

RESEARCH REPORT

Body painting, ultrasound, clinical examination, and peer-teaching: A student-centered approach to enhance musculoskeletal anatomy learning

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Abstract

The presented course, established 2016 as a compulsory elective for 22nd-year bachelor medical students, aimed to enhance deep learning of upper and lower limb anatomy from a clinical perspective by a maximum of student-centered activities combining hands-on skills training with team-learning. Three cohorts (in total 60 students) participated in this study. Students rotated through body painting, ultrasound, and clinical investigation supervised by faculty or an experienced clinician. Teams of 3-4 students prepared presentations on clinical anatomy and pathological conditions, which by teacher- and peer assessments on average achieved >85% (mean 17.8/20 points \pm 1.06). After each activity session, the students reported their learning experience through a reflective diary. Fifty students (83%) evaluated the course by a voluntary anonymous questionnaire combining Likert-type scale and free-text questions to assess, predominantly, perception of course activities and their perceived influence on learning anatomy. Journal reports and questionnaires revealed that the students highly valued the course, and 92% (29 females, 17 males) rated group work satisfying or well-perceived. The highest appreciation achieved ultrasound followed by clinical examination and body painting, which one third proposed to integrate into the regular dissection course. All students recommended the course to their younger peers. This course was feasible to integrate in the pre-existing curriculum. Limiting factors to offer this elective course to more students are availability of clinical teachers, technical equipment, and education rooms. Being student-directed tasks, body painting and reflective diary-writing would be feasible to implement without additional faculty, which we recommend to educators for student engagement activation.

KEYWORDS

body-painting, locomotion tract, peer-teaching, reflective diary, student learning preferences, team-based learning, ultrasound teaching, undergraduate teaching

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INTRODUCTION

The trend of worldwide curriculum modernization of basic medical education has shifted the focus from knowledge- and teacher-centered teaching to student-centered and problem- and research-based approaches, as well as early vertical integration of clinical and scientific skills (Drake, 1998, 2007, 2014; Drake et al., 2002; McBride & Drake, 2016; Eppler et al., 2018), also in Switzerland (Schirlo et al., 2002). Despite these changes over the past 25 years, gross anatomy has remained at the early stage of medical curricula, such as the Bachelor level at the University of Fribourg in Switzerland (Medical Faculty University of Fribourg, 2022). Also, in the majority (58%) of universities investigated in the United Kingdom and Republic of Ireland, gross anatomy is taught in the first two years, but was spread over more than 2 years at 14 (37%) medical schools (Smith et al., 2022), which was more than in a preceding study in the United Kingdom (Gogalniceanu et al., 2009). This increase was attributed to attempts to introduce clinical skills and patient contact earlier in curricula and adoption of spiral and more integrated curricula (Smith et al., 2022). In the latter study, until 2019, that is, before the COVID-19 pandemic, the predominant practical teaching approaches were a combination of dissection and prosection in 34%, prosection in 22%, anatomical models in 10%, dissection in 2% and only in 7%, technology-enhanced learning. Furthermore, 20% of the medical schools could either not identify a predominant approach or used alternative approaches including ultrasound and living anatomy (Smith et al., 2022).

Body painting has emerged over the past decades as a valuable tool to teach surface anatomy from an innovative approach in anatomy textbooks (e.g., Lippert et al., 1990) to practical hands-on courses for students (Op Den Akker et al., 2002; Bennett, 2014; Finn, 2018; McMenamin, 2022; Shapiro et al., 2023). Benefits included promoting knowledge retention and recall, particularly learning for clinical practice by not only combining the use of color and kinesthetic learning with anatomical theory but also diffusing the formal curricula as cost-efficient adjunct to multimodal anatomy. Particularly, high student engagement in an enjoyable activity was emphasized (Cookson et al., 2018), which enhanced self-directed learning opportunities and provided deeper understanding of form and function and practical experience of physical examination (Diaz & Wolley, 2021). Teamwork fosters the use of a broader range of skills to cope with complex tasks (Gibbs, 1995; Plymouth University, 2013) and improved student performance in medical curricula (e.g., Burgess et al., 2012; Eppler et al., 2018), particularly for low-scoring students and heterogeneous classes (Spandorfer et al., 2014; Pizzimenti et al., 2016).

The student approach to learning framework describes the way students engage with a given learning environment (Biggs, 2003). The learning environment is, in addition to personal factors such as age, gender, and individual curriculum, defined by learning styles and the motivations that drive students' learning as reviewed by Feeley and Biggerstaff (2015), who confirmed that while learning styles did not correlate with examination performance, learning approaches did. Students using strategic and deep approaches to learning (i.e., motivated

to do well and to learn deeply, respectively) performed better in medical school examinations such that students' learning approaches can change, and more adaptive approaches may be learned. The authors suggested that helping medical students develop their own positive learning approach using "growth mind-set," was more effective and feasible to succeed academically than attempting to alter their learning styles (Feeley & Biggerstaff, 2015). The shift to multimodal teaching demands exploration of suitability and student perceptions of diverse teaching methods (Estai & Bunt, 2016). The present course aimed at creating a motivating and engaging learning environment to stimulate deep learning and self-reflection at different levels of medical competences according to Miller (1990). Further, the concept is based on Kolb's learning theory (1984), which describes a cyclical constructivist model where learners engage in a concrete experience and then reflect upon and analyze the experience to construct new knowledge.

Study goals

The study goals were firstly, to explore the acceptance of the course concept and activities, that is, student team lectures, body painting, ultrasound, and clinical examination and self-reflection in a diary, with special emphasis on male and female students' learning experience and preferences. Secondly, to explore how medical students describe the influence of these activities on their applied learning of anatomy, and thirdly, how they would appreciate the integration of these activities in the anatomy curriculum. These goals were addressed from an interpretivist epistemological approach, using a broadly phenomenological methodology, where learners' perspective of different tasks was the activity under investigation as described recently for body painting (Shapiro et al., 2023). We hypothesized that medical students would perceive that team and individual activities influenced their application of anatomy knowledge. We further hypothesized that the practical team activities would be generally highly valued and that learning preferences would differ between students. In detail, our research questions were: how do medical students describe their experiences of team activities such as peer teaching, body painting, clinical examination and ultrasound? How do medical students describe their experience with self-reflection in a diary? How do medical students describe the influence of these activities on their applied learning of anatomy? How would medical students appreciate the integration of these activities in the anatomy curriculum?

MATERIALS AND METHODS

Student cohort

The course concept was approved by the medical curriculum committee of the University of Fribourg and established in 2016. This optional course (MH.4901: Locomotion II) was offered as one of the compulsory elective courses for 120 students in the second bachelor study year (Table 1). Twenty participants were randomly selected

TABLE 1 Characterization of the medical curriculum and the optional musculoskeletal anatomy course (based on Medical Faculty University of Fribourg, 2022).

Characteristics	Anatomy courses of the medical curriculum	Compulsory course: Musculoskeletal anatomy course
Enrolment, year of medical school	Compulsory, 2nd year	Optional, self-selected, on a “first come-first serve basis”
Attendees	All 120 BMed students	20 students doing the option unit in the 2nd semester
Duration	2 years (MED1: 1st year, MED2: 2nd year)	13 weeks, spring semester
Preceding Teaching Units for all 120 students	MED 1: Introduction to medical profession: 2 introductory days incl. study organization, learning strategies, self-care, understanding of the medical profession Short-time placement with a general practitioner Training in basic life support, medical, and nursery skills Physics and chemistry for medical students Foundations of biomedicine I Lectures in general histology and cell biology General physiology Medical embryology Introduction, Systems I: Skin, Blood, Genital system Histology practical I (10 practicals: cell biology, basic histology, blood, skin, genital organs) Introduction to medical imaging Medical humanities I: medical psychology and sociology I, Public Health, Scientific thinking and working	Musculoskeletal system of upper and lower limbs Introductory lecture (45 min, course coordinator) Problem-based student lectures (with instructions, 20-30 min, student teams of 3-4 students, compare Table 2): 4 on clinical anatomy, 4 on clinical syndromes or diseases 4 practical sessions with written manuals (3h): 1. Ankle, foot, 2. elbow, wrist, hand, 3. hip and knee, 4. shoulder. Student groups rotate through 3 activities/session (1 h, supervised by faculty member or experienced physician): a. Body painting b. Ultrasound c. Clinical examination Reflecting diary
Anatomy teaching	Gross anatomy of the locomotion tract (lectures, 20 practicals)	
Parallel (2nd year) Teaching Units	Med 2: Medical humanities II, Medical psychology and sociology II	
Anatomy teaching	Foundations of Biomedicine II, Scientific thinking and working II: Immune system, Molecular medicine Systems II: cardiovascular, respiratory, excretory systems, nutrition and metabolism, endocrine system, reproduction and sexuality, nervous system and sensory organs Clinical Competences BMed2: clinical skills training Anatomy, Biochemistry and Systemic Physiology I	

on a first-come-first-serve basis out of approximately 40 students interested in the topic. For this study, three course cohorts of in total 60 students were analyzed.

Medical curriculum and anatomy teaching environment

Each cohort during the first year successfully completed anatomy, histology, and physiology of the musculoskeletal system delivered through theory lectures, histology and physiology laboratory sessions, and an extensive dissection course of 60h (Locomotion MED1). More details on the medical curriculum and anatomy education environment are summarized in Table 1.

Course organization, learning objectives, and materials

The design of the course included a multimodal concept using student team presentations, practical group exercises, an individual

reflective diary, and a final written examination. The course addressed as learning objectives that the students

- apply their previously acquired knowledge on the musculoskeletal anatomy of upper and lower limbs from a clinical perspective,
- acquire a deeper understanding of physiological/anatomical conditions and pathological changes of the musculoskeletal system,
- apply first clinical skills to functional anatomy complemented by body painting,
- learn and apply ultrasound examination of soft tissues and joints,
- become familiar with clinical examination of bones, joints, and muscles from a surface anatomy perspective,
- train team-based knowledge acquisition, scientific literature search, and peer-teaching,
- apply and enhance their scientific skills and literacy through peer-teaching.

The course took place on-site on eight Friday afternoons during the spring semester starting with an introductory lecture of 45 min by the course coordinator (L.F.) covering teaching objectives, content, and administrative information including allocation of the

topics for peer-presentations (Table 2) and self-allocation of the students to the team activities. The introductory lecture also presented scientific skills such as literature search, scientific presentation, and the issue of plagiarism as previously described (Eppler et al., 2018, 2021). The teaching and learning platform Moodle learning management system (2023) serves for course administration, information about content and instructions on the activities, and for submission of student work, monitoring, and performance feedback. Learning material was recommended including the literature database PubMed (National Library of Medicine, 2022) and the Swiss open access anatomy tutorial "*Musculoskeletal System, Clinical and Topographic Anatomy, Histology*" (Groscurth et al., 2022), where musculoskeletal anatomy contents are available in English, French, and German. Further, anatomy textbooks and atlases were recommended, such as Netter (2008), Prometheus (Schuenke et al., 2014), and Sobotta (Paulsen & Waschke, 2010).

Student team presentations

Students were allocated in teams of three to four peers to prepare two presentations of approximately 25-30 min each, related to the main course topics, that is, (1) shoulder, (2) elbow and wrist, (3) hip, (4) knee, (5) ankle and tarsus, and (6) hand and feet joints. The presentations were created using PowerPoint (Microsoft Office, Richmond, WA) and based on factual knowledge acquired in the preceding courses (Table 1), and on instructions and guiding questions by the teacher (Table 2). At the end of the 4th week, the first session of 3 h with focus on clinical anatomy took place, and at the end of the 9th week, the second session on clinical and pathological aspects of locomotion outlining anatomical structures, pathology, clinical investigation, radiological imaging, therapy modalities, and prognosis (Table 2). Teacher and peer students assessed the team presentations using a questionnaire, which had been originally adapted from didactic recommendations by Laura Goering (2003) at

Perlman Center for Learning and Teaching of the Carlton College in Northfield (MN) and applied in other biomedical courses (Eppler et al., 2018, 2021). In brief, the students rated whether the presenters used clear and concise language, the pace of the lecture was appropriate, the lecture flowed logically, the PowerPoint slides were clear and easy to read, the examples/figures clearly explained, and references sufficient. Content was rated with regard to appropriate coverage and understanding, clear structure and interest. Two points were given to "yes," 1 point to "mostly," 0.5 points to "seldom," and 0 points to "never" as previously described (Eppler et al., 2018). The average of peer and teacher assessments rated as levels 1-3 of medical competences according to Miller (1990) and were for each team member worth 30% of the final grade (Table 3). Since teamwork may not fully reflect the individual contribution (Plymouth University, 2013), the recommendation to allocate a maximum of 40% of the grade to teamwork (Gibbs, 1995) was followed as described previously (Eppler et al., 2018).

Practical laboratory sessions

Four practical sessions of 3 h each (Figure 1) were organized covering (1) knees and feet (Figure 1), (2) elbow and hand, (3) hip, and (4) shoulder. Students self-allocated into groups and rotated through (a) body painting, (b) ultrasound investigation, and (c) clinical examination (Table 1). Each activity lasted 1 h under supervision by a faculty member or an experienced physician. Practical course participation was continuously self- and peer-evaluated, which rated as levels 1-2 according to the assessment of competences by Miller (1990) and worth 10% of the final grade each (Table 3). In detail, practical activities (Table 1) were as follows:

- a. **Body Painting** was introduced and suitable underwear clothes were recommended during the introductory lecture. The first session covered feet and knees (Figures 2A,B, and 3C-E), the

TABLE 2 Topics and teacher advice for the presentations on (1) shoulder, (2) elbow and wrist, (3) hip, (4) knee, (5) ankle and foot root, and (6) hand and feet joints.

Clinical anatomy	Bones, joint compounds, ligaments, muscles, innervation and blood supply, movement with focus on most important structures
Clinical/pathological aspects of locomotion	Bone fracture: diagnosis, healing process, therapeutic principles. Differences between childhood during growth and adulthood
	Inflammatory processes of joints: pathomechanism, pathobiology, diagnosis, treatment. Focus on frequent diseases and affected joint type
	Bone metastases: focus on mammary carcinoma. What is a metastasis? Which types of metastases exist and how do they emerge? What are the consequences for the well-being and for the bone itself? What are the therapeutic options?
	Muscle diseases: Focus on Duchenne's dystrophy including development and regeneration of muscles, age-related dystrophia
	Arthrosis: Focus on hip and knee joint. What is an arthrosis? How does it develop, which joints are affected? Pathomechanism? Which therapeutic options are currently applied and what is under research?

Note: Clinical anatomy presentations at the end of the 4th course week (25 min, 15-20 slides) and clinical-pathological aspects of locomotion at the end of the 9th week (30 min, 15-25 slides).

TABLE 3 Assessment of competences according to Miller (1990) and calculation of the final grade in the optional course.

Competence levels	Evaluation tools	Contribution to final grade 100%
Advanced anatomical knowledge of locomotion (levels 1, 2)	Final test MCQ, open questions	40%
Applied anatomical knowledge (levels 1, 2): Body painting, team activities	Practical course participation	Self-evaluation 10% Peer-evaluation 10%
Understanding and presentation of advanced clinical anatomy (levels 1-3), scientific skills, literature search, referencing, team work	Group PowerPoint presentation	Peer + teacher assessments 30%
Advanced understanding of topography, application of clinical skills (ultrasound and clinical examinations), self-reflection (levels 1-4)	Reflective diary	Teacher feedback 10%

Note: Competence level 1: "knows" (gathering factual knowledge as basis), level 2: "knows how" (knowledge to apply that knowledge), level 3: "shows how" (ability to show a certain knowledge) and level 4: "does" (ability to apply the knowledge in a practice setting), adapted to an undergraduate level of education similar to previous study (Eppler et al., 2018).

Abbreviation: MCQ, multiple choice question.

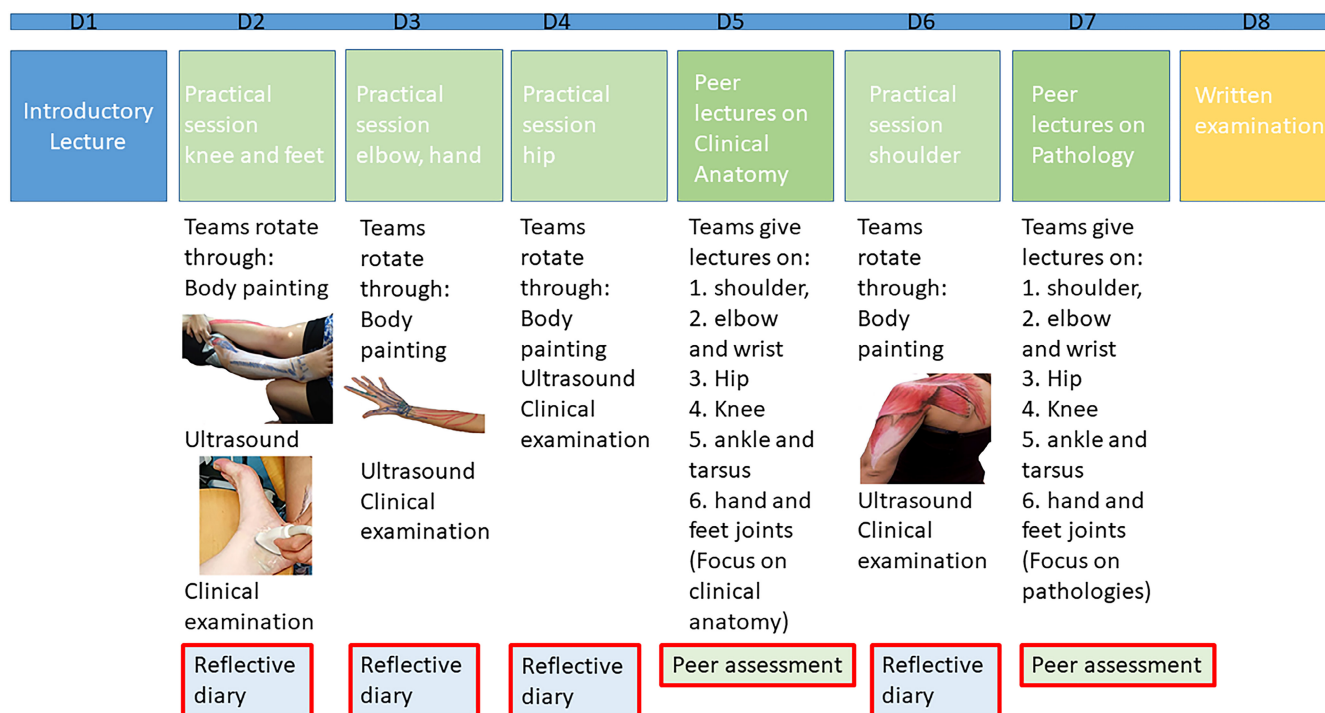


FIGURE 1 Graphical summary of individual and team tasks on the eight course days (D1-D8). Understanding and presentation of advanced clinical and pathological anatomy as a team-learning approach in the practical sessions (light green) where teams rotate through three stations (body painting, ultrasound, and clinical examinations) on the topics of the day, alternating with peer presentations (dark green) delivered in two sessions. Self-reflection (red rims) fostered particularly by the individual reflective diary and peer-assessment.

second session elbow and hand (Figure 3B), the third session hip, and the fourth session shoulder (Figure 3A). In detail, groups of three to four students had the possibility to choose between pens and water-colors. All colors were cosmetically tested for use on healthy skin and approved for body painting. Written manuals, one for each session and activity, complemented by learning recommendations, were provided. Two students of each group volunteered as models. After initial identification of specific structures and landmarks (Figures 2A,B and 3), each anatomical

structure was assigned a predetermined color (Supplement 1). Painting took place in four steps, divided on two students, to define superficial and deep anatomical structures as described in detail (Supplement 1). One side of the body was reserved for painting, and the contralateral side for ultrasound (Figure 2) as follows:

- Ultrasound** examination was conducted in parallel to body painting on the contralateral limb, following the same main topics under supervision of an experienced rheumatologist and



FIGURE 2 Example of the practical sessions on ankle and foot. (A, B) Body paintings. (C, D) Ultrasound examination by (C) teacher and (D) student. (E) Ultrasound image. (F) Student's drawing in the reflective diary. (C–F) Images collected from reflective diaries. For the ultrasound (E), students described to “see the 3 Tibialis vessels in diameter. With a little pressure by the ultrasound probe, the 2 veins are compressed, but the artery in the middle remains open.” (F) The student commented as follows: “structures below the medial malleolus follow the mnemonic: Tom Dick & Very Nervous Harry,” that is, Tibialis posterior, Flexor digitorum longus, Tibialis posterior vessels, Tibialis nerve, Flexor hallucis longus. A.: Artery, digit.: digitorum, flex.: flexor, l./long.: longus, med.: medial, lat.: lateral, M.: muscle, post.: posterior, V.: Vein.

expert in ultrasound. In an inverted classroom approach, students were advised to prepare in advance using recommended basic textbooks (Gaulrap & Binder, 2014; Brasseur et al., 2015), and teaching material of the Society of Ultrasound in Medical Education (2022), and apply their knowledge as described (Supplement 2).

c. The **clinical investigation** was prepared in an inverted classroom approach by self-directed learning using recommended textbooks (Cleland & Koppenhaver, 2012; Müller et al., 2013; Magee, 2014). During the sessions, supervised by an orthopedic surgeon experienced in medical education, the students followed detailed guidelines on how to prepare and conduct a clinical examination of the musculoskeletal system. In detail, the first step was inspection of potential patient's pain locations followed by general examination, palpation of anatomical landmarks, and assessment of the muscle status. The students evaluated active and passive mobility, observed and interpreted the sequence of movements in everyday activities, that is, sitting down, getting up, dressing, undressing, and finally performed a pain provocation test and discussed pathologies.

Individual activities: Reflective diary

After each practical course session, students wrote a personal diary report of approximately two A4 pages on their experience about the course (Figure 1), summarizing and reflecting their activities during the session, for example, by ultrasound documentation (Figure 2C–E) and schematic drawings (Figure 2F). The students were free in the content of the reflective diary. Assessment of the reflective diary depended exclusively on the timely submission of the report, that is, before the consecutive course session, for feedback by the teacher. The reflective diary is rated as advanced understanding of topography and application of clinical skills and self-reflection corresponding to levels 1–4 of medical competences according to Miller (1990) and worth 10% of the final grade (Table 3).

Individual activities: Final examination

At the end of semester, a combined multiple choice and short answer examination took place, which was worth 40% of the final grade (Table 3). For training, a mock examination (Supplement 3) was offered, asking for example, to describe the steps of an ultrasound examination of the carpal tunnel and the respective visible anatomical structures or to describe the clinical examination of a shoulder or knee joint and corresponding anatomical structures. Another task was drawing an ankle from the medial and lateral view with the respective bones, ligaments, tendons, nerves, and blood vessels. The final examination rated as advanced anatomical knowledge of locomotion corresponding to levels 1–2 of medical competences according to Miller (1990) and worth 40% of the final grade (Table 3).

Course evaluation by the students

After cessation of the course, students were invited to voluntarily answer an anonymous online questionnaire, adapted from an original

standardized students' satisfaction perception questionnaire previously applied for medical and biomedical students (Eppler et al., 2018, 2021). The questionnaire designed in French and German language intended to cover all research questions and comprised a combination of Likert-type scale with predominantly 4-5 answer possibilities and free-text (Supplement 4). The content with in total 23 items was not statistically validated. After general information about the students (sex, language), the main part assessed the respective fields of the present study, that is, perception of the course and the different team and individual activities including previous experience with peer teaching and assessment. Further topics were learning preferences, and how the students described the influence of the course activities on their applied learning of anatomy, and how they would appreciate integration of these activities in the anatomy curriculum. Finally, the students were asked whether this course encouraged them to go into a surgical specialty after graduation and whether they would recommend the course to their younger colleagues. The following activities were qualitatively and quantitatively analyzed for all students and for male and female students separately: peer presentations, body painting, ultrasound, clinical examinations, reflective diary, and learning material. Fifty students of the entire cohort (83%) returned the voluntary questionnaire, that is, 30 (60%) females and 20 (40%) males, which was similar to the entire course cohort (data not shown). The majority (70%) were German speaking, 22% French speaking, 2% Italian speaking, and 6% other languages.

Statistical analysis

Quantitative variables were calculated as absolute student numbers (n) and grades/points achieved expressed as range, median, mean and standard deviation (mean \pm SD), and percentages, respectively. Statistical analyses were performed using Microsoft Excel version 2016 (Microsoft Corp., Redmond, WA) and Prism Graphpad (Boston, MA).

RESULTS

The study goals were to explore the acceptance of the course concept and its combined team activities, that is, body painting, ultrasound, and clinical examinations, with self-reflection in a diary and plenary lectures, with special emphasis on male and female students' learning experience and preferences. Further, to explore how medical students describe the influence of these activities on their applied learning of anatomy, and how they would appreciate the integration of these activities in the curriculum.

General evaluation of the course concept

In the reflective diary, one student appreciated the different approaches to learning anatomy and expressed that "it was a bit sad to

end this course with the last afternoon, particularly since it was something new compared to the very theoretical lectures and because it was always very interesting and entertaining." The response rate of the students who answered the questionnaire was 83%. For most students (92%, $n=46$: 29 females, 17 males), group work was satisfying or well-perceived, and all students strongly recommended this course to their younger colleagues. The majority of answers (49%, $n=25$: 14 females, 11 males) indicated that previous knowledge of locomotion was helpful during the course, and 47% ($n=24$: 15 females, 9 males) that previous knowledge in locomotion was essential. Based on 49 replies in the questionnaire, one third of the students (33%, $n=16$: 9 females, 7 males) did not consider the course to encourage them to choose surgery as a career path. On the contrary, the majority (67%) either declared the course could encourage them toward a future career as a surgeon (38%, $n=19$: 12 females, 7 males), or already intended to choose the surgical specialty after graduation (30%, $n=15$: 9 females, 6 males), respectively.

Team presentations: Outcome and student opinion

Six student teams prepared two presentations (Table 2), one related to clinical anatomy and one to representative clinical syndromes or diseases of the musculoskeletal system (Figure 1). From the teachers' perspective, student presentations were excellently prepared and successfully delivered. All students used online material to prepare the presentations (Figure 4), followed by books (88%, $n=44$: 27 females, 17 males) and lecture notes from previous courses (40%, $n=20$: 7 females, 13 males). Since content had been educated in the preceding courses (Table 1), the presentations were overall of high quality (range 15.3-19.7 points), covered all necessary content and achieved a mean (and median) of 17.8 ± 1.06 points, corresponding to at least 85% of the maximum 20 points. Usually, students finished the presentations with quizzes for their peers, which served as an onset for discussion (e.g., "Antoine, 17 years, skiing accident at Verbier. At the hospital, fracture of the os pubis was diagnosed, and he was admitted to hospital. Physical examination revealed painful crossing of the legs. Which movement is compromised, and which muscles are responsible? Which structure could be damaged?"). The quiz questions were a stimulatory initiation of discussions and welcomed by the teachers to engage students. According to the questionnaire, the majority of students (92%, $n=46$: 29 females, 17 males) for the first time had to prepare and give a presentation and recognized (58%, $n=29$: 16 females, 13 males) that preparing the peer presentation was helpful, or even provided an excellent opportunity (14%, $n=7$: 4 females, 3 males) to revise anatomy (Figure 4). Similarly, the clinically orientated presentations were rated as an excellent addition to the course by 24% ($n=12$: 8 females, 4 males), and by 56% ($n=28$: 15 females, 13 males) as helpful complementary activity, while 20% ($n=10$: 7 females, 3 males) declared that it could be abandoned (Figure 4). The majority of the students (60%, $n=30$: 20 females, 10 males) were satisfied with the amount of time spent. Most students (68%, $n=34$: 23 females, 11 males) spent 3-10h preparing the presentations, in



FIGURE 3 Typical body paintings of the upper (A, B) and lower (C–E) limbs. Based on surface anatomy and palpation, students localized bones (white), cartilage, meniscus (light-blue), ligaments, tendons (white, blue), and muscles (black, pink, red) and bursae (pink), nerves (yellow), arteries (red), and veins (blue) as described in detail ([Supplement 1](#)).

detail 42% ($n=21$: 15 females, 6 males) 3–5 h, and 26% ($n=13$: 8 females, 5 males) 5–10 h ([Figure 4](#)).

Body painting

According to the journal, the students tried to depict the surface anatomy of the thigh muscles as realistically as possible: “Again, (...) volunteered as target of our painting skills. It was not very easy, as there were a lot of hairs on the skin of men’s thighs. However, in the end, this did not turn out to be too big a hurdle and we once again had a lot of fun drawing the muscles on the surface of (...). We tried again to make the edges of the muscles clearer with black shading and to emphasize more strongly the fascia of the muscles with white. In the end, we almost ran out of white, but we were lucky, and it was just enough. The most difficult part of body painting for us was always depiction of the vessels, because they are very thin and can’t be depicted very well with the thinnest pencils, which is why we often concentrated on the muscles.” One student highlighted body painting as “fun and nonetheless instructive. Since we had seen the anatomy already at the other 2 stations, body painting was a very good finish, another way of visualization.” The majority of the students pointed out the importance of learning anatomy by complete and live arrangement of body parts without “sectioning,” such as in anatomy books and atlases or dissected specimens. Painting required very precise (deeper) learning of structures and transfer

of two-dimensional knowledge in three-dimensional spatial perception of the anatomical structures: “We learned a lot from the clinical point of view. The practical application of our anatomical knowledge is also very rewarding from a personal point of view and helps to remind us why we chose this path.” Further, a student noted that “it was very positive that this time we could start with the body painting, so that Dr. L. at the clinical examination could use our body painting to explain the clinical examination of the ankle joint.” As outlined in the questionnaire, the students appreciated the body painting sessions as an alternative and enjoyable method to learn anatomy. The majority of answers ($n=26$: 14 females, 12 males) indicated that body painting helped them deepen their knowledge in anatomy, and 36% ($n=18$: 15 females, 3 males) that it should be integrated into the preceding regular dissection course ([Figure 5A](#)).

Ultrasound examination

According to the reflective diary, students found the ultrasound approach difficult, due to their lack of experience. Their main difficulty was correct orientation of the probe during examination, but they valued the opportunity to “exercise now in prevision of the third year.” As evaluated by the questionnaire, ultrasound examination was the highest valued activity ([Figure 5B](#)): 58% of the students ($n=29$: 18 females, 11 males) declared that it improved their anatomical

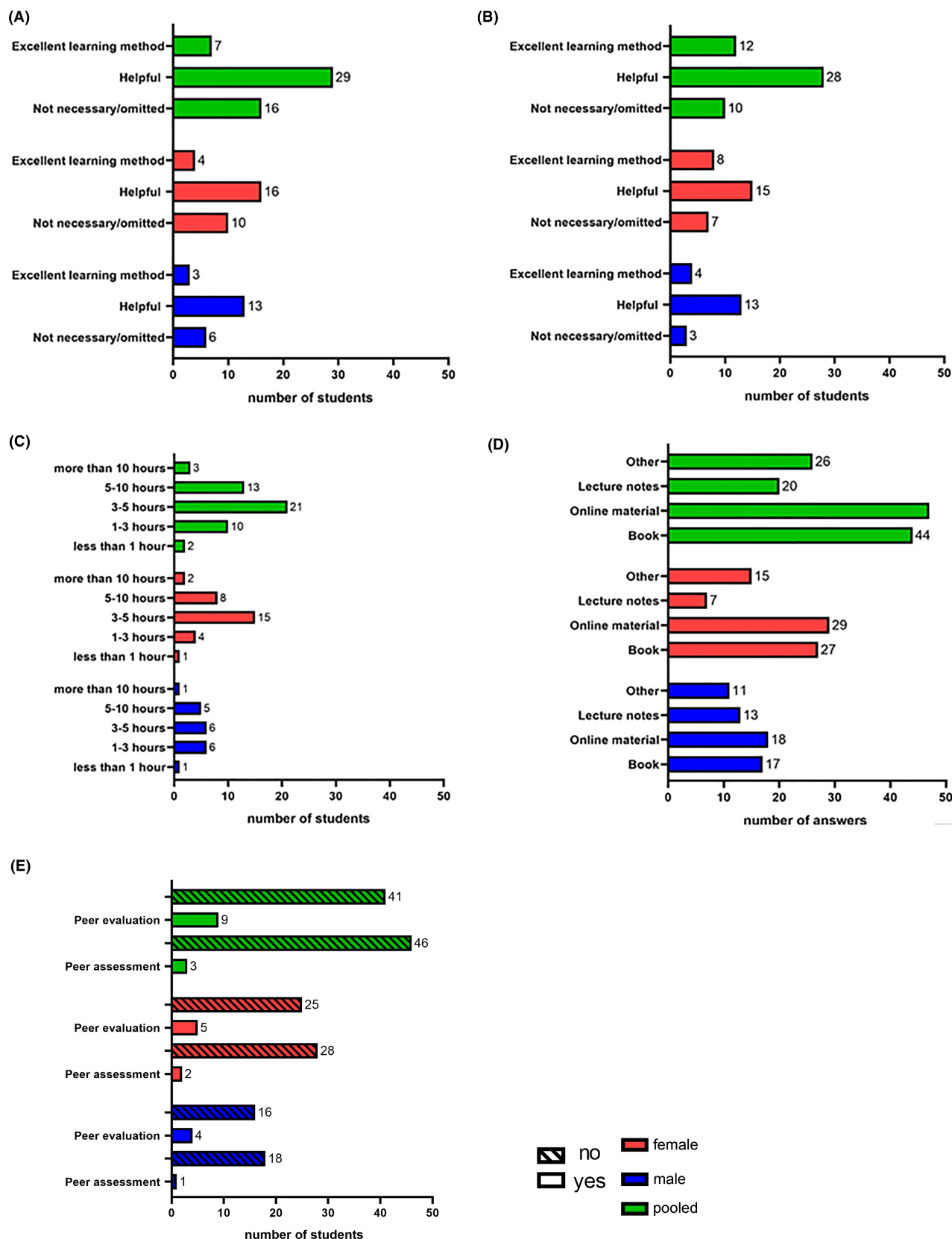


FIGURE 4 Graphical representation of the students' evaluations of the peer presentations in the questionnaire. (A) Feedback on the use of the peer anatomy presentations to revise anatomy. (B) Feedback on the use of the clinical-orientated presentation to revise anatomy. (C) Time spent to prepare the peer presentation. (D) Students' preference for material used to prepare peer lectures. Multiple answers were possible. (E) Feedback on experience with peer assessment and peer evaluation. Striped bars: no experience. Green bars: total number of questionnaires; red bars: number of females out of $n=30$; blue bars: number of males out of $n=20$.

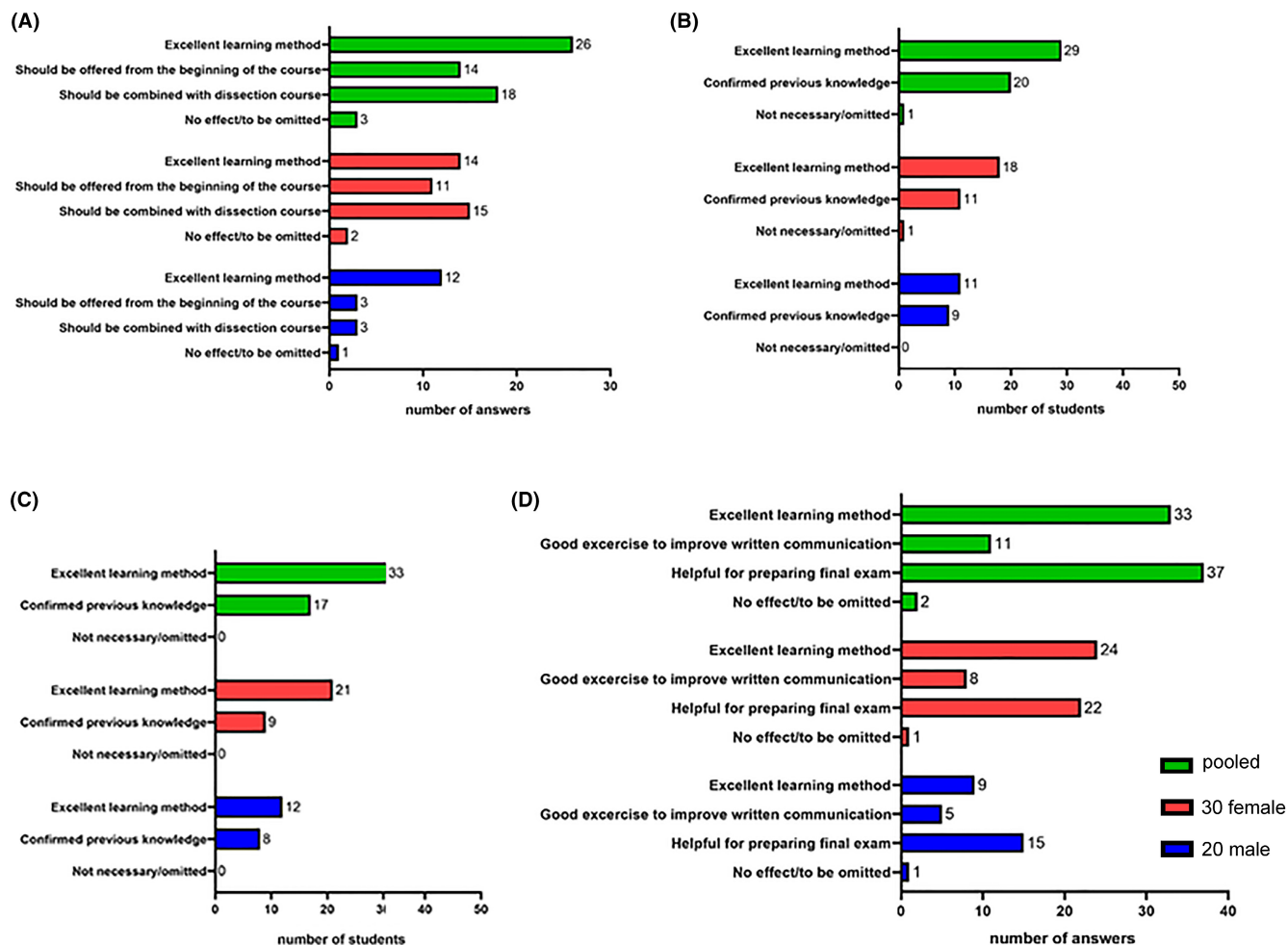


FIGURE 5 Graphical representation of the students' evaluation of the team activities and diary in the questionnaire. (A) Feedback on the use of body painting. Multiple answers were possible. (B) Feedback on the use of ultrasound. Multiple answers were possible. (C) Feedback on the use of clinical examination. Multiple answers were possible. (D) Feedback on the use of a reflective diary. Multiple answers were possible. Green bars: total number of questionnaires; red bars: number of females out of $n=30$; blue bars: number of males out of $n=20$.

knowledge, 40% ($n=20$: 11 females, 9 males) that it consolidated their previous knowledge, while one female student (2%) did not find any effect on her knowledge.

Clinical examination

In the reflective diary, a young woman drew a parallel between her feelings and emotions of a patient during a medical examination, focusing on the sense of discomfort of undressing in front of a stranger, of showing oneself imperfect: "(...) pulse rises, the hands get a little sweaty. Do you really want to undress in front of your fellow students, to be touched? Ok, I will do it ..." The excerpt continued wondering whether perhaps their future patients would feel similarly when undressing for an examination: "When we ask them 'Please undress', they may also get sweaty palms and their pulse goes up. They may also have qualms about letting a stranger touch them. In addition, they are afraid. The fear of being sick and of unclear diagnoses ..." The student concluded her report by expressing her enthusiasm for participating in

the course and volunteering for the clinical examination: "... for this reason, I never want to forget that feeling of being a 'patient' in front of my fellow students at the beginning. In the future, I hope to be able to respond empathetically to patients and take away some of their discomfort and helplessness," "That's why I find it exciting to be a 'patient' myself at the university." In the questionnaire, all students highly valued the clinical examination, and 33 students (66%: 21 females, 12 males) considered it an excellent learning method, and for 17 students (34%: 9 females, 8 males) it consolidated their knowledge (Figure 5C).

Reflective diary

At the end of each session, the students wrote a personal journal (Figure 1), in which they summarized their work, the covered topics and achieved goals, and they reported on their feelings, emotions and experiences. In the questionnaire, the reflective diary received very positive feedback (Figure 5D) as helpful preparation for the final examination (54%, $n=37$: 22 females, 15 males) and excellent

learning method (66%, $n=33$: 24 females, 9 males). Eleven students (22%: 8 females, 5 males) emphasized that it was a good exercise to improve communication.

DISCUSSION

Overall, the students appreciated this course as evidenced by the reflective diary and the questionnaire. According to the questionnaire, all students recommended the course to their younger peers. However, it is important to emphasize as a limitation that the students had chosen the course as one of the elective courses offered to them. This also accounts for the majority of students who felt encouraged by the course to go into a surgical specialty after graduation. The focus of the present study was on the perception of the team activities and their influence on applied learning of anatomy.

Team-based presentations and learning

To date, peer- or near-peer-teaching is used mainly for shared learning experiences including manuals and textbooks, problem-based tutorials and in-course preparation and testing (Nieder et al., 2005; Vasan et al., 2008, 2009; Mason et al., 2023), and to a lesser extent for plenary lectures (Eppler et al., 2018, 2021). In the present study, teams of second-year medical students prepared plenary lectures guided by faculty to communicate core anatomy contents, instead of faculty lectures. For the faculty, peer-based learning is challenging since they have to introduce students to scientific work at an early stage. As reviewed by Tai and co-workers (2017), clinical educators reported on their need for support and development of their education skills and their concerns regarding student compatibility and accuracy of knowledge (Sevenhuysen et al., 2013; Tai et al., 2016, 2017). This is in agreement with students' appreciation of traditional instruction-based learning, which guided them appropriately and ensured that they cover the syllabus in detail (Siddaiah-Subramanya et al., 2017). Furthermore, faculty lectures may be more efficient than peer-teaching in communicating relevant information (Peterson & Tucker, 2005), and a combination of traditional teaching using lectures and student-centered sessions was proposed to have a higher success rate (Siddaiah-Subramanya et al., 2017). Nevertheless, team-based learning in a dissection course resulted in effective assessment (Hafez, 2022) and learning of topographical anatomy and appeared to provide better acquisition of knowledge than previous teaching methods (Burgess et al., 2012), which was similarly observed in a study using self-assessment scores after peer- and faculty-assisted learning in a gross anatomy dissection course (Han et al., 2015).

In general, students take three approaches to learning, which are influenced by the learning environment: deep, surface, and strategic (Biggs, 2003; Reid et al., 2012; Taylor & Hamdy, 2013). In a study of anatomy learning strategies, most preclinical students relied on elaboration ahead of other cognitive strategies and lowest rated critical thinking, and relied more on resource management, effort, time, and regulation of the learning environment rather than the moderately

rated peer learning and help seeking. Nevertheless, in focus groups, they reported that they often narrated or explained to each other what they understood from anatomy lectures, tutorials, and textbooks (Zilundu et al., 2021). In the present study, all students used online materials to prepare their presentations. Books (88%) and atlases (94%) were also primary sources used to prepare their presentations and review anatomy, similar to a study from California where students rated reading the textbook as most important (Shaffer, 2016), but different from a study in Australia, where lecture/tutorial/practical notes ranked first, followed by textbooks, atlases, videos, software, and websites (Choi-Lundberg et al., 2016). As reviewed by Azer (2013), whereas there has been progress in publications addressing surface anatomy teaching, in anatomy textbooks, surface anatomy was not similarly present. Thus, students' learning approaches and preferences in anatomy remain under-investigated (McWatt et al., 2021), particularly for surface anatomy.

Body painting

Body painting has emerged over the past decades as a valuable tool to teach students surface anatomy in practical hands-on courses (Op Den Akker et al., 2002; Bennett, 2014; Finn, 2018), which may be further enhanced as augmented reality (Barmaki et al., 2019) or haptic body painting (Shapiro et al., 2023). In our course concept, which Shapiro and co-workers (2023) may designate as "haptic surface painting," activities may enhance learners' spatial awareness, defined as a cognitive ability constructed from the experience of studying three-dimensional objects and concepts. While high student engagement in an enjoyable activity was emphasized for body painting, unequal involvement because of undressing in the classroom due to cultural and personal considerations may potentially lead to different learning experiences (Cookson et al., 2018). In the present study, undressing and feeling uncomfortable in front of the peers was an issue, at least for one female student in her diary. The relevance of this issue varies between different sociocultural backgrounds; however, this was beyond the scope of this study. A recent study (Diaz & Wolley, 2021) in Australia highlighted that students from many cultures were enthusiastic about body painting and through careful negotiation were able to find areas of their body where they felt comfortable painting, as observed in previous studies from the same group (Diaz, 2013; Diaz & Woolley, 2015). Emotionally intense science activities including joy, wonder, amazement, surprise, anxiety, anger, fear, and hopelessness (Sinatra et al., 2014) have been associated with students' interest and engagement in science learning and longer term memorability (King et al., 2015).

Ultrasound and clinical examinations in the early curriculum

Intertwining anatomy lessons with clinical information is the most powerful method in the medical curricula to improve long-term

retention (Baker, 2022). An objective, structured, ultrasound-based practice examination was successful to test early undergraduate medical students for anatomical knowledge and technical skills in a gross anatomy course, as well as non-technical skills such as teamwork and professionalism (Weiskittel et al., 2021), and ultrasound was feasible for non-medical students to enhance anatomy education outside of medical training (Royer et al., 2017). In particular, musculoskeletal ultrasound was most useful when integrated with soft tissue landmark-based physical examination skills for first-year medical students (Walrod et al., 2018). Ultrasound on body donors is considered of poor quality (Schramek et al., 2013), so it needs to be conducted in a clinical environment. In the present study, body painting and ultrasound, combined with self- and team-directed learning and preparation, were excellent at facilitating the transition from theoretical knowledge to practical clinical examination as observed by students and teachers. Another beneficial effect of combining anatomy and clinical teaching was the early contact with clinical teachers (Smith et al., 2017), which positively influenced students' career choices in another study (Kozar et al., 2003; Hammer et al., 2015). In the present study, the majority of the students stated that the course could encourage them toward a future career as a surgeon or that they already intended to choose the surgical specialty, respectively. In a combined approach by anatomists and surgeons, courses including biomechanics, advanced dissection, surgical approaches, casts and implants, and sports medicine facilitated the appreciation of potential career options in orthopedics, while fostering professional skills during medical training (Klima et al., 2017). This is particularly valuable in light of the predicted demand of surgical disciplines for young physicians (Grover et al., 2009), including the underrepresentation of female surgeons (e.g., Viana et al., 2022), particularly in orthopedic surgery (Rohde et al., 2016). Kim and co-workers (2015) reported that 50% of surgical residents preferred a multimodal learning style and for 64%, the preferences included a kinesthetic aspect, similar to a study in Saudi Arabia, where male and female dental students had a unimodal preference for kinesthetic learning (Hashem, 2022). The necessity to contribute to the formation of students' professional identity as early as possible has been emphasized (Pawlina, 2019), with a greater role attributed to the basic sciences (Bryan et al., 2005; Pawlina, 2006; Netterstrøm & Kayser, 2008; Cruess et al., 2018). A particularly positive effect occurred in the presence of female role models (Geerlings et al., 2016; Harun et al., 2022). Further studies should contribute to optimizing the selection and training of students and junior trainees for surgical residency programs (Preece & Cope, 2016). Anatomy education has been highlighted as a setting for the development of an authentic curriculum (Pawlina & Drake, 2016) where students learn through clinical contexts with peer-to-peer communication, critical reflection through self- and peer assessment so that professional imagination takes root (Pawlina, 2019). Active learning exercises were helpful in seeing images of key ideas and clarifying key course concepts, and image-based exercises were less demanding than text-based activities (Gross et al., 2017).

Reflective diary and individual grade

This aligns well with the idea of written self-assessment and a reflective diary. Reflective writing about clinical issues has gained increasing attention as a means to cope with challenging situations and enhance empathy (Borgstrom et al., 2016; Cowen et al., 2016; Campbell et al., 2020). Nevertheless, its role needs further investigation (Wald & Reis, 2010; Wittich et al., 2013; Lin et al., 2016; Ottenberg et al., 2016; Kiss et al., 2017; Brown et al., 2019), also regarding its value as a student assessment method (Moniz et al., 2015; Eppler et al., 2021). Although reflective thinking correlated with academic performance in dental students (Loka et al., 2019), its value as student assessment rated rather low for medical students (Moniz et al., 2015). Furthermore, male and female learning preferences are still under-investigated. Nevertheless, we considered the reflective diary as a valuable tool to foster self-reflection and professionalism as previously proposed (Lachman & Pawlina, 2006; Wittich et al., 2013), which should at least be included in the assessment with a minimum contribution. In the present study as an innovative approach to enhance reflection and deep learning, 10% of the final grade were assigned to the reflective diary, not based on content, but timely submission of the report, which rated as levels 1-4 of the competence levels (Table 3) based on Miller's (1990) pyramid of clinical competence. This pyramid concept was originally aimed at clinical skills and competencies, but could be adapted to all stages of medical education (Pawlina, 2019). Overall, the individual grade was 60%, with an additional 40% (Table 3) coming from the final examination using multiple choice and open questions, the latter requiring in-depth knowledge (Melovitz Vasan et al., 2018), and another 10% gained from the self-evaluation.

Adult learning considerations and anatomy teaching

A recent study found that by 2019, only 7% of the universities surveyed in the United Kingdom and the Republic of Ireland, were using technology-enhanced learning and a maximum of 20% used alternatives to dissection and prosection including ultrasound and living anatomy (Smith et al., 2022). Since the COVID-19 pandemic, however, anatomy teaching has undergone dramatic changes in the use of technology-based learning (Gasmalla et al., 2022), such as providing material for asynchronous learning (Bruns et al., 2021; Smith & Pawlina, 2021). Following the pandemic, a positive attitude toward their in-person cadaveric dissection course was observed in medical students (Wolniczak et al., 2020), also compared to students who experienced virtual anatomy during the COVID-19 pandemic (Kochhar et al., 2022). These experiences are consistent with constructivist learning theories that students learn best when they are engaged in learning experiences rather than as passive recipients of information. Learning is considered as a social process embedded within a social context as students and teachers work together to build knowledge. Thus, the goal of teaching is to provide experiences that facilitate the construction of knowledge

(Taylor & Hamdy, 2013). To build knowledge, learners need to encounter novel problems and revise existing schemas as they work through challenging situations (Baviskar et al., 2009). In the present course, new knowledge is constructed based on the learners' pre-existing knowledge. Challenges were the practical activities and preparation of presentations as a team using a problem-based approach (Figure 1), where learners acquire knowledge through real-world problems such as musculoskeletal disorders. The peer presentations required students to work together as a team and acquire communication and collaboration skills, in addition to knowledge as suggested in the International Association for Health Professions Education AMEE (AMEE, 2023) Guide No. 83 (Taylor & Hamdy, 2013). In particular, reflection on learning as in the diary and repetition were important. According to The University at Buffalo (2023), for constructivist learning, students should ask their own questions and seek answers as outlined in the present study for the peer presentations, and make connections between their pre-existing knowledge and that gained through the activity and draw their own conclusions.

LIMITATIONS OF THE STUDY

A potential limitation is the cohort size of in total 60 students. Furthermore, as emphasized in the discussion section, the positive perception of the course and its compounds may be influenced by the fact that the students had chosen the course as one of the compulsory electives offered to them so that generalization of the presented data should be looked at with caution.

CONCLUSIONS

The combination of team-based teaching and learning and clinically oriented hands-on activities, that is, body painting, ultrasound, and clinical examination was feasible and could be offered as an optional course yearly with the exception of the COVID-19 close-down in the 2020 pandemic year. Overall, the students appreciated the course, which helped them to construct or at least stabilize knowledge of anatomy. The different tasks achieved a differential feedback, with the ultrasound task being the most appreciated, followed by the clinical examination and body painting. Limiting factors for offering this optional course to more students are availability of clinical teachers, technical equipment and education rooms. If more students were to enroll, a multiplication of the stations would be necessary, which requires corresponding increase in the necessary infrastructure. Otherwise, the activities would have to be repetitively offered and increase the teaching load or require recruitment of additional teachers. Nevertheless, all students who returned the questionnaire recommended the course to their younger peers, and more than one third proposed integrating body painting into the preceding regular dissection course. Since body painting and reflective diary writing are student-directed tasks, unlike clinical examination and

ultrasound, which require the guidance of medical experts, it could be feasible to implement without additional medical teachers and we recommend them to educators to activate student engagement.

ACKNOWLEDGMENTS

The authors gratefully acknowledge teaching and supervision in the courses by Sieglinde Schumacher Major MD, rheumatologist in Tifers, Switzerland, and the orthopedic surgeons Georges Kohut MD, Clinique Générale Ste-Anne, and Marc Lottenbach MD, Cantonal Hospital, Fribourg, Switzerland. The authors are very grateful to the students of MH.4901: Locomotion II for engaged participation in the courses and their readiness to contribute to this educational research project with their essays in the reflective diary, photographs and sketches, and the voluntary questionnaire. Open access funding provided by Université de Fribourg.

ETHICS STATEMENT

All students were informed about the course project prior to their involvement, and agreed to participate with their voluntary signed informed consent. Data were analyzed retrospectively after completion of the course and final examination. Since all data were anonymized, no ethics approval was required for this educational research project according to the regulations of the University of Fribourg.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Bilella A, Eppler E, Link K, Filgueira L. Body painting, ultrasound, clinical examination, and peer-teaching: A student-centered approach to enhance musculoskeletal anatomy learning. *Anat Sci Educ.* 2023;00:1–16. <https://doi.org/10.1002/ase.2334>