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RESEARCH ARTICLE

Leveraging medical imaging for medical education — A cinematic rendering-featured lecture☆

Johannes Binder[a,*], Christian Krautz[a], Klaus Engel[b], Robert Grützmann[a], Franz A. Fellner[c], Pascal H.M. Burger[d], Michael Scholz[e]

[a] Universitätsklinikum Erlangen, Department of Surgery, Krankenhausstraße 12, 90154 Erlangen, Germany
[b] Siemens Healthcare GmbH, Digital Services, Data Architecture & Digital Technologies, Medical Imaging Tech, SHS DS DAT MIT, Hartmannstr. 16, 91052 Erlangen, Germany
[c] Kepler University Hospital, Central Radiology Institute, Medical Faculty of the Johannes Kepler University, Krankenhausstraße 9, 4020 Linz, Austria
[d] Department of Psychiatry, Psychotherapy and Psychosomatics, Psychiatric Hospital, University of Zurich, Zurich, Switzerland
[e] Friedrich-Alexander-University Erlangen-Nürnberg (FAU), Institute of Functional and Clinical Anatomy, Universitätsstraße 19, 91054 Erlangen, Germany

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ABSTRACT

Background: The integration of medical imaging into anatomical education offers advantages in understanding and learning. However, spatial orientation with conventional (2D) imaging data is challenging, and the students' ability to imagine structures in three dimensions is individual. In addition, the quality of current volume rendering methods is limited.
Objective: We tested Cinematic Rendering (CR), a novel visualization technique that provides photorealistic volume rendering, in the setting of an interactive anatomy lecture with first-year undergraduate medical and dental students. Our goal was to estimate the acceptance and positive effects CR adds to the subjects.
Methods: A total of 120 students were surveyed with specifically designed self-assessment questionnaires on the use of CR as a tool in anatomical education.
Results: Of 120 participating students (87 medical and 33 dental) a large majority of 95.9% (Q3) experienced CR as helpful to understand anatomy better. Overall a large majority of the students experienced CR as helpful for learning and understanding, 85% saw an improvement in anatomical education through the integration of CR (Q3–6) and could also imagine using CR as a self-study tool on an electronic device.
Conclusion: Our undergraduate medical and dental students experienced CR as a beneficial tool for anatomical education in the chosen setting (lecture) and see further opportunities for the sensible use of this technique. Future research on the topic should include other application possibilities as well.

1. Introduction

Profound knowledge of the human anatomy is crucial for medical students at university as well as in in their future careers as physicians. Anatomy as a curricular subject is traditionally divided into microscopic anatomy i.e. histology and cell biology, and macroscopic anatomy. Although didactical methods vary between different countries and faculties and have changed over the last few decades, still the traditional lecture remains a key element of anatomical teaching. The integration of radiological medical imaging into these lectures has become more common as it has several advantages. It offers an opportunity to present the human anatomy together with a wide range of varieties and variations to students., Compared to standardised images, anatomical specimen or the presentation of altered anatomy in the cadaver dissection a better presentation of expressive findings in high quality is possible here. Radiological imaging enables students to identify anatomical structures better in medical images on the long run (Erkonen et al., 1992; Erkonen et al., 1990). Moreover, medical students themselves rate the integration of radiological imaging very positive and beneficial for their future careers (Brown et al., 2012; Nyhsen et al., 2013; Silva et al., 2016).

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* Corresponding author.
E-mail address: johannes.s.binder@fau.de (J. Binder).

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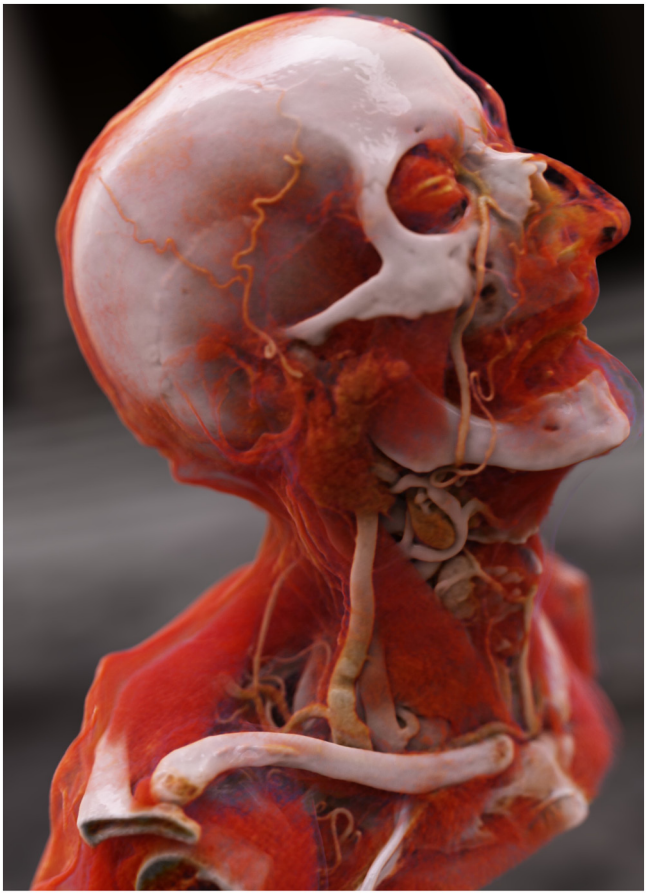

Fig. 1. Example picture of a Cinematic Rendering Image of a CT scan of the upper body. Copyright: Radiologie im Israelitischen Krankenhaus, Hamburg, Germany.

Fig. 2. Example picture of a Cinematic Rendering Image of a CT scan of contrasted brain vessels. Copyright: Radiologie im Israelitischen Krankenhaus, Hamburg, Germany.

Having both, the knowledge about function, and the possibility to understand the spatial orientation of a structure is essential to get a comprehensive picture of the human body. However, students' ability to imagine spatial orientation is individual (Garg et al., 2001). The best way to gain this knowledge is a balance between memorisation, visualisation and understanding (Pandey and Zimitat, 2007).

Medical images such as computed tomography (CT) or magnetic resonance (MR) imaging are mostly presented in two-dimensional greyscale images. The challenge for students and physicians is to mentally reconstruct and create a three-dimensional (3D) image out of it. One method to facilitate the understanding of two-dimensional (2D) images is for example the production of volume rendering 3D-images. A new physically-based volume rendering method called Cinematic Rendering (CR) has recently been released (Comaniciu et al., 2016; Dappa et al., 2016; Fellner, 2016). This technique provides photorealistic and lifelike images out of medical imaging (DICOM) data (Figs. 1 and 2). The images can be altered and enhanced in real-time by different lighting settings, transfer functions and other effects (Eid et al., 2017; Glemser et al., 2018).

With our study we wanted to test the functionality and feasibility of CR as part of the teaching in an interactive lecture on macroscopic anatomy.

2. Methods

We conducted an interactive 90-min-lecture on macroscopic anatomy for undergraduate medical and dental students in their first year at the Institute of Anatomy of the Friedrich-Alexander-University Erlangen-Nürnberg (FAU). Conduct of the study was approved by the relevant Ethics Committee of the Medical Faculty of the FAU.

At our university macroscopic anatomy is taught with basic theoretical lectures and a practical course with anatomical models in the first, followed by a practical dissection course with human cadavers in the second preclinical semester. The students surveyed here had not yet started with the dissection course at the time of the lecture.

The lecture about Cinematic Rendering was divided in two parts presented by two experts on the topic. Dr. Klaus Engel, Principal Key Expert for Visualization at Siemens Healthineers and one of the main developers and inventors of this technology held the first part of the lecture, followed by Professor Franz Fellner, MD, head of the Central Radiology Institute at Kepler University Hospital in Linz and extraordinary professor at the Friedrich-Alexander-University Erlangen-Nürnberg who also gives CR lectures at the Ars Electronica Center (AEC) in Linz, Austria.

The images presented in the lecture were generated with a Cinematic Rendering prototype and projected on a big screen with a 1080p HD projector. The CR software operates with a commercially available wireless game controller, which buttons are configurated to real-time manipulate (e.g. window/leveling, zoom, rotation, cut planes, etc) the image on the screen (Fellner et al., 2017). Additionally, the students were equipped with paper-framed 3D viewing glasses, with one transparent and one grey darkened lens.

The lecture itself consisted of three parts. In the first part, students were introduced into the technical background behind CR. The second part was an interactive presentation of the human anatomy (Figs. 1 and 2). During that part the audience was asked to name anatomic structures and several obvious pathologies in different body parts from several presented patients.

In the third part, students were asked to put on the 3D-glasses to demonstrate the so called Pulfrich-effect, which can regularly be experienced as an illusory perceptual disturbance as well as a phenomenon in different optic neuropathies due to our visual cortex' interpretation of objects in motion (Lanska et al., 2015). We used the effect in order to forge a bridge between technology, anatomy and pathophysiology.

After the lecture the students were asked to fill out a self-assessment questionnaire particularly designed for the purpose of our study. The questionnaire was anonymous and consisted of 9 questions (see Appendix A).

It contained two dichotomous items (yes/no) on experience with radiologic imaging (e.g. internship) and previous education in another medical profession (e.g. paramedic, nurse, etc.). The

Table 1
Sample size, Gender, Q1 "Experience", Q2 "Previous Medical Education".

Value	Quantity	Percentage
Total (n)	120	100%
Medical student	87	72.5%
Dental student	33	27.5%
Gender (Male)	40	33.3%
Gender (Female)	75	62.5%
Gender n/s	5	4.2%
Q1 Experience yes	17	14.2%
Q1 Experience no	101	84.2%
Q1 Experience n/s	2	1.6%
Q2 Education yes	26	21.7%
Q2 Education no	93	77.5%
Q3 Education n/s	1	0.8%

other seven items (Questions = Q) were rated according to a five-level Likert scale: strongly disagree, disagree (score of 2), neither agree nor disagree (score of 3), agree (score of 4) and strongly agree (score of 5). They covered the fields of anatomical education (Q3: "Understanding Anatomy", Q4: "Velocity of Learning", Q5: "Spatial Relationship" Q6: "Improvement of Education") and the link between anatomy and clinical aspects (Q7: "Knowledge Transfer"). Question 8 (Q8: "Self-study") quantified whether students agreed to use CR for self-study on an electronic device (e.g. laptop, tablet, smartphone, etc.). The last question (Q9: "Fears and Concerns") investigated if, in the students´ perception, CR potentially could help to reduce fears and concerns regarding the dissection course. We also added a section for freely formulated comments by the students.

The statistics were performed by usage of SPSS version 25.0 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY). A Spearman's rank correlation was conducted to test whether gender, clinical experience or previous medical education correlated with Q7 and Q9.

3. Results

Altogether, 87 (72.5%) medical and 33 (27.5%) dental students participated the interactive lecture. The response rate of our survey was 100% (120/120).

62.5% (75/120) of our students were female, 33.3% (40/120) were male, 4.2% (5/120) gave no answer. 14.2% (17/120) of all students reported that they already had experience with viewing radiological images (Item1) 84.2% (101/120) negated the question, 1.6% (2/120) did not answer. 21.7% (26/120) reported another training in the medical field before studying in their recent degree course (Item 2), 77.5% (93/120) answered no and 0.8% (1/120) did not answer (Table 1).

At least 85% of our study collective agreed or strongly agreed to each of the questions Q3–6 and Q8 (i.e. 4–5 points on the Likert scale). Q7 was rated positively (i.e. 4–5 points on the Likert scale) in 76.5% of the cases (Table 2; Fig. 3).

There were no significant correlations between Q7 and gender (Spearman's Rho (ρ) = 0.203 with p = 0.030), clinical experience (ρ = 0.057 with p = 0.547) and previous medical education (ρ = 0.11 with p = 0.908).

Regarding Q9 the answers were distributed more heterogeneously. The mean value on the Likert-Scale was 3.41 (SD: 1.15). There were no significant correlations between Q9 and gender (Spearman's Rho (ρ) = 0.025 with p = 0.793), clinical experience (ρ = 0.104 with p = 0.263) and previous medical education (ρ = 0.138 with p = 0.135).

Seven students took the opportunity to give freely written feedback. All comments were similar, rating the event as very positive and adding the wish that this kind of lecture would be conducted again in the future.

4. Discussion

The role of radiological imaging in anatomical education has been a topic of discussion for a long time, ever since these tech-

Table 2
Answers Q3–Q9. Answers Q3 to Q9, showing total numbers, percentages, mean values and standard deviation of all answers.

Question	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)	No entry	Mean (SD)
Q3	0 (0.0%)	1 (0.8%)	4 (3.3%)	26 (21.7%)	89 (74.2%)	0 (0.0%)	4.69 (0.577)
Q4	1 (0.8%)	2 (1.7%)	15 (12.5%)	39 (32.5%)	63 (52.5%)	0 (0.0%)	4.34 (0.825)
Q5	1 (0.8%)	0 (0.0%)	3 (2.5%)	22 (18.3%)	94 (78.3%)	0 (0.0%)	4.73 (0.590)
Q6	0 (0.0%)	1 (0.8%)	6 (5.0%)	34 (28.3%)	79 (65.8%)	0 (0.0%)	4.59 (0.628)
Q7	0 (0.0%)	4 (3.3%)	24 (20.0%)	44 (36.7%)	47 (39.2%)	1 (0.8%)	4.13 (0.849)
Q8	1 (0.8%)	3 (2.5%)	11 (9.2%)	29 (24.2%)	76 (63.3%)	0 (0.0%)	4.47 (0.829)
Q9	5 (4.2%)	20 (16.7%)	40 (33.3%)	24 (20.0%)	27 (22.5%)	4 (3.3%)	3.41 (1.150)

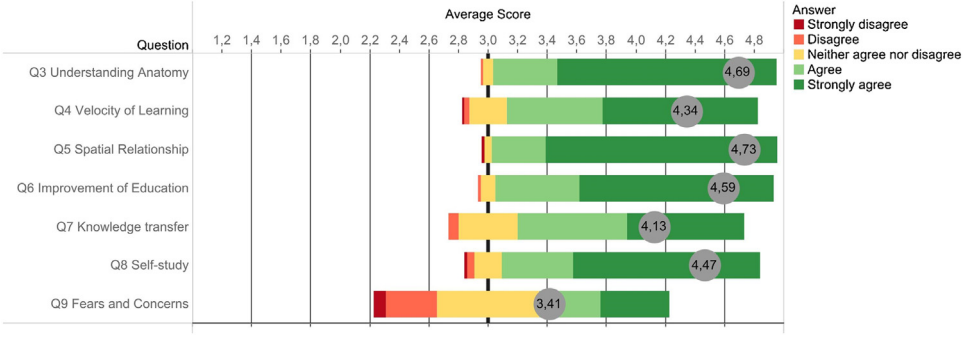

Fig. 3. Evaluation of Q3–Q9.
Evaluation of Q3–Q9, showing the answers in different colouring, whereas more reddish colour indicates disagreement and more greenish indicates agreement. Mean values are illustrated in in grey circles.

niques became feasible for medical use in the late 1960s and 1970s (Bennett, 1968; Forrester, 1971). Over the last decades, imaging quality has increased steadily and thoroughly. Nowadays, digitalization has become more and more important and communication and information technologies play a crucial role in medical education (Valcke and De Wever, 2006; Ward et al., 2001).

In a recent review on the integration of anatomy and radiology the authors state that the clinical application of anatomy increases the students' interest in anatomy and also improves the ability to interpret radiological images (Heptonstall et al., 2016). The implementation of radiological education via cadaver CT scans into gross anatomy was tested and highly appreciated by participating medical students. Furthermore, the students' ability to recognize anatomical structures when working with medical images was enhanced(Erkonen et al., 1992; Erkonen et al., 1990; Paech et al., 2017). Both, CT and MR imaging, seem to be suitable for imaging of embalmed human cadavers (Schramek et al., 2013). The usage of Cinematic Rendering is an approach to increase the quality and realism of conventional 3D reconstructions of CT and MR images (Chu et al., 2018; Rowe et al., 2018a; Rowe and Fishman, 2018a,b; Rowe et al., 2018b,c,d,e,f,g,h). Its potential for a virtual dissection of scanned human cadavers could already be shown (Glemser et al., 2018). Thus, it seemed plausible, that the integration of this innovative technology could improve education and prepare students for future requirements as a physician in a better way.

Our pilot project with an interactive lecture including cinematic Rendering was accepted very well and received an excellent evaluation. From the high percentage of students who rated Q3–6 positively we conclude that those subjects experienced CR as a beneficial addition in anatomical education. Q5, exploring the students' opinion whether CR could help to connect basic anatomical with clinical knowledge, was rated positive by more than 75% of the students, however not as positive as the aforementioned questions. One possible explanation for this observation seemed to be that first-year students may not be able to appreciate the value of CR to its full extent, since they do not have enough insight in the clinical field so far. Hence, we also tested whether students with clinical experience or a previous medical education rated Q5 differently in comparison to those who stated not to have this kind of experience or education. In our study collective, neither clinical experience, nor previous medical education were significantly associated with the observed difference in the ratings. This might be accredited to the circumstance that our study collective is still rather small. The fact that the opinion on that topic was covered by only one question and with that rather undifferentiated may also contribute to the result. To investigate this question more in-deep in the future we should address the topic more differentiated and with more items.

The implementation of e-learning in medical education is progressively common and there are hints that it will be a pivotal element in future teaching as it is highly accepted and rated beneficial by students (Choules, 2007; Frehywot et al., 2013; Huynh, 2017; Ruiz et al., 2006). We see a reflexion of that development also in our students' answer to Q6 where they affirmed that they can also imagine using CR as a self-study tool on an electronic device.

In 2017, a new department of eHealth and mHealth was founded at our Faculty of Medicine stressing the importance of these educational techniques. We find the development of an e-learning tool that works with CR conceivable and a good possibility to integrate a modern way of teaching that is, based on our data, embraced by students into the curriculum. Future research should assess not only the students´ acceptance of this tool but as well the impact of CR as a self-study tool on students' performance.

Interestingly our data indicates that Cinematic Rendering is not perceived as helpful to reduce concerns and fears regarding the (first) contact with human cadavers in the dissection course in our collective, as prompted in Q7. However, the interpretation of Q7 is still disputable. As we did not assess the students' perception as well as their concerns and fears on the dissection course beforehand, it is also possible that our students might not have any relevant concerns or fears at all which sheds a different light on the interpretation of CR's usefulness to address this topic.

In general, we are aware that our short questionnaire was not tested for internal validity beforehand and thus, although being very simply and clearly structured, may be susceptible for some misinterpretations. Still the main goal of our pilot project was to gather information on our students´ acceptance of CR as an educational tool and if this new, innovative tool may offer an additional, student-friendly approach for a modern presentation of anatomy inside the medical curriculum.

Our students' acceptance contributes to the decision if a new method has a chance to be integrated in the curricular teaching successfully.

Apart from that we see great didactical potential in CR and beneficial effects of integrating this technique early during the course of study.

The usage of imaging techniques to create more interesting and realistic images, thus make content more feasible and stimulating for the recipient has a long tradition. Unsurprising many visual techniques have their origin in special effects departments of the film industry. The so-called Pulfrich-Effect which we demonstrated in our lecture, for example, is a very basic principle for the creation of a three-dimensional effect in film animation. This optical illusion was firstly described in 1922 by German physicist Carl Pulfrich. By darkening one eye, a delay in signal transmission to the visual cortex is initiated. This delay creates the optical illusion of a three-dimensional object in motion (Lanska et al., 2015). We used paper-framed 3D-glasses to demonstrate students this effect and teach students basic principles of signal transmission in neuroanatomy and also present different visualization possibilities that could be used in anatomical education. The advantage to use paper-framed glasses is that they are a very cost-effective but effective tool to demonstrate the audience 3D-effects in real-time. In general, the CR prototype is a software tool that processes regular imaging data (DICOM standard). Hence it is capable to work with other active and passive stereoscopic techniques such as shutter systems, polarization systems, anaglyphic systems, and even the use of wearable virtual or augmented reality headsets. Additionally, all images can be manipulated with different kinds of controlling devices.

Spatial understanding is crucial for comprehension of composition and function of the human anatomy however the ability to understand spatial orientation is very individual and differs from student to student (Garg et al., 2001; Pandey and Zimitat, 2007) thus it needs to be trained. We experience CR as an option that could make facilitate the training, an opinion shared by our students (see Q5) and consider it recommendable to try an implementation of this fresh technique into lectures. For future anatomical education, all different stereoscopic systems mentioned are in line for application with CR which might create equal initial conditions in terms of different spatial abilities.

But even outside the subject anatomy we see options aplenty for the application of CR in medical teaching. Interactive Cinematic Rendering images could be implemented into web-based e-learning platforms where students and researchers have access to a database with a great number of patient images, reaching a possibly higher level of comprehensibility by the usage of CR. Macroscopic images could be linked to the corresponding histological slices for virtual microscopy, interactive seminars in small

groups could be held with holograms using virtual or augmented reality technique. It is even conceivable that students and lecturer are remote from each other in telematic lectures, intensifying the teaching process.

In our opinion, radiological imaging and CR could very well be implemented into the dissection course either. At our Institute for Anatomy, we already create radiological images of cadavers using CT-scanners. The resulting data could be presented to students, for accompanying self-study during the course on an electronic device such as a portable tablet with only little additional effort.

This could be an opportunity for, students to prepare themselves better for their next sessions in the dissection course as well as for the respective examinations. At any time, they would be able to review the CR-imaging of the entire body, even though structures would have already been removed during the dissection. By using augmented reality, even a virtual dissection as a tool for repetition of former lessons´ contents seems possible.

Some authors already speculate that teaching with medical imaging might herald the end of the era of teaching anatomy by dissection (McLachlan, 2004). This opinion, however, is controversial and also represents a point of view we cannot share in Erlangen. We are convinced that imaging techniques may develop to be a very valuable add-on to the hands-on dissection course but will not be able to replace it sufficiently.

Outside the frame of anatomy, an early introduction to imaging techniques like CR should help students to get gather early positive experiences with medical imaging in general. An implementation of radiological imaging by integrating CR into the curriculum of medical schools could also reduce students' reservations regarding the use of medical images (Darras et al., 2017). CR might help to get students actively involved in the topic of medical imaging early on and help to understand the benefit of newly developed techniques as it could help to illustrate patent cases more impressively and memorable.

As anatomical knowledge is crucial for the understanding of medicine in general and some sub-specifications like all surgical subjects, subjects linked to radiology, neurology and others, CR can contribute to train our medics in a better way.

All this, however, will not come for free and it will also be up to the commitment of the medical faculties if these revolutionary techniques will be integrated in the curricular process as the regular usage of such highly advanced technologies like CR would also need considerable initial investments for expertise and equipment.

5. Conclusion

In this study, we surveyed students' opinion of an anatomy lecture that was held by using a very recent imaging technology called Cinematic Rendering. Taken together, our results indicate strongly that students have the opinion that the implementation of this new technique enhances anatomical education. As a next step, we plan to estimate the possible impact of CR on the learning outcome. We want to examine whether students will benefit from working individually with an autonomous use of CR in addition to lectures and the dissection course and achieve better results and knowledge of the human anatomy.

Acknowledgement

The present work was performed in (partial) fulfillment of the requirements for obtaining the degree "Dr. med."

Appendix A.

Questionnaire: Cinematic Rendering (CR) for Students

Questionnaire: Cinematic Rendering (CR) for Students

Dear students, we want to survey your experience with our Cinematic Rendering lecture. Please answer this questionnaire anonymously. Thank you!

1) Field of study:

Medicine ☐ Dental Medicine ☐

2) Gender:

Male ☐ Female ☐

I do have **Experience** with viewing radiological images (Placement in Department of Radiology, etc). Yes ☐ No ☐

I have finished a previous **Medical Education** before my medical studies (Paramedic, Nurse,etc.). Yes ☐ No ☐

Desired **Medical Spezialization**: _____

Question		Strongly Disagree----------Strongly Agree				
		1	2	3	4	5
3	The use of CR could help me to understand the human anatomy better					
4	The use of CR could help me to conceive the whole human anatomy at first sight faster					
5	The use of CR could help me to comprehend the spatial relationship of anatomical structures better					
6	The implementation of CR would improve education in anatomy					
7	The imaging of CR would help me to connect basic anatomical with clinical knowledge					
8	I can imagine using CR to self-study on a (private) electronic device (e.g. laptop, tablet, smartphone, etc.)					
9	CR could help me to reduce my concerns and fears regarding my (first) contact with human cadavers at the dissection course					

Please don't hesitate to give us feedback:

_____
_____
_____
_____

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