus on specific structures or areas of interest. They can also include additional educational resources like audio/video explanations or quizzes to further engage students in the learning process.

Collaboration: Digital slides can be easily shared and accessed by multiple students simultaneously. This allows for collaborative learning and discussion, as students can annotate slides, share their observations, and engage in virtual discussions with peers and instructors.

Preservation of slides: Physical histological slides are prone to damage, loss, or deterioration over time. Virtual microscopy eliminates these concerns by digitizing the slides, ensuring their long-term preservation and availability for future reference.

Overall, virtual microscopy in histology teaching offers a versatile and efficient way to engage students in the study of cellular structures and tissue morphology. It provides an interactive and accessible platform that enhances learning, collaboration, and the overall educational experience in the field of histology.

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While virtual microscopy offers many benefits in histology education, it is important to consider some of its drawbacks and potential problems:

Lack of Haptic Feedback: Virtual microscopy cannot replicate the tactile experience of using a physical microscope. The ability to feel and manipulate the slide, adjust focus, and perceive depth through haptic feedback is lost in the digital environment. This tactile feedback can be valuable in developing fine motor skills and spatial understanding, essential in histological analysis.

Limited Real-Time Interaction: Virtual microscopy platforms may have limitations in providing real-time interactions. Students may face delays or difficulties in navigating the digital slides, adjusting magnification, or accessing specific regions of interest. This can affect the flow of the learning process and hinder spontaneous exploration of histological features.

Technical Requirements and Access: Virtual microscopy relies on computer technology and internet connectivity. Access to suitable devices, software, and a stable internet connection may pose challenges for some students, especially those from economically disadvantaged backgrounds or regions with limited infrastructure. Technical issues or compatibility problems with different operating systems or devices can also hinder the learning experience.

Loss of Whole Slide Context: Virtual microscopy often involves viewing high-resolution images of individual fields or regions of a histological slide. This approach may limit the ability to appreciate the entire context of the tissue sample. Students may miss the overall architecture and relationships between different regions of the slide, which can be crucial in understanding tissue organization and identifying abnormal features.

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Lack of Physical Slide Examination: Virtual microscopy eliminates the opportunity to examine physical slides under different lighting conditions, which can provide valuable information about the staining quality and structural characteristics. Observing slides under different light sources, such as polarized light or phase contrast, may reveal additional details that are not easily replicated in the digital format.

Loss of Authenticity: Virtual slides may not capture the exact appearance of the original histological samples due to variations in image quality, color representation, or resolution. This loss of authenticity may impact the accuracy and realism of the learning experience, especially when it comes to subtle histological features or artifacts that are challenging to replicate digitally.

Despite these drawbacks, virtual microscopy remains a valuable tool in histology education, particularly when used in conjunction with traditional microscopy. Combining virtual microscopy with hands-on laboratory experiences can help mitigate some of these limitations and provide a more comprehensive learning environment.

2. Mapping research (literature review) of the use of VM in Histology and Histopathology teaching.

While developing WP2 in this project, we conducted extensive research on the current publications on the topic. Before focusing on the situation of each of the partner countries presented in the national reports, we decided to explore the general literature available. Figure 1 shows the increased interest in the field of VM applied to histology and histopathology teaching. We found 521 papers with the use of the keywords ("virtual" AND ("microscope" OR "microscopy") AND "histology").

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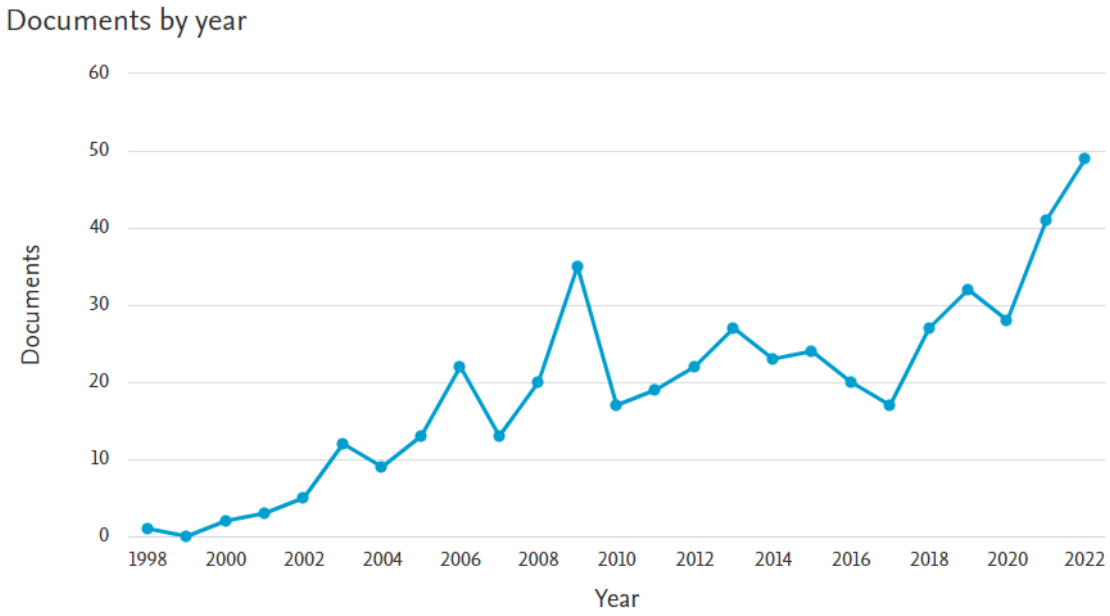

Figure 1. Number of publications per year on VM in teaching Histology after a search on SCOPUS with the keywords combination ("virtual" AND ("microscope" OR "microscopy") AND "histology")

After reviewing the list of publications, we selected those more related to the exact purpose of the project. As a result, table 1 shows the main characteristic of the 49 articles selected in this stage of the mapping research.

Table 1. Bibliographic References used on the mapping research.

DOI or bibliographic reference.	Year of publication.	Region (EU, Country of a Partner, Other Countries)
https://doi.org/10.1002/ar.b.10037	2003	USA
https://doi.org/10.1002/ar.b.20066	2005	USA
https://doi.org/10.1186/1746-1596-3-S1-S10	2008	
https://doi.org/10.1016/j.acthis.2008.09.003	2009	
https://doi.org/10.1016/j.humpath.2009.04.010	2009	USA
https://doi.org/10.1016/j.aanat.2010.01.008	2010	
https://doi.org/10.4415/ANN_10_02_07	2010	
https://doi.org/10.1186/1746-1596-5-73	2010	Europe - Hungary
https://doi.org/10.1038/modpathol.2009.190	2010	

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https://doi.org/10.4415/ANN_10_02_03	2010	
https://doi.org/10.1186/1746-1596-6-S1-S13	2011	Poznan, Poland
https://doi.org/10.5858/135.2.211	2011	
https://doi.org/10.1186/1472-6920-11-4	2011	USA
https://doi.org/10.1002/ase.262.	2011	USA
https://sciendo.com/pdf/10.2478/v10052-011-0003-4	2011	EU Poland
https://doi.org/10.1111/j.1600-0463.2011.02869	2012	Europe- Nothern Ireland
https://doi.org/10.1002/ase.1353	2013	
https://doi.org/10.1002/ase.1350	2013	USA
https://doi.org/10.1002/ase.1353	2013	Europe- Belgium
https://doi.org/10.1186/s13000-014-0208-6	2014	
http://dx.doi.org/10.1016/j.humpath.2014.06.007	2014	
http://hdl.handle.net/10045/49169	2015	Europe - Spain
http://drj.mui.ac.ir/index.php/drj/article/view/1870	2017	India
https://doi.org/10.1002/ase.1844	2018	
https://doi.org/10.1002/ase.1774	2018	
https://doi.org/10.1097/JPA.0000000000000198	2018	
https://doi.org/10.21815/JDE.018.084	2018	Brazil
https://doi.org/10.1002/ase.1774	2018	USA
https://doi.org/10.1111/eje.12410	2018	Europe - Czech Republic & Austria
https://doi.org/10.21315/eimj2019.11.4.5	2019	
https://doi.org/10.1002/ase.1940	2019	Taiwan
https://doi.org/10.1109/ISETC50328.2020.9301150	2020	Europe - Romania
https://doi.org/10.1109/ISETC50328.2020.9301122	2020	Europe - Romania
https://doi.org/10.1109/EHB50910.2020.9280225	2020	Europe - Romania
https://doi.org/10.32015/JIBM/2020-12-1-8	2020	Europe - Romania
https://doi.org/10.4103/JMAU.JMAU_67_20	2020	Saudi Arabia, Egypt
https://doi.org/10.1016/j.jds.2021.03.011	2021	

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https://doi.org/10.1111/ahe.12765	2021	Europe -Czech Republic & Austria
https://doi.org/10.1002/ase.2072	2021	Brazil
https://doi.org/10.1002/ase.2038	2021	Australia
https://doi.org/10.18295/squmj.4.2021.009	2021	United Arab Emirates
https://doi.org/10.1177/23742895211006819	2021	USA
https://doi.org/10.21315/eimj2021.13.4.4	2021	Malaysia
https://doi.org/10.34808/x55q-sz53_dyr_roz3	2022	Europe-Poland
https://doi.org/10.1002/ase.2239.	2022	
https://doi.org/10.1016/j.acpath.2022.100059	2022	USA
https://doi.org/10.1016/j.jds.2022.04.008	2022	Taiwan
https://doi.org/10.1016/j.mjafi.2022.02.002	2022	India
https://doi.org/10.3390/diagnostics13030558.	2023	

To analyse relationships and trends in the selected articles, we used different tools to make a qualitative analysis. Figure 2 shows the grouping on different categories obtained by using the software IRIS. AI. We can see that the papers are related to the main topics of the project and aligned with the pursued objectives.

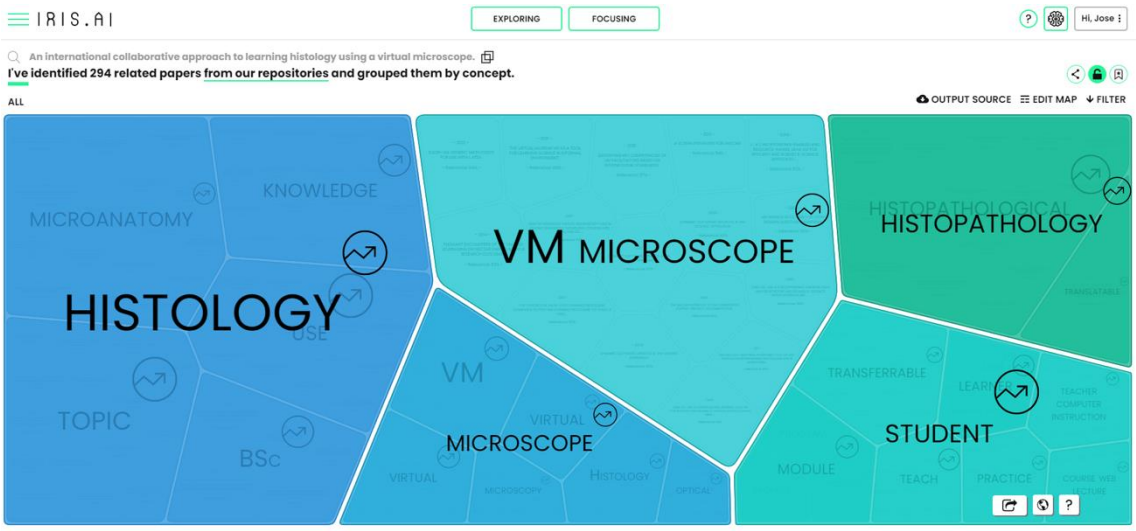

Figure 2. Mapping research result by using IRIS.AI software on the topic distribution between the selected articles.

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We also used "Connected Papers" software to study the relationship between the articles analysed. Figure 3 shows an example of the relations between the papers departing from a review article published in 2023 entitled "Virtual Versus Light Microscopy Usage among Students: A Systematic Review and Meta-Analytic Evidence in Medical Education"[3].

Figure 3. Relationships between research papers as shown by using Connected Papers software.

From the analysis of the connections, we can observe a huge impact of the COVID-19 situation, with a significative increase in the interest and impact of the use of VM for teaching purposes.

[3] Maity, S., Nauhria, S., Nayak, N.P., Nauhria, S., Coffin, T., Wray, J., Haerianardakani, S., Sah, R., Spruce, A., Jeong, Y., Maj, M.C., Sharma, A., Okpara, N., Ike, C.J., Nath, R., Nelson, J., & Parwani, A. (2023). Virtual Versus Light Microscopy Usage among Students: A Systematic Review and Meta-Analytic Evidence in Medical Education. Diagnostics, 13. https://doi.org/10.3390/diagnostics13030558

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3. Experts group on the use of VM in Histology and Histopathology teaching.

3.1. Methodology of the interview questionnaires applied.

One of the objectives of this work package was to conduct Institutional research to discuss and collect data on VM potential use in their teaching practices. The first step was to create an Expert Group of didactic staff in the discipline. For this purpose, we contacted and enrolled a group of 35 experts with experience teaching both Histology and Histopathology. They were distributed between the countries of the partners groups as it is shown in Table 2.

Table 2. Distribution of Experts between the partner's country.

Partner	Country	Number of Experts participating
P1: "Grigore T. Popa" University of Medicine and Pharmacy, Iasi	Romania	10
P2: Gdanski Uniwersytet Medyczny	Poland	15
P3: Meditcinsky Universitet-Plovdiv	Bulgaria	5
P4: Universidad de Alicante	Spain	5

In collaborative work, all the partners elaborate on the tool for the institutional research by interviewing the Experts through a questionnaire. The questionnaire comprised 16 items, 10 Likert scales, 2 multiple choice and 4 open-answer questions. Here we reproduce the questionnaire provided to each expert through a Google form. The final structure of the questionnaire was as follows:

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	Totally disagree	disagree	neutral	agree	Totally agree
1. I am familiar with VM technology and VM based teaching.	1	2	3	4	5
2. I would be interested in accessing a free VM library to improve my knowledge of histology or histopathology.	1	2	3	4	5
3. VM will increase my/the student's understanding of the histological sections.	1	2	3	4	5
4. VM may strengthen the teacher-student relationship.	1	2	3	4	5
5. It would be helpful for students to introduce a VM tutorial on using the digital slide platform in the introductory lecture on histology.	1	2	3	4	5
6. It would be useful to introduce the Multiple Choice Questions MCQ / quiz section regarding virtual slide understanding for self-testing the student's level in histology & histopathology.	1	2	3	4	5
7. I would like to contribute with my collection of slides to a VM library of histology, cytology and histopathology.	1	2	3	4	5
8. A VM system, accessible outside a limited institutional frame, can be prone to electronic fraud and IT hacking.	1	2	3	4	5
9. Virtual microscopy will reduce the time for studying the histological sections.	1	2	3	4	5
10. I prefer a "whenever and wherever" method of education	1	2	3	4	5

11. Do you use a slide collection for histology / histopathology (in classes, in the office or at home)?

____ Yes ____ No

12. If available, which of the three methods would you apply to your teaching?
(VM= Virtual Microscopy LM= Light microscopy)
___ A. only VM. ___ B. VM and classical slides LM ___ C. only LM

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Justification of the answer (optional):

13. In your opinion, what are the advantages of virtual microscopy over conventional microscopy?

14. What hardware and software limitations can a teacher have?

15. What hardware and software limitations can a student have?

16. In your opinion, what would be the limitations of applying VM in the curricula of a histology and histopathology teaching program?

3.2. Overall analysis of the applied interview questionnaire

Q1. 92% answered that they are familiar with VM technology and VM-based teaching. Only 2% of the experts declared it partially familiar (Fig 4).

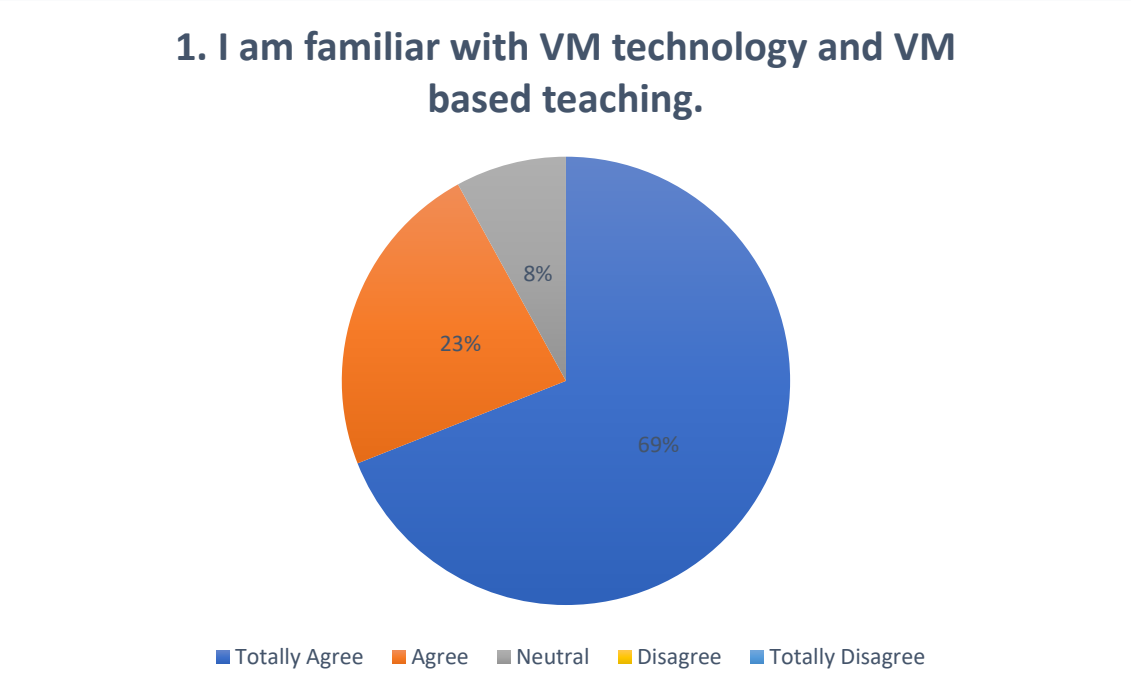

Fig 4. Q1 of the questionnaire.

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Q2: All respondents answered that they would be interested in accessing a free VM library to improve their knowledge of histology and histopathology (Fig. 5).

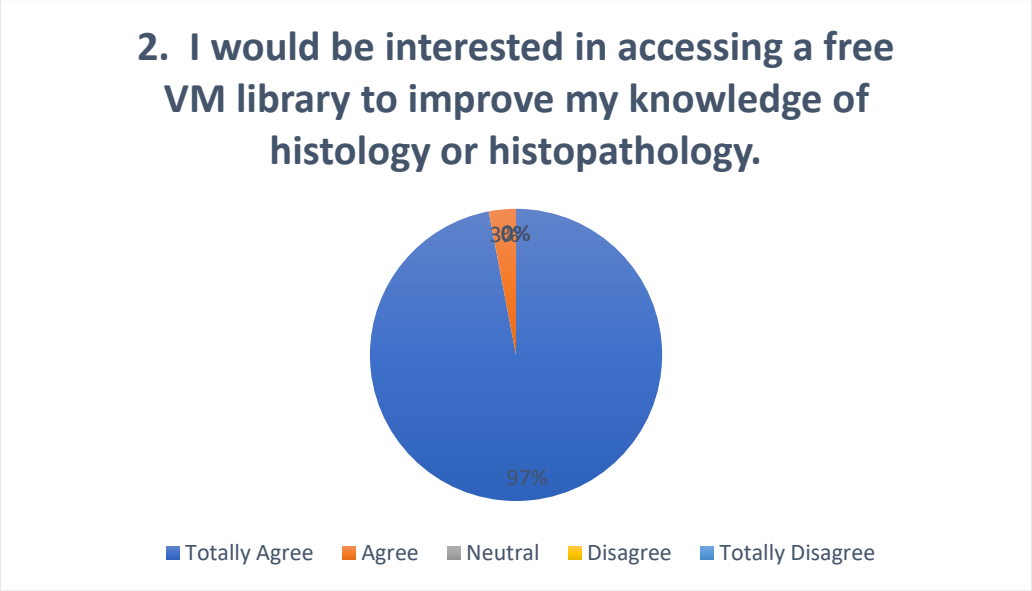

Fig 5. Q2 of the questionnaire.

Q3: All respondents answered that VM will help students understanding of the histological structures of the different tissues (Fig. 6).

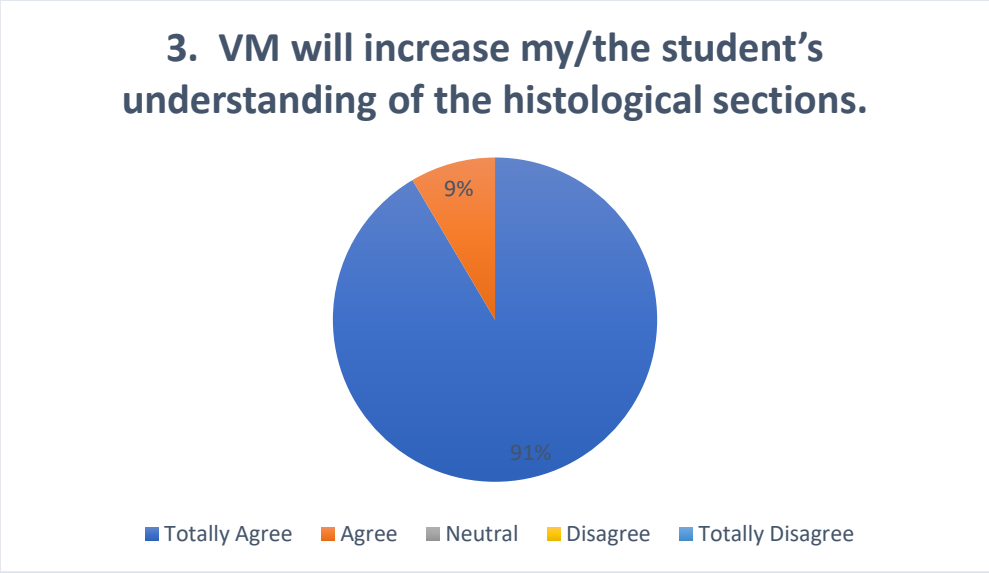

Fig 6. Q3 of the questionnaire.

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Q4: There is less consensus on the impact of VM on the teacher-student relationship (Fig. 7).

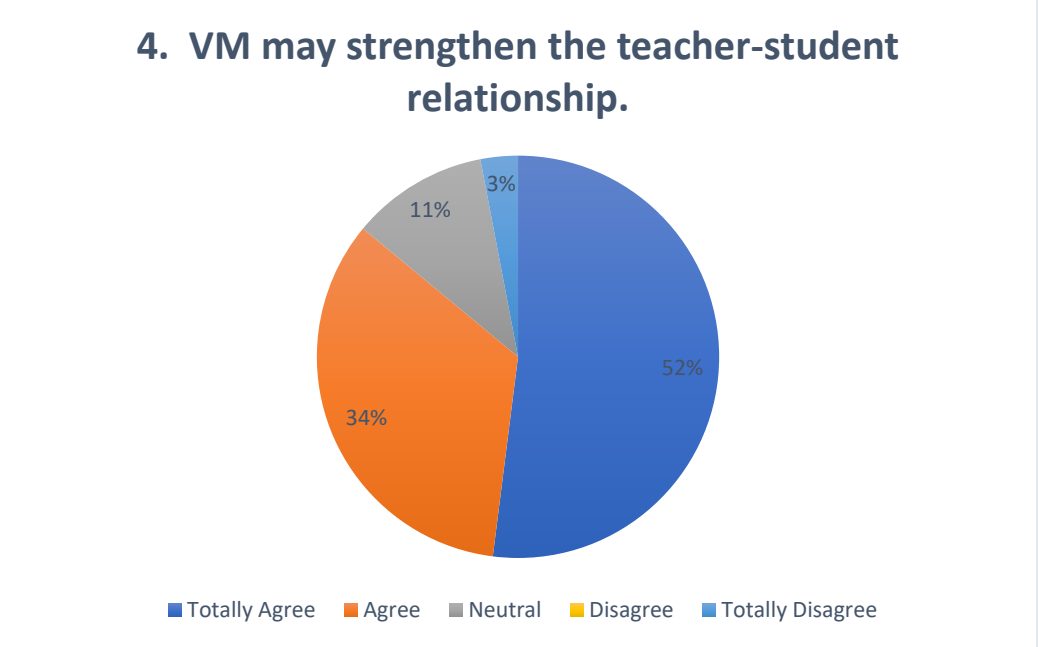

Fig 7. Q4 of the questionnaire.

Q5: All the experts except one answered that it would be helpful for students to have a tutorial on using the digital slide platform (Fig. 8).

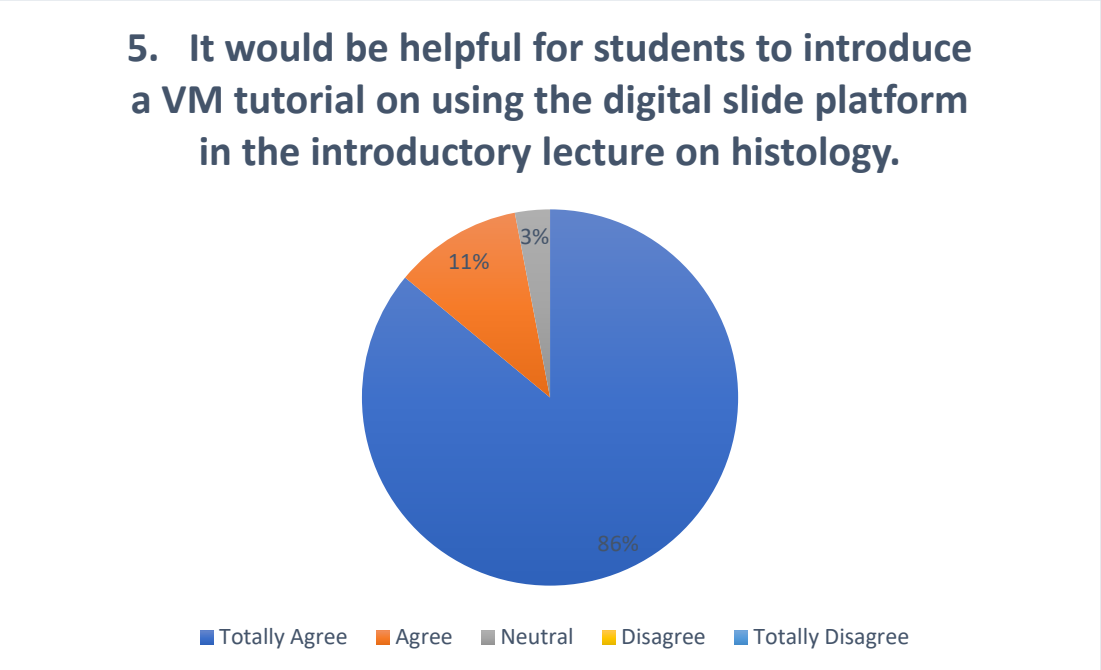

Fig 8. Q5 of the questionnaire.

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Q6: All the experts see it necessary to introduce Multiple-Choice Questions MCQ / quiz section for self-testing in the VM platform (Fig. 9).

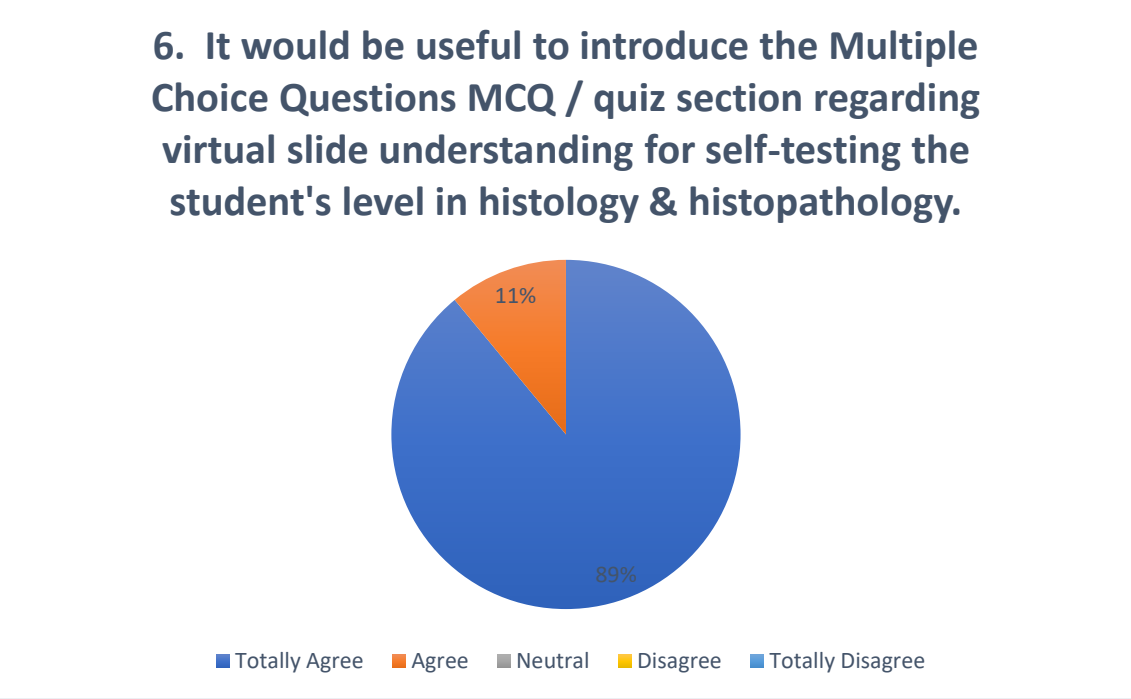

Fig 9. Q6 of the questionnaire.

Q7: The majority of the responders would like to contribute providing their own collection of slides, to a VM library of Histology, Cytology and Histopathology. (Fig. 10).

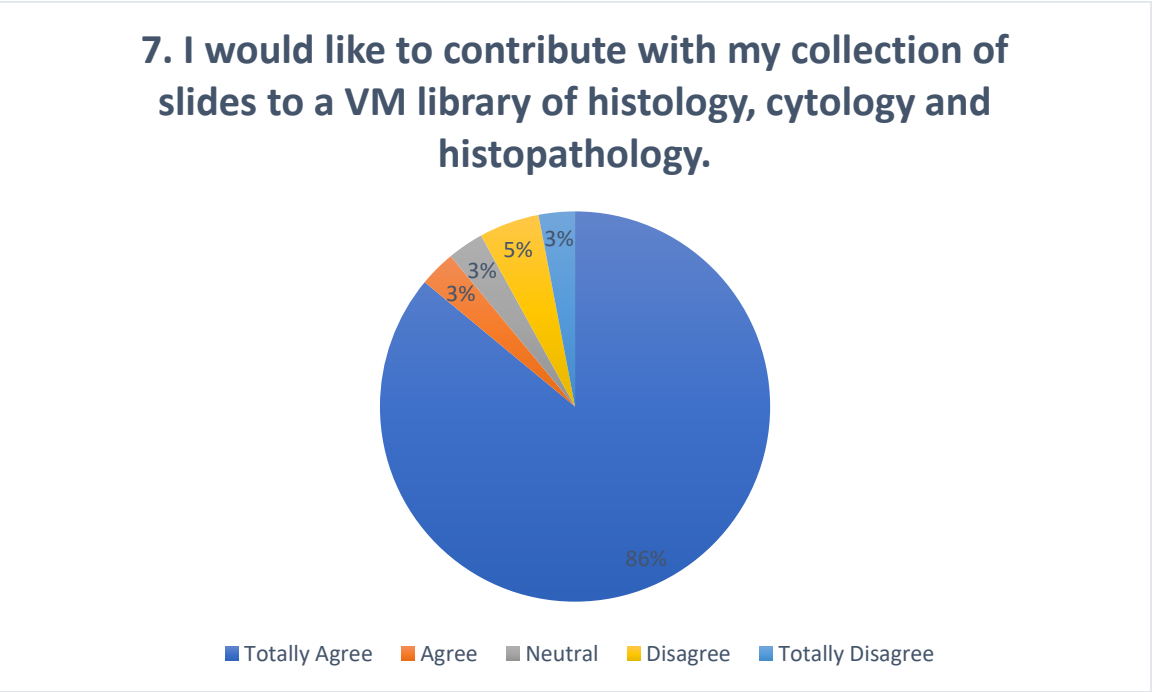

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Fig 10. Q7 of the questionnaire.

Q8: There is no consensus on the security risks of a VM platform. The majority of responders thinks that the risk is medium-high (Fig. 11).

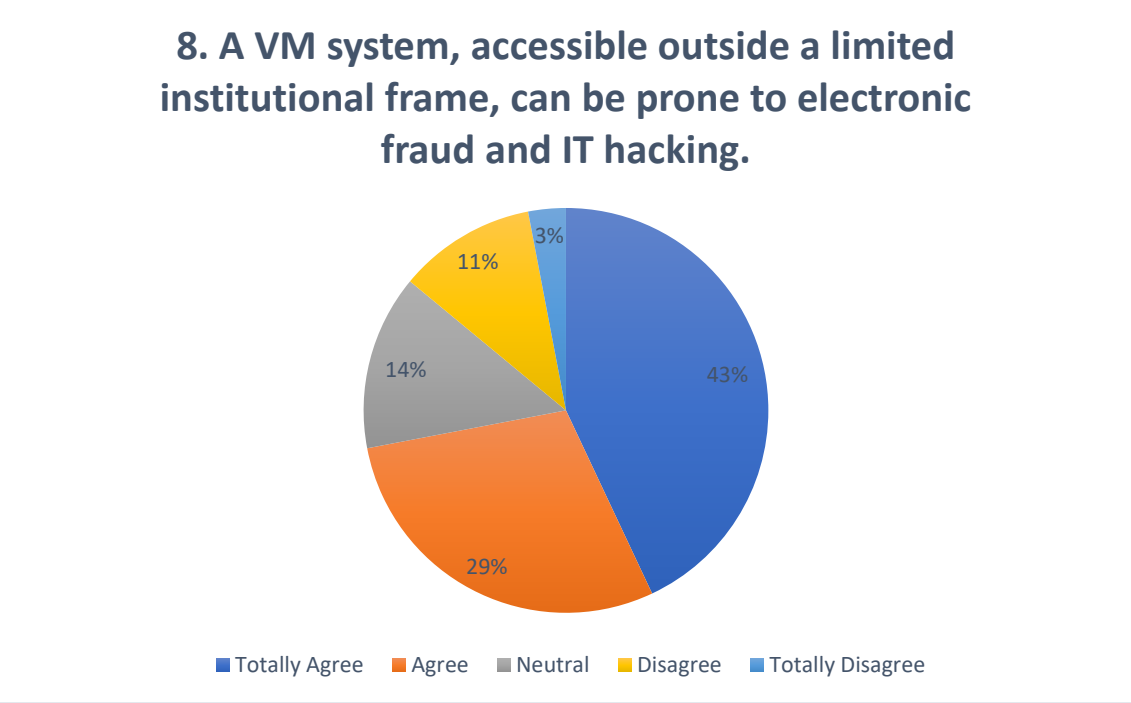

Fig 11. Q8 of the questionnaire.

Q9: The majority of responders thinks VM will reduce the study time of histological sections (Fig. 12).

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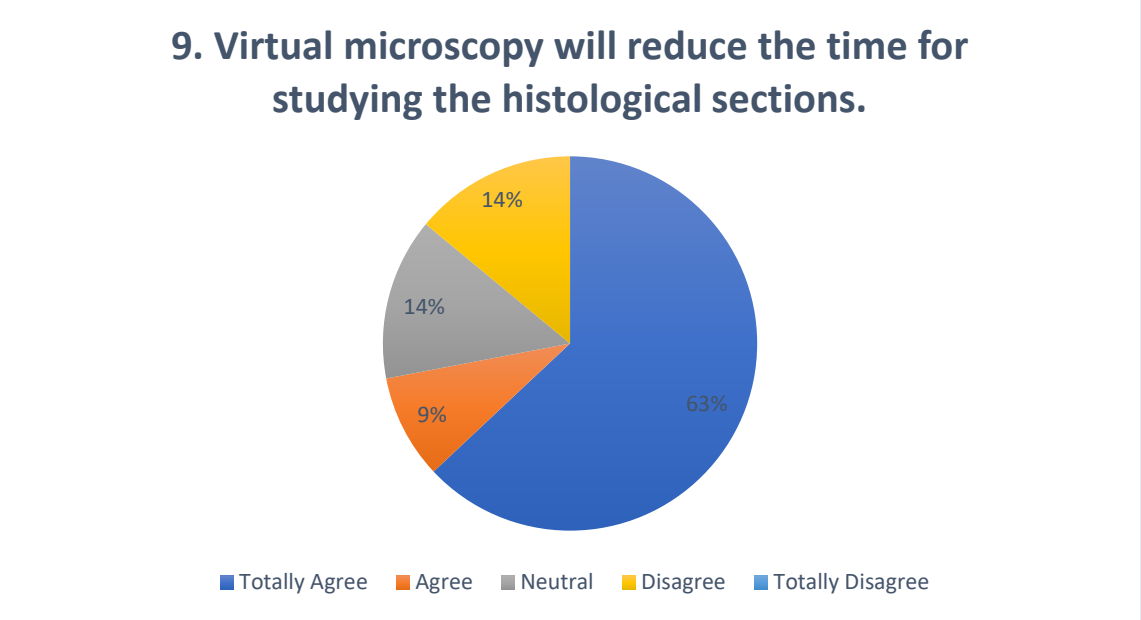

Fig 12. Q9 of the questionnaire.

Q10: There is no consensus regarding the type of education. Even there is a tendency to favor self-learning by students, there is not a clear positioning of the experts (Fig. 13).

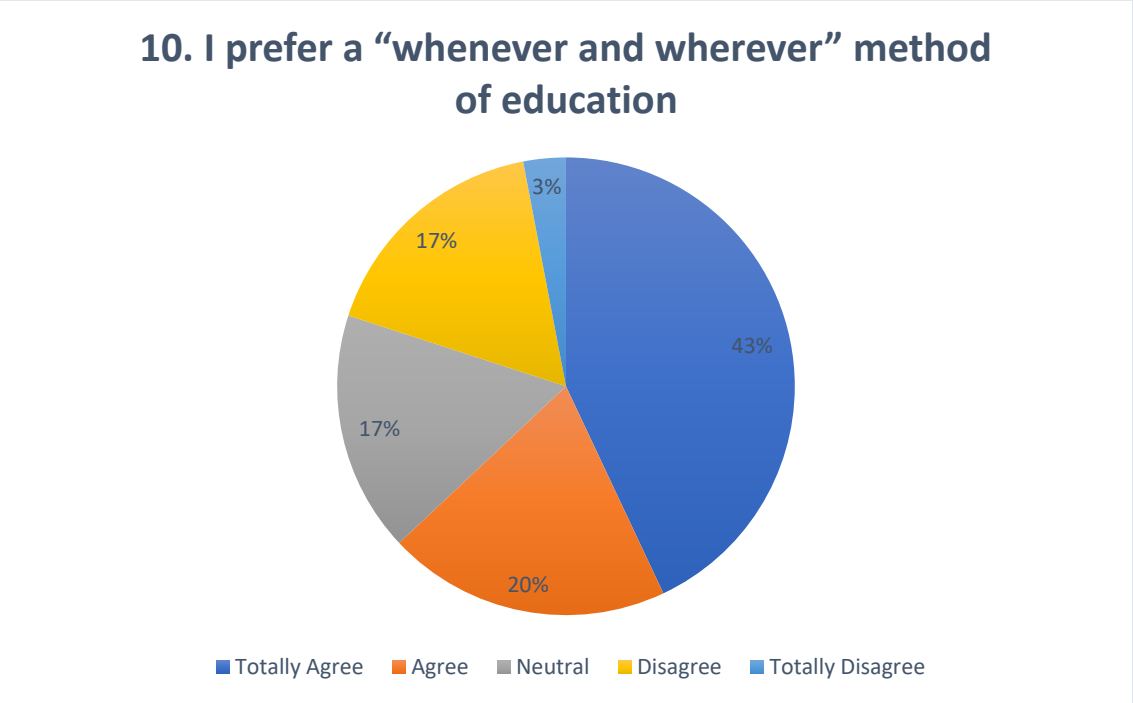

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Fig 13. Q10 of the questionnaire.

Q11: All the responders say they use a slide collection for histology/ histopathology, which is according with their condition of experts.

Q12: All the Experts considered better a combination of both VM and traditional Light microscopy practices.

The national reports show the answers in each one of the countries. From the open-answer questions we can make a general analysis. Particularly of Q13 we can observe a prevalence in some terms as it is shown on figure 14.

Figure 14. Word cloud analysis of the responses to Q13 of the questionnaire.

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