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Innovative Strategies for Dental Anatomy Education: A Qualitative Exploration of Online Learning Perceptions

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Abstract- ***Purpose:*** COVID-19 mandated emergency remote (online) teaching of dental anatomy at King's College London. To overcome the challenges of online learning in practical subjects such as dental anatomy, novel approaches to teaching were employed in an attempt to maintain learning quality. Online tutorials were tailored to incorporate technology enhanced learning using digitised lecture slides that emphasised 3-dimensional tooth structures and case-based problem solving along with a key, in-hand, visual aid, namely 1:1 acrylic teeth which were given to each student as a learning accessory. This contemporary online learning format has remained to date. Thus, this work set out to assess the effectiveness of these innovative efforts in online dental anatomy learning and elucidate the key elements that drive learning success. Through this, valuable strategies for improved future course delivery were gained.

Methodology: Upon gaining informed consent, semi-structured qualitative interviews, thematic analysis and interpretive phenomenological analysis on lived experience of participants was performed. This approach to research design uniquely revealed the unquantifiable realities of the social phenomena that underpin the human experience when learning dental anatomy.

Results and conclusions: Findings suggest that participants preferred the online format to a face-to-face format citing improved engagement, interaction, technology enhanced learning (TEL) and visual aided learning (VAL) as key advantages, and therefore, themes. A positive learning environment appeared to be gained and maintained owing to these themes. Findings further suggest it may be instrumental for the success of future online dental anatomy learning strategies to place engagement and interaction as prime strategic teaching objectives and to use elements of TEL and VAL to enable these objectives. Perhaps most interesting was that participants suggest a desire for a blended learning approach with online and face-to-face lectures that would gain the pros while mitigating the cons of either format if applied individually.

Keywords: online dental anatomy learning, tooth morphology education, medical anatomy e-learning, blended learning, practical subject education, thematic analysis, phenomenology, pedagogy.

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I. Introduction

The onset of the COVID-19 pandemic caused unprecedented disruptions to lifestyles of dental staff and students in dental schools globally (Alwan et al. 2020; Farrokhi et al. 2021). In the United Kingdom, national lockdowns were imposed that resulted in the suspension of dental school face-to-face lessons (Bashir et al. 2021). This mandated staff to creatively employ innovative techniques to facilitate Emergency Remote Teaching (ERT), *i.e.* the use of remote teaching solutions for education that would otherwise be delivered face-to-face. Online and electronic learning (e-learning) rose to prominence at this time (Allen and Seaman 2014; Ahmed et al. 2020; Ferrel and Ryan 2020; Wasfy et al. 2021; Dyrek et al. 2022).

While online learning involves tutor interaction, e-learning is defined as self-directed learning based on the use of electronic media and devices and can be entirely technology driven without face-to-face contact. If online or e-learning involve a mix of traditional and digital learning methodologies, they are then known as blended learning (Rowe et al. 2012; Duque et al. 2013; Makhdoom et al. 2013). Across disciplines, data suggests that well designed online and e-learning can lead to student enhanced motivation, satisfaction, and learning (Zheng et al. 2021). Some work has gone on to show that medical students prefer the online learning format to face-to-face formats due to advantages such as greater accessibility, resource scalability, self-paced learning, and cost effectiveness. However, notable disadvantages with online learning are known to exist particularly regarding the lack of peer-to-peer and peer-to-teacher contact, along with learning inefficiency. This is perhaps particularly so in more practical medical subjects such as dental anatomy because these subjects involve more complex visual-dependent learning, and learning institutions have raised concerns about the possibility of lowered academic integrity (Mukhtar et al. 2020; Stecuła and Wolniak 2022). While research pertaining to the efficacy of learning dental anatomy is lacking, in other fields, a growing body of evidence suggests online learning, may produce better if not the same learning outcomes in comparison to face-to-face learning (Means et al., 2012; Pei & Wu,

2019). Alongside this, contemporary work across higher education institutions suggests that blended learning systems may achieve better learning outcomes for more practical subjects (Fermozelli et al. 2017; Chin et al. 2020; Vallee et al. 2020; Kumar et al. 2021; Sarkar et al. 2021; Atwa et al. 2022).

Tooth morphology or dental anatomy is a good example of such a practical subject and it is a year-spanning course offered to first-year dental and hygiene therapy students at King's College London. Upon the onset of the COVID-19, dental anatomy teaching moved purely online. Although this format was conceived as an ERT format, it has since remained in an online learning format. Learning efficacy is imperative in this online learning dental anatomy component as upon completion, students are expected to enter the dental labs and complete wax ups of teeth, thus gaining invaluable foundational clinical skills, a pre-requisite to clinical dental restorative work.

Anatomy is known to be challenging even in face-to-face formats (Peirce et al. 2014; Bączek et al. 2021; Byrnes et al. 2021). In an attempt to overcome some of the anticipated challenges of online learning dental anatomy, high quality digital modelling resources, visually stimulating 3-D lecture slides, and acrylic 1:1 primary and secondary teeth per student were provided. Conscious attempts to generate student to teacher feedback, student motivation, and student self-discipline were also made as these are established limiting factors to online learning (Mukhtar et al. 2020; Bączek et al. 2021; Yang et al. 2021). Given that online learning is a novel approach to dental anatomy, a crucial question remained, 'How effective is online learning for dental anatomy?'

This study was carried out by direct formal assessment of student lived experience and student perception using inductive thematic phenomenology, an established assay in qualitative research of this nature. The aim of this study was to gauge efficacy of the innovative strategies in this online learning approach, to elucidate the key elements that drive learning success, and thus identify areas for growth to improve course delivery and, in turn, produce better dental clinicians. The online learning format here offers a cost-effective teaching strategy for practical subjects in a rapidly digitising world, therefore, it is important that such benefits do not come at the expense of learning quality.

II. Methodology

a) Background

Semi-structured qualitative interviews were conducted and thematic analysis was performed to assess lived experience of participants. Interpretive phenomenological analysis allowed identification of common themes. This approach to research design uniquely revealed the unquantifiable realities of the social phenomena that underpin the human experience when learning dental anatomy.

Informed consent was gained from each participant via a detailed information sheet, verbal conversations, and a consent form signed by each participant. Interviews were conducted until thematic saturation was reached, this was evident at n=10 participants. Since several students volunteered to participate in this study, participants were chosen at random.

At the time of interview, students had completed the online module, and subsequent in-person dental wax-up labs. Since they were required to put into practice what was learnt in the online modules in the laboratory sessions, it is inferred that participants were better able to effectively feedback on the quality of the online module and if it sufficiently prepared them.

b) Data collection

Participants were asked to attend an online recorded interview and to respond genuinely to standardised open ended semi-structured questions conducted by one researcher. A potential influence on the results collected may have occurred due to the researcher conducting the interview having been part of the teaching staff. However, an attempt to minimise this was made by motivating the participant to be as candid and critical as possible to improve course delivery. Data gained suggests this was achieved.

Following the interviews, verbal responses were transcribed and anonymised to maintain participant confidentiality prior to analysis by the researcher that was not involved in the interview process.

c) Standardised interview questions

1. How do you feel your dental anatomy online sessions went this year?
2. Was there anything you liked about the online tutorials?
3. Was there anything you disliked about the online tutorials?
4. What did you think about the acrylic teeth visual aids provided?
5. Did the online tutorials prepare you for your dental lab tooth wax up sessions? Please elaborate.
6. How would you do things differently to have better aided your learning?
7. Do you prefer an online or a face-to-face format? Please elaborate.

d) Data analysis

Interpretive phenomenological analysis on the anonymised data and an inductive and semantic approach of thematic analysis (Braun and Clarke 2006; Maguire and Delahunt 2017) was performed using Microsoft Excel on data gained. Themes were flagged based on the frequent mentioning of key words or

meanings in statements by different participants. Thematic analysis was independently verified by both researchers involved in the study.

Abbreviations

PLE – Positive Learning Environment

ERT – Emergency Remote Teaching

TEL – Technology Enhanced Learning

VAL – Visual Aided Learning

VLE – Virtual Learning Environment

III. Results

Six themes emerged from interviews of 10 participants by using thematic analysis using an inductive approach. The identified semantic themes, based on explicit and surface meanings, are strongly related, and linked to the data collected. Analysis did not include anything beyond what was said by the participants. The emergent themes gained were:

1. *A positive learning environment*– a measure of teaching success
2. *Interaction*– learning necessitates interaction
3. *Engagement*– engagement generates interaction
4. *Visual aided learning* – aid complex system learning beyond verbal explanations alone
5. *Technology enhanced learning (TEL)*– offers on-demand, portable and convenient learning
6. *Classroom format (Online vs. Face-to-face vs. Hybrid)*– a hybrid approach emphasises the pros and limits the cons of online and face-to-face individually

1) Positive learning environment

Studies show that student perception of instruction quality, including the learning environment, enhances the quality of learning (Cohen 1980). Thus, an overall positive learning experience (PLE) can serve as a measure of teaching success making it one of the most critical components of a skills-based health education classroom (Rusticus et al. 2023). A PLE is thought to be achieved in a learning environment where all students feel valued, safe, and supported (Allen et al. 2021; Amerstorfer and Freiin von Münster-Kistner 2021).

In this study, analysis of the data gained suggested that all participants in this study had an overall positive learning experience with the online tutorials. In support of this, two participants said:

'The online tutorials were fun, I gained quite a bit and heard good things from others.'

'The online tutorials were really good and insightful, before them I did not feel like I had a good grasp of tooth morphology, following them, things were much clearer.'

At the time of interview, students had completed the dental wax up lab modules where they were expected to put into practice what they had learnt in the online learning component suggesting more insightful responses. The findings suggest that the online learning format was overall effective at achieving a PLE.

2) Interaction

Interaction was the most frequent theme among participants, most commended it and requested more opportunities for it.

'I liked the images of skulls and their features and using them to determine age, it was interactive and fired participation.'

'Lectures were engaging and interactive, when we were asked questions, I chatted answers. I liked it, but more interaction maybe.'

'Interaction helped learn.'

Some comments suggested that teaching styles varied affecting interaction.

'I questioned even coming to the lectures because things were so similar to the pre-recorded lectures. I wish the tutorials were more question based and interactive.'

'I wish they had more questions throughout them, there's a lot of info so it would help to recap regularly.'

'I did not like the speaker reading the slides to us.'

These findings suggest that learning in the online learning setting may not exist without interaction. According to the literature, this idea is not novel. Interaction is known to play a critical role in contemporary learning system effectiveness, particularly so in online learning (Billings et al. 2001; Boyle and Wambach 2001; Bernard et al. 2009). In online learning courses, interaction is known to occur synchronously or asynchronously (Smith and Dillon 1999) and further to this, interaction occurs in three ways: learner-content interaction, learner-instructor interaction, and learner-learner interaction (Moore, M. G. ve Kearsley 2012). A fourth, novel but influential type of interaction, is learner-interface interaction (Hillman et al. 1994; Ehrlich 2002; Thurmond and Wambach 2004). Since most participants commended interaction, our findings suggest that interaction was a well-accepted feature of the dental anatomy online learning environment. Furthermore, useful comments offered ideas as to how interaction in the online learning format could be improved.

'Better quality of interaction through smaller breakout groups, maybe setting a task like skull age determination then letting us solve it and get back with an answer, instead of asking the whole class.'

'More quizzing in smaller groups to interact with other students.'

3) Engagement

Learning engagement has been described as 'constructive, enthusiastic, willing, emotionally positive,

and cognitively focused participation with learning activities' (Christenson et al. 2012). Engagement is known to predict academic achievement (Lei et al. 2018) and retention (Álvarez-Pérez et al. 2021). Interestingly, some teaching practise suggests that learner engagement generates interaction (Gherghel et al. 2023). These findings infer an intimate relationship between interaction, engagement, and learning.

Participants expressed positive sentiments toward engagement further inferring that interaction was a critical theme supporting the acceptance of the online learning format.

'The content was engaging and the lectures covered useful information.'

Some remarked positively to methods used to prompt engagement.

'Polls in chat is a really nice way to get people involved.'

However, comments also indicated issues with engagement online that are useful to build future strategies on.

'People like me may be reluctant to answer in big groups, it would be less intimidating in smaller groups. Sometimes the Teams sessions felt isolating and I felt like I was alone in the classroom although it was a big class, it may be better to have seen the people doing this with me and it could encourage discussions and different thinking. Maybe having the very first workshop session in person so everyone can meet and find comfort in the presence of one another, then it can move online and everyone kind of knows who they are sharing the virtual room with. People may feel more confident presenting answers.'

'Maybe smaller groups online would make me feel more comfortable asking questions about the tooth models.'

'I wish they had more questions throughout them.'

'It wasn't the most engaging because on Teams it can feel awkward because everyone is hesitant to answer questions.'

The findings thus suggest that learners found the content engaging and suggested better targeted opportunities to generate learner engagement are needed. This may foster a learning environment where students feel safe to share and participate thus improving interaction further.

4) Visual aided learning

Visual explanations and accessories have been shown to aid learning of complex systems beyond verbal explanations alone, this is particularly so for participants of low spatial ability (Azer and Azer 2016). The known benefits gained from visual aided learning are plentiful (Zacks and Tversky 1999; Hegarty et al. 2003; Tversky and Suwa 2009; Kessell and Tversky 2011; Bobek and Tversky 2016; Leung et al. 2020).

Tooth morphology is a critical foundational course for the dental professional (Eid et al. 2013; Kellesarian 2018). This means it is imperative that students gain proficiency in the 3D structure of teeth. Prior to COVID-19, students could attend in person lectures where they had opportunities to interact with extracted teeth to consolidate anatomical learning. Following this, these pre-laboratory tutorials were migrated wholly online, thus there was a need for innovative visual aid use. Lecture delivery using a virtual learning environment had to be re-invented to place emphasis on gaining a 3-dimensional understanding via 2-dimensional verbal teaching. Clinical photographs, skull/tooth images, and interactive exercises, helped orientate students, however, this alone lacked any 3-dimensional student accessory. An aseptic solution to aid a 3-dimensional understanding was gained using acrylic primary and secondary teeth sets at 1:1 scale. The importance of this aid has been documented in other teaching designs (Eid et al. 2013; Azer and Azer 2016; Lone et al. 2018; Kirkup et al. 2019; Risnes et al. 2019; Wang et al. 2020). Each student received their own set.

We assessed the efficacy of the acrylic teeth visual aids based on participants experience. It appeared that participants reacted overall positively to the acrylic teeth sets.

'It's one thing being told about features on a screen and another thing being able to see it in place 3-dimensionally. So, it was helpful to have something physical, I could really see differences between primary and secondary teeth.'

'Really helpful to just have and like look at as we were going through the lectures.'

'I am a very visual person and would like to see things up close, really helped.'

Participants also remarked positively to other visual aids employed:

'I liked the images of skulls and their features and using them to determine age.'

'I liked the 3D approach in presentations and the mouse pointer so we could follow along.'

Useful critical comments were also gained offering valuable feedback that can aid future visual aided learning delivery.

'It may be better to view the models in person because I think my tutor didn't have good lighting so I missed things in the camera.'

Our results suggest that visual aided learning using acrylic teeth and detailed 3-D images in presentations were useful techniques that must be further developed.

5) Technology enhanced learning (TEL)

The virtual learning environment developed for this online learning course was possible due to TEL. TEL is often used to describe the use of digital technology to support and offer educational activities (Goodyear and Retalis 2010) and its use in higher education has markedly grown in recent years (Kirkwood and Price 2014; Trelease 2016; Clunie et al. 2018). TEL's utility is increasingly recognised for its transformative approach to education even where barriers, such as those posed by COVID-19, exist (Nicoll et al. 2018). Literature also indicates that mobile devices increasingly play a role in student learning (Ozdalga et al. 2012).

Comments from participants in this study indicated that TEL overall aided the learning experience. These comments cited either TEL directly or referred to TEL resources that were recommended in course content.

'I really liked the prompts on how to learn dates on Youtube.'

'I especially liked the summary slide, could carry them on my phone.'

'Having the slides to refer to on my phone was really helpful in revision and wax ups.'

Challenges raised with TEL, were not new to online learning:

'Sometimes the internet connection was poor and it created confusion.'

Participants also offered useful feedback on ways to improve delivery.

'Would be nice to have 3D moveable images in the lectures so we can see the tooth move around and follow with the models - more similar to a patient.'

'I would have 3D animations to see model teeth details over using a live camera.'

'Good idea to recommend more online website quizzes or visual activities instead of books because it's a very visual thing rather than actually reading, in my opinion.'

Overall, TEL was well accepted by students suggesting online learning as an effective way to learn dental anatomy.

6) Classroom format (Online vs. Face-to-face vs. Hybrid)

Since online learning was an ERT approach to tooth morphology, it was necessary to determine whether participants preferred the purely online learning format to a face-to-face approach.

Most comments suggested that participants preferred the online learning format.

'I did not mind online sessions, I revise at home anyway so did not make a difference to me.'

'Online did work well and was encouraged to meet peers to go over things together in our own time.'

'Online is useful and flexible but I think that I could have really benefitted from having someone in person to ask things to at least once, the classes were too big.'

'I liked the ability to ask the lecturer anything online by chatting and to recap things I didn't understand.'

However, some participants highlighted key problems with a purely online learning approach.

'I often shy away from the camera too, so it's easy to think you're alone in the room, isolated.'

'I like answering questions more in person, it's a lot less awkward.'

'Sometimes the teams sessions felt isolating and I felt like I was alone in there although it was a big class.'

'I would prefer if the sessions were in person so I can understand details better.'

'Maybe having the very first workshop session in person so everyone can meet and find comfort in the presence of one another, then it can move online and everyone kind of knows who they are sharing the virtual room with. People may feel more confident presenting answers.'

Interestingly, the students suggested that several of these issues could be resolved through employing a hybrid learning format.

'I liked the format but a final extra session in person to recap everything and show us the models close up would be better.'

'Online is useful and flexible but I think that I could have really benefitted from having someone to in person ask things to at least once, the classes were too big.'

'If I was forced to choose, I think a hybrid between the two would be more beneficial.'

'I do like it in online as well because I can go back and look at the recordings if I'm unsure and actually like hear him speak again rather than just like working through my own. In my opinion, I think like a mix of both.'

The findings here identify that students prefer the purely online learning format of dental anatomy to a purely face-to-face format. However, student perceptions strongly suggest that a blended learning or hybrid approach (online learning with face-to-face) to dental anatomy may offer the most effective learning.

IV. Discussion

The online learning format here offers a cost-effective teaching strategy for practical subjects in a rapidly digitising world, therefore, it is important that such benefits do not come at the expense of learning quality. The aim of this qualitative study was to gauge

efficacy of the innovative strategies in learning dental anatomy, a complex practical subject, online, based on student perceptions. Further aims were to understand the key elements that drive learning success, and thus identify areas for growth to improve course delivery. It is worth noting that the participants had completed the online learning module and subsequent in-person practical dental anatomy laboratory module where they put into practice what was learnt in the online learning module. Thus, having conducted interviews at this time suggested more insightful responses were gained from the students as they would be more aware of knowledge deficiencies and quality of learning. Data analysis revealed six themes through thematic analysis; 1) positive learning environment (PLE), 2) interaction, 3) engagement, 4) visual aided learning, 5) technology enhanced learning, 6) classroom format. The delineation of each of this themes offered orderly identification of areas of success and weakness thus generating valuable data that is likely to be of value to those coordinating online learning classrooms that teach practical subjects. Furthermore, through this work, findings strongly suggest a composable interplay between each of the themes with engagement and interaction featuring as indispensable elements that drive success accessorising the TEL and VLE resulting in a PLE.

The first success of this dental anatomy online learning approach was well demonstrated by students' unanimous comments in favour of a PLE having been gained through online learning dental anatomy. This finding is important because a PLE is achieved in a learning environment where students feel valued, safe, and supported. A PLE is also linked to student perception of instruction quality and the quality of learning. Thus, an overall PLE is suggested to serve as a measure of teaching success and has been referred to as a critical component of the skills-based health education classroom inferring success of the approaches used in dental anatomy online learning.

Interaction was the most apparent theme regarding what students valued most about the online learning classroom. The comments gained regarding interaction showed that students valued efforts made to nurture interaction within them appreciating the periodic recapitulatory quiz slides, and the opportunity to chat answers and questions. On the other hand, some critical comments gained insightfully indicate that a more uniform effort to nurture interaction by all teaching staff would be better received. Additionally, a student suggested the use of smaller problem-solving breakout rooms to enable interaction, this would offer an opportunity to generate progressive comfort with interacting in the larger online learning classroom. Perhaps the most important feature of the data gained was that students believed interaction would improve if they felt safer sharing as they seemed to find the online classroom 'intimidating', 'isolating' and 'awkward'.

Engagement has been suggested to generate interaction, predict academic achievement and knowledge retention. This highlights the importance of this theme. Several comments by students described the lessons as engaging and their explanations eventually tied into interaction. This suggests that the strategies used to generate interaction generated engagement as well. Notably, a few comments praised the use of 'polls in the chat' to answer questions. The periodic use of polls may have served as a low stake engagement prompt that generated engagement from students that may not have otherwise participated, thus, the use of polls in the chat is a valuable tool for engagement and interaction in future course development that may lead to increased engagement. All together these findings suggest that engagement and interaction do appear linked and are critical themes of the online learning dental classroom that can influence success or failure of learning. The interaction strategies employed in this dental anatomy online learning course were sufficient but further opportunities to interact and efforts to make students feel safe to share and participate would likely add marked value.

Visually heavy explanations and accessories are known to aid learning of complex material and these constituted the theme visual aided learning (VAL). Dental anatomy requires future dental professionals to gain proficiency in the 3D structure of teeth. Clinical photographs, 3-D digitised skull/tooth images, and in-hand acrylic primary and secondary teeth were availed to students. Comments from students suggested each of these elements to be a resounding success in aiding learning 3-dimensionally. Notably, students appreciated the instructors mouse pointer as a guide when navigating through slide images during lectures, a small but apparently crucial element. While the acrylic teeth were highly beneficial, a key issue raised suggested a limitation based on the resolution of the instructors camera when placing the acrylic teeth in camera focus to instruct the students on how to navigate these visual aids. Thus, it may be of importance to provide high resolution orientation videos about the acrylic teeth for access by the students on the virtual learning platform, this will ensure unincumbered clarity. All in all, the findings suggest that the VAL elements employed were a success and can offer inspiration to other instructors that teach complex subjects via online learning.

Students also received technology enhanced learning (TEL) well. Comments suggested that students enjoyed learning from the convenience and flexibility offered by TEL, saving time they would ordinarily require to prepare for the day and commute. Students also enjoyed use of other digital platforms (YouTube and tooth morphology apps) and their mobile phones to learn on the go. Suggestions to improve TEL centred

around increasing opportunities to learn this way with more prompts to other resources that could aid learning, thus it may be worthwhile to research and compile a list of quality resources that are available on the market and incorporate or recommend them during the course in future years.

Finally, directly determining whether students preferred the online learning format to face-to-face learning was necessary to guiding future strategies. Comments suggested students were mostly in favour of online learning over face-to-face learning citing several advantages previously mentioned. However, many of the same students claimed to feel unable to share and participate due to feeling isolated and awkward in an online room. Interestingly, students also went on to suggest that a hybrid format that involved online learning and face-to-face classes would solve the challenges of pure online learning due to the opportunity to bond with their peers and feel more comfortable participating. The ability to interact between peers was markedly limited due to COVID-19 and perhaps most deleterious for first-year university students. Based on this valuable feedback, a blended learning or hybrid approach (online learning with face-to-face) to dental anatomy may indeed offer the most effective learning as it may balance the pros and cons of each if employed individually. Through this, students are crucially enabled to bond and interact on a human level while they pursue their formal education. Interestingly, blended learning is gaining recognition as an optimal format for learning when compared to pure online learning and pure face-to-face strategies.

It is worth mentioning that there are author-perceived limitations to this study that may be of value to the reader. Firstly, the participants lacked a direct comparison of a concurrent module that was solely face-to-face since most of the first-year learning was primarily digitised. However, it is worth noting that the participants had attended face-to-face subsequent modules such as the dental laboratory wax up module that may still offer a solid retrospective comparison of learning quality. With this in mind, the timing of interviews may present with a limitation given the order of class formats when comparing learning quality along with the time elapsed (approximately 3 months) between the online module and the completion of the dental labs, when the interviews were performed. Lastly, the n=10 sample size may serve as a limiting factor.

Nonetheless, this work has identified online learning dental anatomy to be a successful teaching strategy. This work has also offered a unique feedback mechanism from students to dental anatomy course coordinators likely improving course delivery in the future, in turn improving the quality of dental professionals produced at King's College London. Notably, the data gained here-in is also of value to other practical subject course coordinators as the ideas and approaches can inspire improved approaches to teaching.

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Ethical approval

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