IJAE
ITALIAN JOURNAL OF ANATOMY AND EMBRYOLOGY

Firenze University Press
www.fupress.com/ijae

Citation: Alberti, P. (2024). 3D Digital tools in neuro-anatomy teaching: from *peer-to-peer* tutoring to clinically oriented approaches. *Italian Journal of Anatomy and Embryology* 128(2): 125-134. https://doi.org/10.36253/ijae-15763

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

3D Digital tools in neuro-anatomy teaching: from *peer-to-peer* tutoring to clinically oriented approaches

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Abstract. Neuroanatomy knowledge is pivotal due to the constantly increased use of neuroimaging in everyday clinical practice, even in the emergency setting as it is for patients potentially affected by stroke. To empower our students, we are relying on innovative 3D digital tools to teach human anatomy, exploiting several approaches among which *Anatomage Table*™, also fostering a *peer-to-peer* tutor program. We present here the results of a pilot phase of these initiatives. First year med students from the Italian and International Course used *Anatomage Table*™ under the supervision of fourth-, fifth-, or sixth-year med students, as *peer-to-peer* tutors. Participants were divided into groups (10-12 people each). Three sessions lasting 2 hours were planned with a predefined topic: thorax (topic 1), abdomen/pelvis (topic 2), neuroanatomy (topic 3). A questionnaire was filled at the end of each session rating satisfaction/impact. One-hundred-thirty students (105 from the Italian course and 25 from the international course) participated. More than 90% of students rated the neuroanatomy session as highly satisfactory and more than 95% as highly useful, and 100% of them would suggest others participate. Based on these results, a further implementation is planned for the next year, also exploiting DICOM data to present the students with real clinical cases bearing a highly didactive anatomical content. Specifically, in the international course, based on a vertical track approach, we are also strongly relying on flipped-classroom approach. Digital tools to teach neuroanatomy are also being implemented for clinically oriented teaching for residents/consultants.

Keywords: human anatomy, virtual dissection, innovative teaching methods, Anatomage™ table, peer-to-peer tutoring.

INTRODUCTION

Neuroanatomy is pivotal in the daily management of patients affected by disorders involving the central and/or the peripheral nervous system: a detailed and robust understanding of neuroanatomical aspects is an essential guide to correctly perform and interpret the neurological examination and then appropriately run diagnostic exams, since most of them have a high neuroanatomical correlation, such as neuroimaging [1-5] (Computer Tomography [CT] scan, magnetic resonance imaging [MRI], nuclear medicine techniques, and ultrasounds [US]) and neurophysiological techniques [6].

Moreover, neuroanatomy has gained an even more relevant role in everyday clinical practice and not only for specialties directly related to neuro-psychiatric disorders (e.g., neurology, neurosurgery, psychiatry, childhood psychiatry/neurology, neuroradiology, …), given advancements in acute stroke care [7-10]: thrombolytic agents as well as mechanical recanalisation of large blood vessel occlusions have been a game changer in acute ischemic stroke management. This led to the implementation of an emergency system that involves different health-care professionals, making not-negotiable a robust neuroanatomical knowledge (https://www.agenas.gov.it/comunicazione/primo-piano/2233-reti-ictus-presentazione-relazione-conclusiva-del-board-agenas).

Another example of a wider use of neuroanatomy by health care professionals different from neurologists/neurosurgeons is the implementation of US to study the peripheral nervous system: on top of the most obvious diagnostic application for diagnosis of neuropathy [3,4], US can be used, in fact, to guide procedures such as local anesthesia and pain management targeting a specific branch of the peripheral nervous system [11-14].

Therefore, this highlights once again the relevance of neuroanatomy for a broader audience of health care providers. To build a robust knowledge, not faltering over the years, exposure to clinically oriented neuroanatomy is essential as soon as the first years of training, possibly relying on advanced, innovative and digital approaches, especially in the lack of easy access to a fully-equipped dissection facility; in Italy, in fact, despite the approval in 2020 of a law on body donation [15], it is still difficult in most Centers to widely implement real dissections in all human anatomy teachings.

In our University, *Anatomage Table*^{TM} has been implemented in the last few years: *the Anatomage Table*^{TM} Software (*Anatomage Inc.*, Santa Clara, California, US) allows 3-D reconstructions of 5 different segmented cadavers, enabling hands-on virtual dissections. Moreover, it contains (in its own case library) and allows the upload of Digital Imaging and Communication in Medicine (DICOM) data to be then reconstructed with photorealistic filters.

We present here a pilot experience relying on digital instruments, aiming at enabling students to be an active element in the process of learning via a *peer-to-peer* tutoring activity.

METHODS

Population

First year students in Medicine and Surgery were offered the opportunity to participate in this initiative as an extracurricular, not mandatory, activity. Students were enrolled from the two different master's degrees in medicine and surgery available at our university: the standard course, named from now as the *Italian* course, and the *International* course (all teaching activities are carried out in English language). In the former, students receive human anatomy teachings as a single course during the first year, equivalent to 20 European Credit Transfer and Accumulation System (ECTS), with a horizontal track approach. Whereas, in the latter students are given a more basic course during the first year, named *Fundamentals of Human Morphology* (8 ECTS), and receive further human anatomy teachings in the subsequent years with a vertical track approach; this means, as an example, that in the Neuroscience vertical track, students will receive 4 more ECTS only on neuroanatomy.

Peer-to-peer tutors' selection and training

Both cohorts were given the opportunity to take part in *peer-to-peer* activities during the second semester of the first year, after the topics were already covered in frontal lessons. They were allowed to actively cooperate with a fourth-, fifth-, or sixth-year med student, among a pool of nine tutors who were selected via a public call among those who already passed the human anatomy full exam. Tutors participated in 10 hours of training and were then available for 2-hours sessions (10 each). *Peer-to-peer tutor* training was performed both on-line and on-site. Tutors independently completed a training course available on *Anatomage Share – Training Portal*, provided by *Anatomage Inc*. free of charge (https://www.anatomageshare.com/training-portal) and a 1-hour zoom call was scheduled to revise together the main functionalities. The on-site training was then performed directly on *Anatomage Table*^{TM}: the first 2 hours were intended to make tutors confident in using all the functions of the tools and other sessions were then organised with a professor to harmonise all tutors' actions for the three different topics to be revised with students (see the following section). The instructor devised a well-defined workflow for all the topics and prepared presets/selected specific visualization to maximize the impact of all activities and ensure all students received the same information regardless of the tutor they worked with. All tutors were provided with detailed instructions on the workflow to be followed.

Activities organisation

Students from the Italian cohort were named as *Cohort-ITA* and ones from the international course as *Cohort-ENG*; activities were held separately for the two cohorts, since for *Cohort-ENG* all activities were carried out in English language, while for Cohort-ITA in Italian language. Participants from both cohorts were divided into groups (no more than 10-12 students each). Three sessions lasting two hours were planned. The first session was mostly dedicated to revising the thorax region and the hearth (*Topic 1*), in the second session the abdomen/pelvis regions were revised (*Topic 2*), and in the third session neuroanatomy was revised (*Topic 3*).

Data collection and analysis

Data was collected anonymously via a Google module made accessible via a QR code. Participants were asked to fill in a questionnaire before starting the first session and at the end of each session, using their cell phones. Questions were meant to explore the impact and satisfaction of the initiatives carried out. The same grading system (on a 0-10 scale) used by our university to rate students' opinion on didactic activities was followed (https://opinionistudenti.unimib.it/valdid/): low (0-4), intermediate (5-7), and high score (8-10).

A descriptive statistic of all quantitative data was generated and differences among different topics/cohorts were tested with parametric test or non-parametric test based on the distribution of the data (normally or not normally distributed respectively), setting a 2-sided test (significance at p-value 0.05).

RESULTS

Overall, 130 students took part into the initiative: 105 (62%) students of Italian course and 25 (52%) of the international course. In Table 1 satisfaction and usefulness descriptive statistics and Mann-Whitney U-test results are presented.

Preliminary survey before starting the first session

Before starting Topic 1 activities, students were asked about the frequency of their use of the anatomy room for independent study: we obtained 47 replies from Cohort-ITA and 21 replies from Cohort-ENG (results are summarised in Figure 1). For what regards Cohort-ITA: 55.4% never used the room and did not plan to use it later in the semester, 19.1% never used the room but planned to use it later in the semester, 14.9% already used rarely the anatomy room for independent study, 10.6% did not know they could use the room for independent study. For what regards Cohort-ENG: 57.1% never used the room but planned to use it later in the semester and 42.9% did not know they could use the room for independent study. The perceived usefulness of the current opportunity offered by the anatomy room (i.e., without the possibility of exploiting *Anatomage™ Table*) was also tested (see Figure 2): the median

Table 1. Descriptive statistics and Mann-Whitney U-test results for the survey questions assessing satisfaction and perceived usefulness.

Item	Cohort	Time point	Median score	Q1	Q2	Mann-Whitney U-test (p-value)
Perceived usefulness of the anatomy room with no use of the Anatomage™ table	Cohort-ITA	T_0	7	5	8	0.9493
Perceived usefulness of the anatomy room Anatomage™ table	Cohort-ENG	T_0	7	4.5	8	
Satisfaction regarding the presented topic	Cohort-ITA	T_1	9	8.5	10	0.3576
Satisfaction regarding the presented topic	Cohort-ENG	T_1	9	8	10	
Perceived usefulness of the presented topic	Cohort-ITA	T_1	9	8	10	0.6378
Perceived usefulness of the presented topic	Cohort-ENG	T_1	9	8	10	
Satisfaction regarding the presented topic	Cohort-ITA	T_2	10	9	10	**0.0481**
Satisfaction regarding the presented topic	Cohort-ENG	T_2	9	8	10	
Perceived usefulness of the presented topic	Cohort-ITA	T_2	10	9	10	**0.0276**
Perceived usefulness of the presented topic	Cohort-ENG	T_2	9	8	10	
Satisfaction regarding the presented topic	Cohort-ITA	T_3	9	8	10	0.5795
Satisfaction regarding the presented topic	Cohort-ENG	T_3	9	8	10	
Perceived usefulness of the presented topic	Cohort-ITA	T_3	9	8	10	0.5683
Perceived usefulness of the presented topic	Cohort-ENG	T_3	9	8.5	10	

T_0: before starting the whole initiative; T_1: after completing Topic $_1$; T_2: after completing Topic 2; T_3: after completing Topic 3.

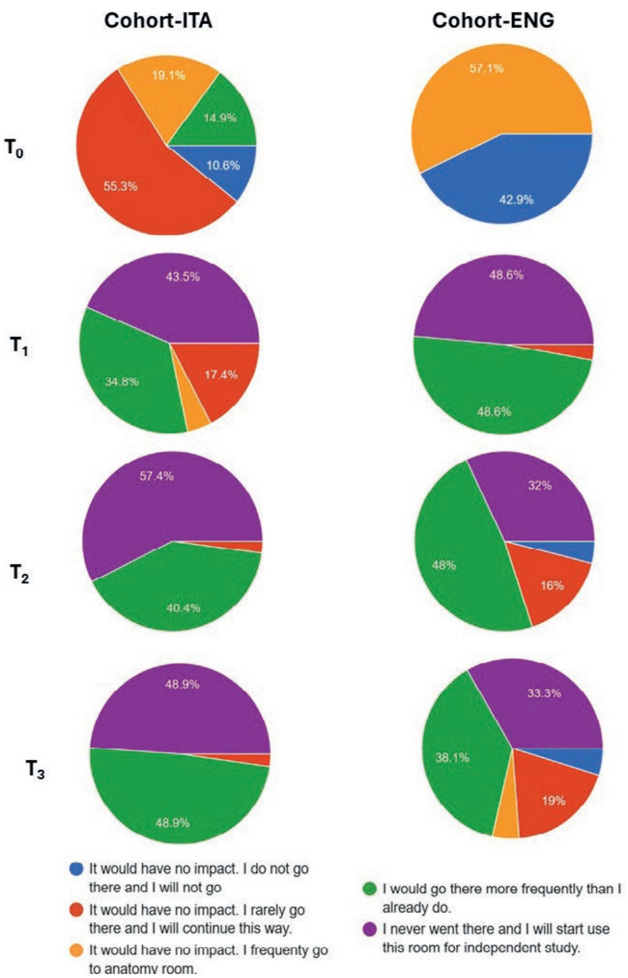

Figure 1. Willingness of the students to use the anatomy room for independent study. T_0: before starting the initiative; T_1: after completing Topic $_1$; T_2: after completing Topic 2; T_3: after completing Topic 3.

score assigned by Cohort-ITA was 7 (Q1:5; Q3: 8) and by Cohort-ENG was also 7 (Q1: 4.5; Q3: 8); more in details: 8% of Cohort-ITA assigned a low score (i.e., score values 0-3), 58% an intermediate score (i.e., score values 4-7), and 34% a high score (i.e., 8-10), while for Cohort-ENG the proportion of different score classes were respectively 19%, 38%, 43%. No statistically significant differences were observed between the 2 cohorts.

Survey results after Topic 1 activities

After completing Topic 1 activities, level of satisfaction and usefulness were evaluated: 105 responses were collected from Cohort-ITA and 23 from Cohort-ENG. For what regards satisfaction (see Figure 3), Cohort-ITA assigned a median score of 9 (Q1: 8.5; Q3: 10), with 94% of replies being set in the highest score class and 6% in the intermediate score class; whereas, Cohort-ENG assigned a median score of 9 (Q1: 8; Q3: 10), with 96% of replies being set in the highest score class and 4% in the intermediate score class. No statistically significant differences were observed between the 2 cohorts.

For what regards perceived usefulness, Cohort-ITA assigned a median score of 9 (Q1: 8; Q3: 10), with 86% of replies being set in the highest score class and 12% in the intermediate score class; whereas, Cohort-ENG assigned a median score of 9 (Q1: 8; Q3: 10), with 96% of replies being set in the highest score class and 4% in the intermediate score class. No statistically significant differences were observed between the 2 cohorts.

Participants were then asked if they would implement more independent study in the anatomy room if the *Anatomage^{TM} table* was made available. Cohort-ITA replies can be summarised as follows: 48.6% stated that would increase the frequency of their access shifting from no access at all to going to the anatomy room for

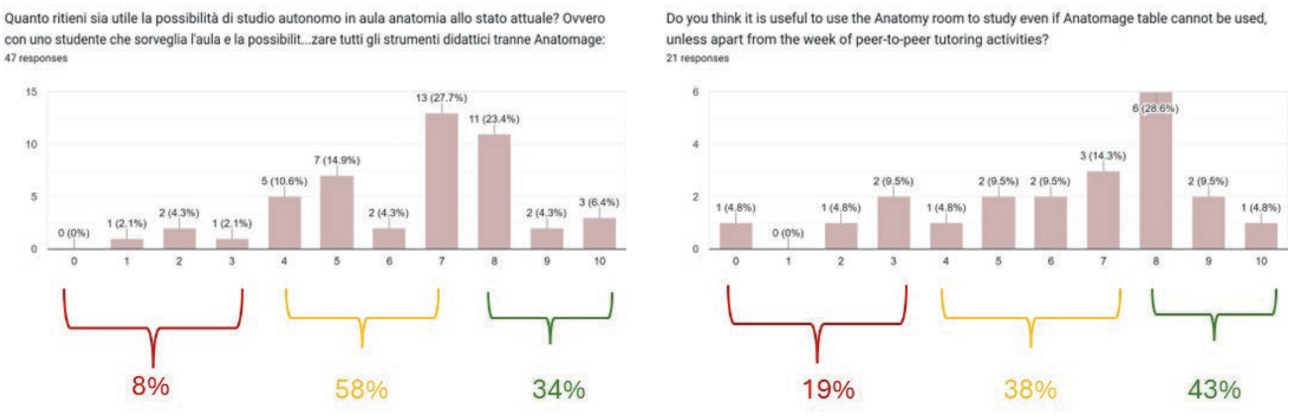

Figure 2. Perceived usefulness of the access in the anatomy room without the opportunity to use the *Anatomage Table^{TM}*.

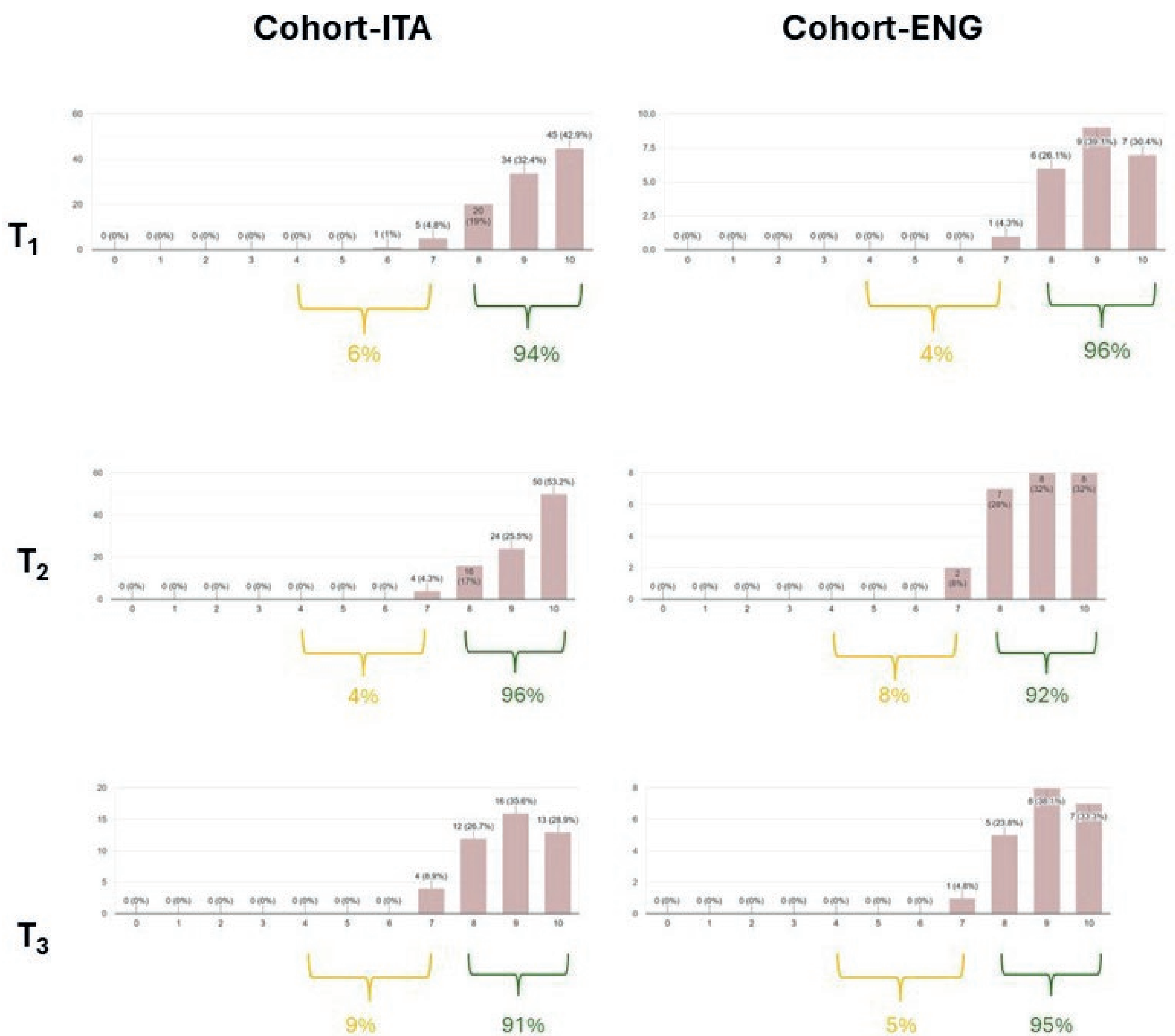

Figure 3. Satisfaction of the students regarding the activities. T_0: before starting the initiative; T_1: after completing Topic $_1$; T_2: after completing Topic 2; T_3: after completing Topic 3.

independent study if this tool were to be made available, 48.6% stated that would increase the frequency of their access shifting from rare access to a more frequent access, 2.8% stated that they rarely used the room and the frequency of access would be the same. Cohort-ENG replies can be summarised as follows (see Figure 1): 43.5% stated that would increase the frequency of their access shifting from no access at all to going to the anatomy room for independent study if this tool were to be made available, 34.8% stated that would increase the frequency of their access shifting from rare access to a more frequent access, 17.4% stated that no impact on the current frequency (rare) of access would be in place, and 4.3% % stated that no impact on the current frequency (quite frequent) of access would be in place.

Participants were also asked to state if they would suggest others participate after completing this activity: 100% replied they would in both cohorts (see Figure 5).

Survey results after Topic 2 activities

After completing Topic 2 activities, level of satisfaction and usefulness were evaluated: 94 responses were collected from Cohort-ITA and 25 from Cohort-ENG (see Figure 3). For what regards satisfaction, Cohort-

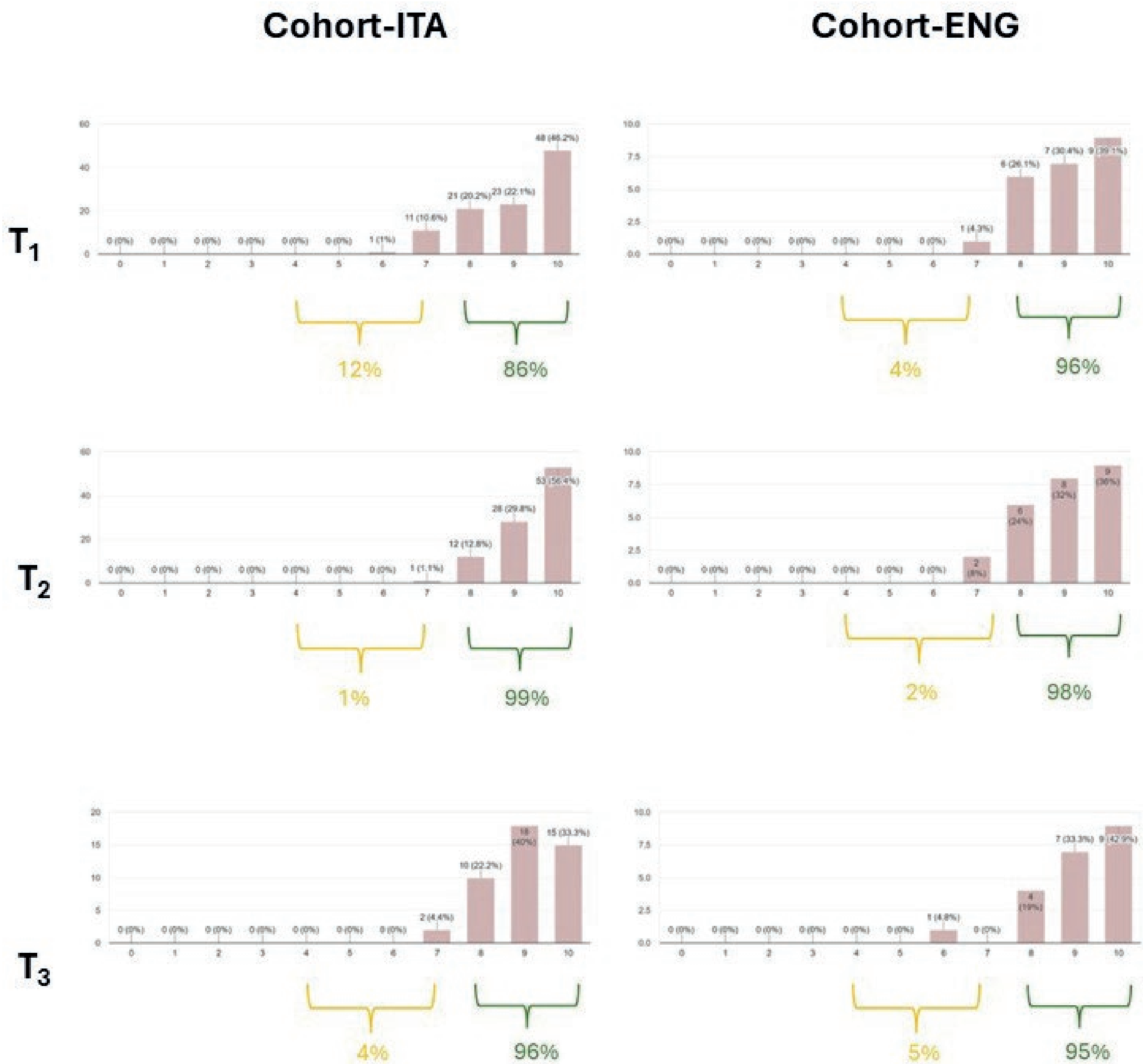

Figure 4. The usefulness of the activities perceived by the students. T_0: before starting the initiative; T_1: after completing Topic $_1$; T_2: after completing Topic 2; T_3: after completing Topic 3.

ITA assigned a median score of 10 (Q1: 9; Q3: 10), with 96% of replies being set in the highest score class and 4% in the intermediate score class; whereas, Cohort-ENG assigned a median score of 9 (Q1: 8; Q3: 10), with 92% of replies being set in the highest score class and 8% in the intermediate score class. A slight statistically significant difference we observed between the 2 cohorts (p-value: 0.0481, Mann-Whitney U-test).

For what regards perceived usefulness (see Figure 4), Cohort-ITA assigned a median score of 10 (Q1: 9; Q3: 10), with 99% of replies being set in the highest score class and 1% in the intermediate score class; whereas, Cohort-ENG assigned a median score of 9 (Q1: 8; Q3: 10), with 98% of replies being set in the highest score class and 2% in the intermediate score class. A Statistically significant difference was observed between the 2 cohorts (p-value: 0.0276, Mann-Whitney U-test).

Participants were then asked if they would implement more independent study in the anatomy room if the *Anatomage*^{TM} *table* was made available (see Figure 1). Cohort-ITA replies can be summarised as follows: 57.4% stated that would increase the frequency of their access shifting from rare access to a more frequent access, 40.4% stated that would increase the frequency of their access shifting from no access at all to going to the anatomy room for independent study if this tool were to be made available, 2.2% stated that they rarely used the room and the frequency of access would be the same. Cohort-ENG replies can be summarised as follows: 48% stated that would increase the frequency of their access, 32% stated that would increase the frequency of their access shifting from no access at all to a more frequent access, 16% stated that no impact on the current frequency (rare) of access would be in place, and 4% stated that no impact on the current frequency (no access at all) of access would be in place.

Participants were also asked to state if they would suggest others participate after completing this activity: 100% replied they would in both cohorts (see Figure 5).

Survey results after Topic 3 activities

After completing Topic 3 activities, level of satisfaction and usefulness were evaluated: 45 responses were collected from Cohort-ITA and 21 from Cohort-ENG. For what regards satisfaction (see Figure 3), Cohort-ITA assigned a median score of 9 (Q1: 8; Q3: 10), with 91% of replies being set in the highest score class and 9% in the intermediate score class; whereas, Cohort-ENG assigned a median score of 9 (Q1: 8; Q3: 10), with 95% of replies being set in the highest score class and 5% in the intermediate score class. No statistically significant differences were observed between the 2 cohorts.

For what regards perceived usefulness (see Figure 4), Cohort-ITA assigned a median score of 9 (Q1: 8; Q3: 10), with 96% of replies being set in the highest score class and 4% in the intermediate score class; whereas, Cohort-ENG assigned a median score of 9 (Q1: 8.5; Q3: 10), with 95% of replies being set in the highest score class and 5% in the intermediate score class. No statistically significant differences were observed between the 2 cohorts.

Participants were then asked if they would implement more independent study in the anatomy room if the *Anatomage^{TM} table* was made available (see Figure 1). Cohort-ITA replies can be summarised as follows: 48.9% stated that would increase the frequency of their access shifting from no access at all to going to the anatomy room for independent study if this tool were to be made available, 48.9% stated that would increase the frequency of their access shifting from rare access to a more frequent access, 2.2% stated that they rarely used the room and the frequency of access would be the same. Cohort-ENG replies can be summarised as follows: 38.1% stated that would increase the frequency of their access shifting from rare to a more frequent access, 33.3% stated that would increase the frequency of their access shifting from no access at all to a more frequent access, 19% stated that no impact on the current frequency (rare) of access would be in place, 4.8% stated that they would not start to use the room for independent study, and 4.8% stated that no impact on the current frequency (quite frequent) of access would be in place.

Participants were also asked to state if they would suggest others participate after completing this activity: 100% replied they would in both cohorts (see Figure 5).

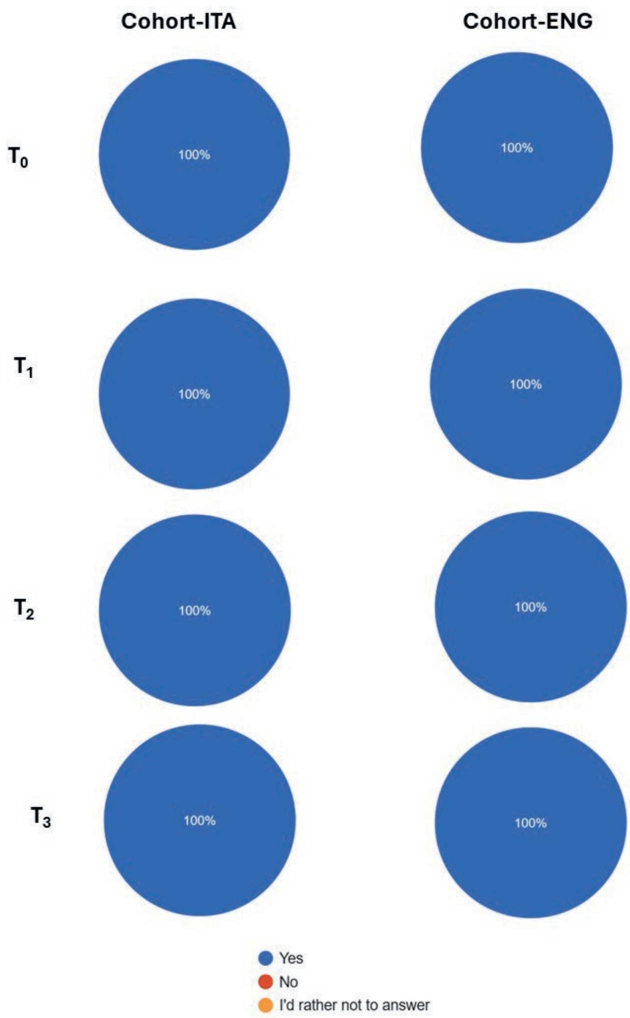

Figure 5. Replies to the question: "Would you suggest others to participate in an initiative such as this?". T_0: before starting the initiative; T_1: after completing Topic $_1$; T_2: after completing Topic 2; T_3: after completing Topic 3.

DISCUSSION

The pilot experience presented here was broader in topics than neuroanatomy, but it is a fair example of how innovative approaches could be eventually implemented in neuroanatomy teachings stemming from positive results as the ones shown above. Both cohorts, in fact, gave back a feedback rating both satisfaction and perceived usefulness as high and no item was rated in the low score category. Comparing all topics intra- and inter-cohorts emerged that *Topic 2* (abdomen/pelvis) received a slightly higher appreciation in Cohort-ITA but in general scores were more than satisfactory as already stated. Furthermore, all participants agreed on suggesting others take part in similar initiatives with no exceptions. Quite striking is also the relevant increase in access to the anatomy room if the *Anatomage^{TM} table* were to be made available for independent study, shifting for a low rate to a high rate of exploitation of this room and its tools during exam preparation. This is even more impressive for the Cohort-ENG since teachings for this course are usually located in Bergamo (Polo di Formazione Universitaria *Papa Giovanni XXIII*), while the anatomy room is in Monza (Asclepio/u8 building); therefore, students from this cohort accepted the logistic nuisance of travelling to exploit what offered in the anatomy room. The relevance of the initiative can also be perceived for both cohorts evaluating the increasing percentage of students willing to exploit the anatomy room in case *Anatomage^{TM} table* was made available for independent study.

Of course, the data presented here is just part of an exploratory study and some limitations should be recognised. First, the number of questionnaires available for evaluation each time was different for each cohort and the numerosity of the 2 cohorts is quite different, making comparison potentially less robust. Second, we measured cross-sectionally students' perceptions of the usefulness and satisfaction for the initiative, but we did not make any correlations with the final mark received at the exam and the participation or not to the initiative. Last, but not least, we did not make any comparison with other possible interactive teaching methods (e.g., paper copy exercise, use of 3D plastic models/dummies, …).

However, data presented here are in line with previous studies showing how virtual dissections and tools can enhance anatomy learning either in case of the availability of real dissections or in case they are not a feasible option [16-29]. In particular, Singer et al. [30] showed how these virtual approaches could be pivotal in enhancing engagement of students while learning anatomy, conducting a study to evaluate students' perception of virtual anatomy platforms.

Therefore, it could be suggested that this kind of approach can empower students and engage them more and provide a direct link to a clinically oriented approach in neuroanatomy exploitation in their subsequent career as health care professionals. In the past few years, in fact, *Anatomage^{TM} Table* was used to tailor approaches in different pathologies with a highly relevant anatomical impact related to the head and neck region [31-34]. More specifically related to neuroanatomy, Sadiq et al. [35] showed how case-based learning exploiting virtual 3D tools enabled to ameliorate neuroanatomy and neuroradiology teachings. Nyangoh Timoh et al. showed the potential application of digital tools to enhance the understanding and then guide clinical procedures related to the excision of endometriosis nodules of the sciatic nerve [36]. Ahmed et al. showed the potential implications of digital tools to ameliorate procedures such as anterior petrosectomy of the skull [37]. Robin et al. implemented the virtual dissection to better understand the anatomical relations between uterine veins, ureter and hypogastric nerve for uterine transplantation providing robust knowledge to proceed to such a delicate procedure [38]. Strantzias et al. [39] proposed the use of the virtual reconstruction via the Table to manage the anatomical variations of the marginal mandibular nerve during surgery. La Torre et al. [40] tested this tool to provide a 3D anatomical visualization to a neurosurgical procedure, the retrosigmod approach, to prevent injuries to the great occipital, lesser occipital, and greater auricular nerves.

In line with all these previous exploitations of the *Anatomage^{TM} Table*, we are implementing its use in all courses relying on advanced neuroanatomy knowledge. The international course in our university, in fact, proposes a vertical track named *Neuroscience* (4^{th}-5^{th} year). In this case, students have already received basic neuroanatomy teachings during the first year, therefore we can implement the use of the table even further, relying mostly on virtual dissections during the teachings rather than the classical slide deck with plain 2D images; an opportunity easy to provide since the number of students is quite limited (maximum per year: 48). Therefore, neuroanatomy lessons exploit all the options available ranging from basic functional anatomy maps, ultrasound of peripheral nerves to the opportunity to use DICOMs of clinical cases with a highly relevant neuroanatomical correlation. The same options are now being offered also to lessons devised for residents in neurology, neurosurgery, psychiarty and childhood neurology, to link easily neuroanatomy knowledge to the understanding of clinical cases both for diagnosis and patients' management. Furthermore, we are providing consultants with the opportunity to consolidate their knowledge in specific courses detailing, for example, the peripheral nervous system anatomy and how to approach it with the US. As the next step, we are implementing virtual tools in all teachings related to neuroanatomy at all levels (from the most basic to the most advanced), aiming also to detect the impact on the learning curve of all these implementations.

CONCLUSION

A digital and innovative approach to human anatomy teachings, and specifically neuroanatomy, can provide students with solid neuroanatomy knowledge to support clinical practice. Furthermore, empowering them by giving an active role in the learning process can make their path in becoming the next generation of health-care professionals smoother and more robust.

ACKNOWLEDGEMENTS

We thankfully acknowledge the *Anatomage Europe team* in supporting us during the on-line and on-site training activities of the *peer-to-peer* tutors.

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