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Research report

Improvement in anatomy knowledge of medical cohorts when utilizing a novel cyclical "Observe-Reflect-Draw-Edit-Repeat" (ORDER) process is dependent on delivery approach but is independent of student artistic background and visual learning preference

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ABSTRACT

Innovative educational strategies can provide variety and enhance student learning while addressing complex logistical and financial issues facing modern anatomy education. *Observe-Reflect-Draw-Edit-Repeat* (ORDER), a novel cyclical artistic process, has been designed based on cognitivist and constructivist learning theories, and on processes of critical observation, reflection and drawing in anatomy learning. ORDER was initially investigated in the context of a compulsory first year surface anatomy practical (ORDER-SAP) at a United Kingdom medical school in which a cross-over trial with pre-post anatomy knowledge testing was utilized and student perceptions were identified. Despite positive perceptions of ORDER-SAP, medical student (n = 154) pre-post knowledge test scores were significantly greater (P < 0.001) with standard anatomy learning methods (3.26, SD = ±2.25) than with ORDER-SAP (2.17, ±2.30). Based on these findings, ORDER was modified and evaluated in the context of an optional self-directed gross anatomy online interactive tutorial (ORDER-IT) for participating first year medical students (n = 55). Student performance was significantly greater (P < 0.001) with ORDER-IT (2.71, ±2.17) when compared to a control tutorial (1.31, ±2.03). Performances of students with visual and artistic preferences when using ORDER were not significantly different (P > 0.05) to those students without these characteristics. These findings will be of value to anatomy instructors seeking to engage students from diverse learning backgrounds in a research-led, innovative, time and cost-effective learning method, in the context of contrasting learning environments.

Keywords: Gross **a**natomy education, Medical education, Undergraduate medical education, Anatomical illustration, E-learning, Teaching of anatomy.

INTRODUCTION

To improve anatomy teaching and learning it is necessary to develop strategies for enhancing student experiences, while simultaneously addressing the myriad factors that influence modern anatomy education (Sugand et al., 2010). While human cadaveric material has been traditionally used for the study of anatomy due to its physical and educational advantages (Dyer and Thorndike, 2000; Biasutto et al., 2006; McLachlan and Patten., 2006; Korf et al., 2008), this resource has economic disadvantages in terms of the staff time, facilities, equipment, consumables and transportation required to maintain it, (Aziz et al., 2002; McLachlan, 2004; McLachlan and Patten, 2006) in addition to practical barriers related to body donation and cadaver availability (Richardson and Hurwitz, 1995; Boulware et al., 2004). Curriculum time for anatomy teaching has been reduced within medical programmes (Dyer and Thorndike, 2000; Aziz, et al., 2002), which is juxtaposed with increasing student numbers and a reduction in qualified anatomy teachers (Sugand, et al., 2010). Although students favor dissection and prosection as methods of learning gross anatomy (Lempp, 2005; Chapman et al., 2013; Davis et al., 2014), restrictions on teaching time and resources can compromise the benefits of these approaches (McLachlan et al., 2004), while students are also known to embrace alternative contemporary methods including anatomical models, computer-aided learning, surgical videos and bodypainting (Davis, et al., 2014). The complex modern climate of anatomy education has resulted in heightened concern for anatomy educators to deliver not only core anatomical knowledge using a variety of both traditional and innovative educational resources, but also to provide valuable educational experiences and lifelong learning strategies for students (Sugand, et al., 2010). In the United Kingdom (UK) for example, the necessity for a core anatomy curriculum has arisen from the constrained time available for anatomy teaching due to the redesign of medical curricula in order to incorporate emerging disciplines (McHanwell et al., 2007; Smith et al., 2016), while the introduction and subsequent recent increases in tuition fees have impacted upon student expectations and satisfaction with respect to the quality of their education (Rolfe, 2002; Jones, 2010).

The initial aim of this work was to develop an innovative learning method that could be readily incorporated into the current educational terrain and contribute to satisfying the needs of students in terms of learning and experience. It is proposed that any successful novel anatomy learning method should be designed with the potential to be practically and efficiently applied to undergraduate and postgraduate education across multiple degree programmes and learning environments for surface anatomy, gross anatomy and their associated regions and systems, in addition to the topics of clinical imaging and embryology. The method should also possess qualities that allow it to be implemented and utilized at minimal cost to both anatomy departments and students without the need for additional outlay on expensive facilities or equipment. To maximize impact and efficiency, it is proposed that the approach should effectively translate from a taught environment for use in blended (Eagleton, 2015) and self-directed (Choi-Lundberg et al., 2016) learning, including integration into practically usable e-learning platforms (Ruiz et al., 2006; Choules, 2007; Van Nuland and Rogers, 2016a). The method should have a research-informed basis, strong theoretical foundations and the capacity to engage students. A visual artistic method was chosen for several reasons.

A close relationship between anatomy and drawing with origins that arose from the pioneering anatomical illustrations of the Renaissance era endures to the present day (Ione, 2010; Ghosh, 2015) and this association continues to evolve through the development of visual artistic learning methods for modern anatomy students (Nayak and Kodimajalu, 2010; Naug et al., 2011; Lyon et al., 2013). Recent work has explored the value and rising popularity of arts-based educational research and research methodologies (Sinner et al., 2006; Carpenter and Tavin, 2010) and has identified a theoretical basis for artistic learning methods (Catterall, 2005). The practical application of arts-related learning activities (Rodenhauser et al., 2004) as tools and processes within the wider context of education has also been established. There is a rich history and tradition of the visual arts in anatomy and medical education, and recent studies have described and demonstrated important current roles for artistic approaches in enhancing acquisition (Collett and McLachlan, 2005; Nayak and Kodimajalu, 2010; Ainsworth et al., 2011; Azer, 2011; Moore et al., 2011; Naug et al., 2011; Perry et al., 2011; Lyon et al., 2013) and long term retention (Balemans et al., 2016) of anatomical knowledge. Artistic methods have also been employed for supporting the development of key skills that are required by medical and healthcare students, such as observation and communication (Bardes et al., 2001; Dolev et al., 2001; Haq et al., 2004; Shapiro et al., 2006; Naghshineh et al., 2008; Pellico et al., 2009; Moore et al., 2011; Jasani and Saks, 2013; Bell and Evans, 2014). Visual artistic methods can provide aspects of engagement and interactivity that can improve performance (Hake, 1998) and enhance learning through increasing the variety of available educational methods (Ward and Walker, 2008; Eagleton, 2015) both within and outside of the dissecting room. Artistic approaches can be implemented at low cost with minimal additional resources (Bennett, 2014) and are viewed as interesting and informative by students (de la Croix et al., 2011). Artistic learning methods are appropriate for application to taught anatomy learning environments (Nayak and Kodimajalu, 2010; Naug, et al., 2011; Lyon, et al., 2013), while recent advances in e-learning technologies (Ruiz, et al., 2006; Evgeniou and Loizou, 2012; Feng et al., 2013) indicate that artistic methods could also be applied to self-directed learning within this context.

The work presented here constitutes the pursuit of an artistic learning method that fulfills the criteria described above. The design of a novel *Observe-Reflect-Draw-Edit-Repeat* (ORDER) learning process (**Figure 1A**) is based upon trans-theoretical concepts and recent studies of drawing in anatomy education. The term ORDER is intended to describe the progressive, stepwise nature of the process, rather than conveying an instructive approach. Concepts from cognitivist theory and cognitive constructivism have facilitated construction of a cycle of learning whereby prior knowledge is built upon (Ausubel, 2012) and acquired knowledge is transformed through experiential learning (Kolb, 1984), while drawing processes that have been previously used in anatomy learning (Nayak and Kodimajalu, 2010; Naug, et al., 2011; Lyon, et al., 2013) have also been incorporated into the design. Findings from the evaluation of ORDER in both practical and e-learning environments are described here. Initially ORDER was delivered in the context of a compulsory first year surface anatomy practical (SAP) session within a UK undergraduate medical degree. The intervention session (ORDER-SAP) was compared to a session in which standard anatomy learning methods were delivered (Control-SAP). Based on experimental data and survey findings, an online gross anatomy ORDER interactive tutorial (ORDER-IT) was subsequently developed and then evaluated in comparison with a standard gross anatomy online interactive tutorial (Control-IT). To identify areas for the future development of ORDER, and to further explore the impact of ORDER on learning, student perceptions of ORDER-SAP and ORDER-IT were investigated.

Due to the strong theoretical and practical basis of ORDER, it was hypothesized that significant improvements in student test scores would occur with delivery of the ORDER intervention when compared to a control. It was also expected that students with artistic and visual learning preferences would have a significant advantage over their peers in terms of learning performance (Pandey and Zimitat, 2007; Lufler et al., 2012; Schlegel et al., 2015), and so the impact of these student characteristics were identified in both ORDER-SAP and ORDER-IT evaluations.

MATERIALS AND METHODS

Delivery of anatomy education within a UK medical curriculum

The M.B.B.S. (Bachelor of Medicine and Surgery) degree at Newcastle University, UK, is a five-year undergraduate programme delivered as an integrated, case-led curriculum with early clinical experience. The qualification allows graduates to practice medicine within the UK and apply for further professional post-graduate training following an initial two year foundation position. Pre-admission criteria for the programme are normally based on school leavers' qualifications at age 18 (including but not limited to UK A-level qualifications, International Baccalaureate or equivalent), in addition to the United Kingdom Clinical Aptitude Test (UKCAT) and interview. The majority of Stage 1 (first year) M.B.B.S. students are aged 18 on entry and intake for each academic year is of around 200 students with an approximate 50:50 male:female ratio. The degree comprises Phase I, which involves mainly lecture and practical-based teaching and is delivered over two years (Stage 1 and 2), and Phase II, which comprises clinical placements in Stage 3 and 5 and lectures, problem-based learning and student selected component projects in Stage 4. A major outcome of the degree programme requires that as graduates, students will approach clinical practice with an understanding of basic and clinical sciences and their underlying principles. This outcome is delivered in Phase I, with each strand based around 48 consecutively integrated clinical case studies. Teaching is delivered in the form of compulsory units of study based around a specific strand, e.g. nutrition and metabolism; cardiovascular, renal and respiratory medicine. The curriculum therefore determines that anatomy teaching is delivered in a combined regional, systems and clinical approach. Anatomy is delivered only in Phase I through formal whole-cohort lectures and practical sessions held in the Anatomy and Clinical Skills dissecting room. On commencing their studies, the cohort are randomized into 12 subgroups, for the purposes of seminars and anatomy practicals. Ordinarily, practicals are delivered twice, to 6 of the subgroups each time in an approximate 1:18 staff:student ratio. Each practical subgroup is facilitated by a junior doctor (resident) anatomy demonstrator. Five core academic staff members deliver anatomy teaching of approximately 50 hours of anatomy lectures and 60 hours of practical sessions provided for each student in total, divided between the 8 units of study in Phase I. Each session has a unique set of specific knowledge and skill-based learning outcomes on which students are assessed in examinations. Resources utilized in the dissecting room include prosections, cadaveric specimen pots, plastic models and clinical imaging software. Interactive online tutorials and other online resources are made available for self-study purposes and are provided as adjuncts intended to support, rather than to deliver, Phase I learning outcomes. Whole body dissection is available as an option to a small number of undergraduate students during Stage 4 student selected projects. Anatomy teaching in the Anatomy and Clinical Skills Centre at Newcastle is also delivered for Dental

Surgery and Biomedical Sciences degree programmes and courses for other healthcare professionals.

A student partner approach to design and evaluation of a novel artistic learning process

A student partner approach (Healey et al., 2014) has been employed throughout, whereby undergraduate medical project students have been instrumental in the conception of the ORDER process, study design, evaluation and data analysis. The aim of this approach is to gain valuable insights from the student perspective and to encourage development of student partner research experience and transferable skills. This approach is reflected in authors M.B., M.F., J.H. and C.S.T. contributing to the work as undergraduate project student partners.

Delivery of ORDER in a surface anatomy practical session

ORDER-SAP design

The ORDER-SAP format, test questions and questionnaire items were initially developed through a small-scale pilot with volunteer medical and art students (n = 12). The finalized ORDER-SAP session was structured with a carefully timed schedule to be delivered within a one hour practical. ORDER-SAP was delivered with the expectation that by the end of the session, students would be able to identify surface landmarks of the thorax and to describe the surface reflections of the lungs, pleura and heart and identify the anatomical and auscultation positions of the heart valves. Brief verbal instructions (5 minutes in duration) on the timing and nature of each step were provided to the whole class (n = 55) during the session so that all six subgroups (n = 9/10) underwent the same process in parallel. Following the pre-test (7.5 minutes), ORDER-SAP began with an introductory two minute *warm up* drawing exercise (Lyon, et al., 2013) for the whole class led by a visual artist, in preparation for the drawing process. This exercise involved students initially making pencil marks on paper followed by the creation of a simple drawing of an everyday object. Based on prior knowledge only and without access to, or observation of, any resources, students were then asked to follow a procedure similar to the previously described *blank page* technique (Naug, et al., 2011) to visualize and draw the surface markings of the thorax using a pre-drawn outline (4 minutes). An ORDER cycle began when students, in subgroups, engaged in a guided process based on the concept of *critical looking* (Lyon, et al., 2013) through viewing an anatomical image on a large monitor screen (*Observe*, 1 minute). The image was then removed and students were encouraged to engage in reflection by silently considering what they had seen (*Reflect*, 0.5 minutes) and illustrating the important structures they had observed (*Draw*, 2 minutes). Students then modified and corrected their drawings when the image was reshown (*Edit*, 1 min) through guided reflection and peer discussion facilitated by an anatomy demonstrator and artist. This step provided a brief opportunity for students to show their drawings to their peers, to discuss the areas they had missed or drawn incorrectly, to add labels identifying the structures they had drawn or to discuss how they had attempted observation and reflection. The artist and demonstrator were available as a supportive presence to guide discussions. The artist could provide drawn examples and technical advice for the drawing process, and the demonstrator provided anatomical direction. The subsequent cycle (*Repeat*), began either with further detail added to content from the previous cycle with the intention of building on previous knowledge (Ausubel, 2012), or once the first topic had been completed, on material relevant to a new and separate topic. The first ORDER cycle concerned osteological surface anatomy, and subsequent cycles focused on building upon osteology knowledge to include the markings of the lungs, pleura and heart borders respectively, thus providing a process of progressive drawing (Nayak, et al., 2010). Five ORDER cycles were completed, and following the final ORDER cycle, the final step (4 minutes) in the ORDER-SAP session involved combining the previously drawn structures in order to produce a completed drawing of the major surface landmarks of the thorax (**Figure 1B**). The final 15 minutes of the one hour session was allocated for the post-test (7.5 minutes) and questionnaire (7.5 minutes).

Control - Surface Anatomy Practical (SAP) Design

Control-SAP was delivered with the expectation that by the end of the session, students would be able to identify and palpate surface landmarks of the abdomen, describe the surface reflections of abdominal viscera and appreciate the cross-sectional anatomy of the abdomen. Students were arranged in dissecting room in the same groups as the ORDER-SAP session. The one hour control session included a variety of standard anatomy teaching and learning resources that the students would normally experience in an M.B.B.S. Stage 1 anatomy session at Newcastle University. Anatomy demonstrators initially delivered a 10 minute didactic introduction and summary of the basic anatomy of the abdomen, reminding students of the key anatomical features and the nine region and four quadrant models. Demonstrators then delivered interactive small group teaching using prosected abdominal cadaveric specimens and plastic models of the abdomen and abdominal viscera on which the relevant features could be identified. Students were provided with a paper copy of a text and image based practical guide which included tasks that involved filling in blanks in text descriptions, labelling diagrams of anatomical features of the abdomen and included a template on which students could draw the surface reflections and landmarks of abdominal features. Students were encouraged to identify and palpate abdominal surface landmarks on each other. At the time of the ORDER-SAP evaluation, during the month of March, students had already experienced some delivery of teaching of gross anatomy and clinical image interpretation of the thorax and abdomen in both lectures and dissecting room practicals. Students had also been taught to apply their knowledge of surface landmarks of these regions in clinical skills sessions. The time spent, number of learning outcomes and emphasis placed on the gross anatomy of each region had been approximately equal. Thorax anatomy (topic of ORDER-SAP) had been delivered in semester 1 (September-December) and abdominal anatomy (topic of Control-SAP) was primarily delivered in semester 2 (January-March).

ORDER-SAP population and sampling

A census sampling approach was utilized for a Stage 1 M.B.B.S. cohort (*n* = 220, approximate 50:50 male: female ratio, median age 18 when commencing course at Newcastle University). From this cohort, students gave informed consent to participate and for their data to be used for research (*n* = 177, 80.5% response rate of whole Stage 1 cohort). Participants completed questionnaire items regarding their artistic background (*n* = 119, 67.2% response rate from 177 consenting participants) and learning preference (*n* = 147, 83.1% response rate from 177 consenting participants). Initial questionnaire items outlined below requested student learning preference and artistic background in order to identify the characteristics of the cohort (answer options are in parentheses):

1. Which method do you normally prefer to use in order to learn anatomy? (*Visually; reading; writing; listening; handling prosections*)

2. Do you have any formal art qualifications, e.g. GCSEs/A-levels, vocational qualifications? (*Yes; No*)

3. Do you ever do any drawing or art in your spare time? (*Yes; No*)

4. Do you ever use drawing in your self-study of anatomy? (*Yes; No*)

Of the participants responding to item 1 (*n* = 147), 38.7% considered themselves to possess a visual anatomy learning preference (*n* = 57). Students were categorized as possessing an artistic background if they responded *Yes* to one or more of the items 2-4. Of participants responding to items 2-4 (*n* = 119), 61.3% of responders were categorized as possessing an artistic background (*n* = 73). GCSE (General Certificate of Secondary Education) and A-level (Advanced level) are secondary and further education leaving qualifications respectively and are sat by students in schools in England, Northern Ireland and Wales.

ORDER-SAP cross-over randomized controlled trial

The whole Stage 1 M.B.B.S. cohort (*n* = 220) participated in the Control-SAP session and the ORDER-SAP intervention session within in a randomized cross-over format. In this case the cohort was distributed equally across four practical sessions rather than the usual two. All students were invited to complete pre and post anatomy knowledge tests during both sessions. Of the consenting participants (*n* = 177), students completed pre and post tests for both the control and ORDER-SAP intervention (*n* = 154, 87% response rate from 177 consenting participants). Control and ORDER-SAP intervention sessions were held over a two week period during March of the Stage 1 M.B.B.S. academic year. The cross-over format was implemented primarily for ethical purposes, with the intention of comparing student performance while ensuring that all students would experience both learning methods to achieve the same set of learning outcomes. In week 1, half of the cohort, split over two sessions (Group AB) attended the Control-SAP practical (surface anatomy of the abdomen) in and the other half, also split over two sessions (Group CD) attended the ORDER-SAP practical (surface anatomy of the thorax). The groups then crossed over in week two. Within each session, each quarter of the cohort (Group A, B, C and D) was subdivided into separate subgroups (n = 10) that were taught in separate bays within the dissecting room. Each of these subgroups was facilitated by an academic or anatomy demonstrator assisted either by a professional visual artist or postgraduate art student. For Control-SAP, students were taught by a demonstrator in identical subgroups for one hour on surface anatomy of the abdomen. Pre-post testing was carried out to account for differences in prior knowledge. Equal time periods (7.5 minutes) were allocated for pre-post testing in both ORDER-SAP and Control-SAP sessions. Power calculations determined that the sample size of consenting test participants (n = 154) would be sufficient. Participating students completed 15 pre and post session single-best answer from five multiple choice questions of assessment standard on the anatomy of the thorax for the ORDER session or on the anatomy of the abdomen for the control session. Participating cohort (n = 154) pre-test scores (6.08, ±1.81 for Control-SAP, and 7.37, ±1.78 for ORDER-SAP), and post-test scores (9.34, ±2.3 for Control-SAP, and 9.54, ±1.3 for ORDER-SAP) indicated a similar difficulty of test questions. Statistical analysis by paired t-test showed that the difference between Control-SAP and ORDER-SAP pre-test scores were highly significant ($P < 0.001$), while the difference between the means of the Control-SAP and ORDER-SAP post-test scores were not significant ($P > 0.05$), suggesting significantly lower cohort prior knowledge of surface anatomy of the abdomen compared to surface anatomy of the thorax. Pre and post questions were identical and were completed by students at the start and end of each session. Student performance was calculated and is defined here as the difference between individual pre and post test scores.

ORDER-SAP Likert-type scale questionnaire

It was important to identify student perceptions not only to complement experimental investigations by demonstrating a more complete picture of the value of ORDER-SAP and to allow further interpretation of study findings, but also to develop ORDER for future use in alternative learning environments and contexts. A mixed approach has previously been utilized when investigating artistic anatomical learning methods (Finn and McLachlan, 2010; Finn et al., 2011). Students were invited to complete a post-ORDER-SAP questionnaire in the final period of the intervention session. Of the consenting participants (n = 177), there was variation in responses to individual Likert-type scale questionnaire items (n = 150 - 177, 84.7% - 100% response rate of consenting participants). It was determined that answers from a four point Likert-type scale would be appropriate to identify student perceptions of drawing and ORDER (Leung, 2011). It was considered that students would be able to make a judgement in either agreeing or disagreeing with all questionnaire items so no neutral value was included. Items were designed and agreed upon by authors (I.D.K., M.B. and M.F.), tested in an ORDER-SAP pilot study and checked post-hoc for reliability using Cronbach's alpha, achieving a value of 0.747, where a value of between 0.70 and 0.90 is acceptable (Tavakol and Dennick, 2011) and for validity using Pearson's parametric correlation analysis as recommended for Likert-type scales with normal distribution (Sullivan and Artino, 2013), using responses from participants in a separate medical cohort (n = 16). Students chose from four options (*Strongly agree; agree;*

disagree; strongly disagree) to provide their views on ORDER and drawing and how they should be used in future anatomy teaching sessions:

5. Drawing is a valuable tool for learning anatomy.

6. The ORDER exercises in this session were enjoyable.

7. ORDER improved my knowledge of thorax surface anatomy in this session.

8. I felt that I learned more by using ORDER than I would have by just drawing.

9. I felt that I learned more than I would have in a "normal" anatomy session.

10. I felt more engaged by using ORDER than if I was just drawing the anatomy.

11. I will consider using ORDER in my self-study and revision of anatomy.

12. I would recommend using the ORDER process to future students.

Students were also asked to select one of five options in response to the following question, firstly regarding ORDER and then regarding drawing:

13. In future dissecting room anatomy sessions I would prefer a. *To just use ORDER/drawing techniques*; b. *To use a combination of learning techniques with ORDER/drawing as the main component in every session*; c. *To use a combination of learning techniques with ORDER/drawing as a supporting component in every session*; d. *To only occasionally use ORDER/drawing to aid my learning (not every session)*; e. *To never use ORDER/drawing to aid my learning*.

ORDER-SAP free-text questionnaire and content analysis

Questionnaires included a two-part free text question. Of the consenting cohort (*n* = 177), students provided free-text responses to questionnaire items (*n* = 125, 71% response rate of consenting participants):

(1) Do you have any suggestions on how the session could be improved?

(2) Please leave any other comments you may have.

A content analysis of themes from the qualitative free-text responses to these items was then performed. A quantitative content analysis approach based upon counting the frequency of themes that arose during the analysis was utilized in order to provide a systematic and objective analysis of the content units (Franzosi, 2008). Part (1) and (2) free text comments were initially independently coded into themes that were subsequently agreed upon by authors (I.D.K. and C.S.T.). The frequency of each theme was calculated from the number of students mentioning each theme and was expressed as a percentage of the total number of students (Webb and Choi, 2014) who responded to part (1) (*n* = 125) and part (2) (*n* = 46) of the item.

Delivery of ORDER in an online interactive tutorial (IT)

ORDER-IT design

Based on findings from the ORDER-SAP evaluation, the delivery approach of the process was modified in order to enhance student learning and experience. The steps of the *Observe-Reflect-Draw-Edit-Repeat* process were maintained, and were presented in a step by step online video to allow students to pause and restart the process and to therefore complete the steps of the ORDER cycle at their own rate. Text instructions were provided in the ORDER-IT tutorial informing students that they would require paper and a pencil. A 14 minute ORDER-IT video tutorial on gross anatomy of the inguinal canal explained how students should complete each task in the ORDER process. Students were first shown a model pelvis and asked to observe the bony features (*Observe*). They were then guided through the drawing of a simple representation of the anterior superior iliac spine and pubic tubercle that form the bony attachments of the inguinal ligament (*Reflect*, **Figure 1C**), then were asked to pause the video, to reflect on the anatomy they had observed, and then make a line drawing of the attachments and the inguinal ligament itself (*Draw*). On resumption, students were shown the completion of the simple drawing (**Figure 1D**) and a separate detailed drawn diagram of the region **(Figure 1E)** and were asked by the narrator to edit their initial drawing (*Edit*). The anatomy of the inguinal canal and associated layers of the anterior abdominal wall were added in five further ORDER cycles with the use of modelling clay attached to the model pelvis to demonstrate the anatomical features (*Repeat*). Further verbal instructions were provided in each ORDER cycle during the tutorial to prompt students to pause the video in order to again reflect upon the anatomy they had observed and then to draw it. Instructions regarding the time it should take to complete each step or to complete the whole process were deliberately not included. A separate 11 minute video demonstrating the ORDER process for learning surface anatomy of the thorax and explaining the steps involved was also provided to familiarize students with the process, should this be required. Online interactive ORDER-based tutorials for topics in embryology, surface anatomy and clinical imaging were simultaneously delivered for purposes of student revision. Control tutorials for each of these topics were not provided so the data collected were not considered valid for this study. As some gross anatomy of the abdomen teaching is delivered between March and May, the cohort that completed ORDER-IT would be expected to have had greater prior knowledge of this region than the previous cohort described above who experienced ORDER-SAP.

Control-IT design

The control tutorial delivered a text and image-based description of the anatomy of the perineum. A text description was provided on various topics within this region, with key features that can be examined by palpation highlighted and labelled diagrams that could be interactively enlarged. The first topic covered the anal triangle, the second covered the urogenital triangle and major features of the male and female reproductive systems, the third topic covered muscles of the perineum and the final topic covered the male and female external genitalia. Students were asked to take time in carefully studying each topic, but again no guidance on specific time limits was provided.

ORDER-IT Population and sampling

A census sample of the Stage 1 M.B.B.S. cohort (n = 213) from the subsequent academic year to the ORDER-SAP cohort at Newcastle University (approximate 50:50 male:female ratio) were invited to participate in the ORDER-IT study through advertising in lectures, with posters and on social media. Tutorials were made available to all medical students from all stages of the M.B.B.S. degree programme at Newcastle University via login to their virtual learning environment through the Newcastle University Learning Technologies Support Unit *Interactive* system. Tutorials were accessible for five weeks (April-May) prior to the end of Stage 1 M.B.B.S. examinations to allow time for a sufficient sample to be collected and to encourage students to utilize the tutorials for revision. A proportion of the Stage 1 M.B.B.S. cohort accessed the tutorials and agreed to participate in the research, and answered at least one questionnaire item (*n* = 133, 62.4% response rate from whole cohort), while a smaller proportion completed both the ORDER-IT gross anatomy of the inguinal canal and the Control-IT gross anatomy of the perineum tutorial (*n* = 55, 25.8% response rate from whole cohort, 41.3% response rate from participating cohort, 49:51 male:female ratio). This attrition in response rate was most likely due to the optional and online nature of both the tutorials and the evaluation. Only a very small number of students from other stages of the degree programme accessed the tutorial (*n* = 10) and so these data were not analyzed. A brief questionnaire was administered to participating students in the final part of the tutorial after post-testing. The first two items concerned student characteristics and perceptions to determine if such factors impacted upon their learning and experience with the tutorials. Of the consenting cohort (*n* = 55), participants responded to item 1 (*n* = 48) and item 2 (*n* = 53):

1. Which method do you prefer to use when learning anatomy? (*Visually – drawing or looking at diagrams; Listening to lectures, practicals or other media; Reading text; Writing notes; Handling prosections, bones and models*).
2. Art is a useful tool when learning anatomy (*Strongly agree; agree; neutral, disagree, strongly disagree*).

Of the participants responding to item 1 above (*n* = 48), the majority considered that they had a visual learning preference (70.8%, *n* = 34), while the remaining 29.2% (*n* = 14) of responders considered themselves to prefer other approaches to learning anatomy. Of participants responding to item 2 above ($n = 53$), 94.3% ($n = 50$) strongly agreed or agreed that artistic methods were valuable anatomy learning tools.

ORDER-IT controlled trial

Pre and post knowledge tests comprising twelve multiple choice single best answer from five questions of assessment standard were included online before and after the ORDER-IT and Control-IT tutorials in a similar format to those already used in the ORDER-SAP evaluation. Questions were based around identifying features in four labelled images, with three questions per image. The images used in pre and post testing were identical but pre and post questions differed in the diagram labels they concerned. Pre test scores for Control-IT (9.62, ±1.79) and ORDER-IT (7.47, ±1.73) and post test scores for Control-IT (11.19, ±1.35) and ORDER-IT (10.14, ±1.49) were calculated. The difference between the means were highly significant ($P < 0.001$) for both pre and post testing, suggesting a significant difference in the prior knowledge of the cohort in the anatomy of the perineum (Control-IT) and anatomy of the inguinal canal (ORDER-IT).

ORDER-IT Likert-type scale questionnaire

Having completed the post-test, participants were asked to complete a questionnaire that began with the questions regarding their characteristics described above, and continued with a five-point Likert-type scale questionnaire (Leung, 2011) to identify student perceptions of ORDER-IT and Control-IT:

3. The ORDER technique is a useful method for learning anatomy/ This text based technique is a useful method for learning anatomy? (*Strongly agree; agree; neutral; disagree; strongly disagree*).
4. This tutorial aided my anatomical knowledge (*Strongly agree; agree; neutral; disagree; strongly disagree*).
5. The tutorial questions helped my learning (*Strongly agree; agree; neutral; disagree; strongly disagree*).
6. I would recommend this tutorial to other students (*Strongly agree; agree; neutral; disagree; strongly disagree*).
7. I would utilize more tutorials like this (*Strongly agree; agree; neutral; disagree; strongly disagree*).

Items were designed based upon prior experience of the ORDER-SAP pilot and study items outlined above, and were agreed upon by the authors (I.D.K. and J.H.). Items were checked for reliability post-hoc using Cronbach's alpha. A value of 0.782, where 0.70-0.90 is acceptable (Tavakol and Dennick, 2011) was calculated from participants who responded to all items (n = 65). Validity of the instrument was checked using Kendall's Tau-b non-parametric correlation analysis as recommended for Likert-type scales with a non-normal distribution (Sullivan and Artino, 2013).

Statistical analysis ORDER-SAP and ORDER-IT

It was hypothesized that firstly, there would be highly statistically significant differences between student test score improvement when comparing the ORDER-SAP session and

ORDER-IT tutorial to Control-SAP and Control-IT respectively and secondly, that there would be a highly significant statistical difference in test score improvement of students with visual learning preferences and artistic backgrounds when using ORDER-SAP and ORDER-IT compared to students without these characteristics. In each case, a value of $P < 0.05$ was considered to be significant, a value of $P < 0.001$ was considered to be highly significant, and a value of $P > 0.05$ was considered to be not significant. To test the first statistical hypothesis, a paired-sample t-test was used to calculate the statistical significance of mean test score improvements of the cohort in the ORDER-SAP and Control-SAP sessions and in the ORDER-IT and Control-IT tutorials. Parametric analysis was carried out in each case due to the approximate normal distribution of data. To test the second hypothesis, a two sample-unequal variance paired t-test was used to identify the statistical significance of mean test-score improvements of students with either visual or non-visual learning preference (ORDER-SAP and ORDER-IT) and from students categorized as artistic or non-artistic (ORDER-SAP), due to approximately normal distribution and unequal sample sizes. Finally, it was hypothesized that there would be significant differences in responses to Likert-type scale items. The mean and standard deviation of responses to each Likert-type scale item were calculated (where *strongly agree* = 4, *agree* = 3, *disagree* = 2 and *strongly disagree* = 1 for SAP and *strongly agree* = 5, *agree* = 4, *neutral* = 3 *disagree* = 2 and *strongly disagree* = 1 for IT). Significant differences between Likert-type items were statistically analyzed by paired t-test and two-sample unequal variance t-test, depending on the number of responders to the items being compared. Data entry and statistical analysis was performed using IBM SPSS Statistics for Windows version 22 (IBM Corp., Armonk, NY, USA.) and Microsoft Excel 2013 (Microsoft Corp., Redmond WA, USA).

Ethical assessment

Proposals 00716 (ORDER-SAP) and 00865 (ORDER-IT) were approved by the Newcastle University Faculty of Medical Sciences ethical approval committee. Students were given the opportunity to give anonymized informed consent to participate in the study, informed that they could withdraw at any time and were debriefed on completion of research. Alternative resources were provided in the ORDER-SAP session for students not consenting to participate. Both ORDER-SAP and ORDER-IT were designed to supplement and reinforce learning outcomes that had already been delivered through conventional teaching.

RESULTS

Student performance and perceptions using ORDER-SAP

Impact of student background on performance using ORDER-SAP

From the mean student test scores described above, the improvement between pre and post testing with both Control-SAP and ORDER-SAP was highly significant ($P < 0.001$) in each case. The standard anatomy learning methods delivered in the Control-SAP session produced a highly significant difference ($P < 0.001$) in the change between pre and post test scores (3.26, ±2.26) of the cohort (n =154) when compared to ORDER-SAP (2.17, ±2.31) (**Figure 2A**). The majority (61.69%, n = 95) of these participants improved their score to greater extent when using Control-SAP, while the remaining 38.31% (n = 59) of students achieved either an equal or greater improvement in their score when using ORDER-SAP. Mean test performance with either artistic (n = 73, 2.18, ±2.19) or non-artistic (n = 46, 2.26, ±2.25) background characteristics using ORDER-SAP (**Figure 2B**) were not significantly different ($P > 0.05$). Mean test performance of students with either a visual (n = 57, 2.23, ±2.34) or non-visual (n = 90, 2.14, ±2.27) learning preference (**Figure 2C**) were also not significantly different ($P > 0.05$).

Student perceptions of ORDER-SAP

Having shown experimentally that fewer students benefitted from ORDER-SAP when compared to the control session, the potential broader value of ORDER was explored by identifying student perceptions of their experiences of ORDER-SAP (**Figure 3A**). Based on a mean response > 2.5 from four-point Likert-type scale indicating an overall agreement with each statement, the cohort would consider using ORDER in their self-study (n = 173, 2.54, ±0.81); would recommend ORDER to future students (n = 172, 2.70, ±0.74); learned more than they would have by drawing (n = 157, 2.59, ±0.81); felt more engaged than they would have with drawing (n = 158, 2.59, ±0.89); and perceived that ORDER had improved their knowledge of anatomy (n = 170, 3.01, ±0.74). The cohort did not agree overall that they had learned more than they would have in a standard anatomy session (n = 170, 2.40, ±0.90). Having identified student perceptions of ORDER-SAP, their views on how ORDER could be used in the future were sought, in order to provide a basis for introduction of the process into the curriculum and for future development and modification of ORDER-SAP. The perception held by the majority of the cohort (n = 155) was that ORDER should be used either occasionally (n = 54, 34.84%) or as a supporting component (n = 60, 38.71%) within anatomy teaching, while a smaller proportion of students perceived that ORDER should be used as the main component in teaching sessions (n = 18, 11.61%), considered that ORDER should never be used (n = 20, 12.90%), or suggested that only ORDER should be used in practical anatomy sessions (n = 3, 1.94%).

The incidence of themes that arose from a quantitative content analysis of part (1) of the ORDER-SAP free-text questionnaire item and the proportion of students mentioning each theme are shown in **Figure 3B**. Students primarily recommended increasing the time allowed to complete ORDER steps or cycles (*Timing*), but also suggested changes to the ORDER process (*Process*); proposed changes in how the session was taught in terms of the topic and practical session used (*Delivery*), advised improved information about the session or increased input from anatomy demonstrators and artists (*Guidance*) and requested improvements to images, diagrams and labelling (*Technical*). Examples of student responses within each theme are given below. Text in parentheses below is included to clarify the assumed intended meaning.

Timing

"I felt rushed and pressurized during the session;" "I think similar exercises over longer periods would be helpful;" "Longer [time] to study pictures [is needed], it was very hard to remember all of the detail;" "More time for each task [is needed];" "More time to observe the image before drawing [is needed];" "More time [is needed] to draw and to observe an image;" "More time to actually gain knowledge [is needed];" "Review and edit time was not sufficient;" "The session was a bit too rushed – I focused more on just drawing rather than reflecting on what I was learning from the drawings;" "There wasn't time to process what we were doing."

Process

"Begin by pointing out surface anatomy on each other first;" "Discuss features before drawing;" "Do more pictures [cycles] showing less [detail];" "Draw from memory again after correcting [editing];" "Draw things twice without looking before editing;" "Draw twice instead of once to reinforce memory;" "I like to draw the image in front of me rather than from memory;" "I think drawing should follow a less structured method;" "I think it would be better to draw from the screen then redraw without the screen;" "It was useful having time to memorize then edit;" "[Make it] less repetitive;" "Maybe have ORDORDER – like two remembering [Observe-Reflect-Draw] bits per [cycle];" "More facts alongside to improve learning;" "More information regarding the positions of organs [should be] given, i.e. telling us where exactly the heart is in 3D [three dimensions];" "Redraw on another diagram;" "Show anatomy on cadaver – not just on screen;" "Talk about it and then draw."

Delivery

"Allow us to select to do it [ORDER-SAP] or not;" "Do alongside teaching;" "Do this [ORDER-SAP] in advance, then study prosections;" "Extend to other areas of the body." "I think body painting would be additionally helpful;" "Perhaps use drawing as a supplement to traditional teaching;" "Should be done at the start of anatomy [sessions] to give background information;" "Use ORDER as supporting technique."

Guidance

"A bit more discussion about what each individual needed to change [is needed];" "An explanation of what I'm supposed to reflect on [is needed];" "Artist could be more involved;" "Clearer instructions [are needed];" "Drawing on my own felt unsupported;" "Explain more about what we have to do;" "More artist involvement [is needed];" "More conversation with or critique by the art student [is needed];" "More detailed explanations by instructor;" "More explanation from the demonstrator is required;" "More explanation [is needed] rather than just copying a diagram;" "Would be improved with more input from demonstrator."

Technical

"[It would be better to] be closer to image, [the] screen was hard to see;" "Make the picture of the heart clearer;" "Use pictures that were the same as those we were taught."

From part (2) of the ORDER-SAP free-text questionnaire item, themes were identified by content analysis as categorized as below. Of participants providing a response to this item, (n = 46), a total of 82.61% perceived value in ORDER for learning either for themselves (60.87%) or for others (21.74%) (**Figure 3C**). Examples of student comments in each theme are given below:

The student perceived value in ORDER for their own learning

"I found it helpful in visualizing the landmarks;" "[ORDER is a] useful tool and more enjoyable [than a standard session];" "I enjoyed the session and think it was effective in improving my understanding of anatomy;" "I learnt more than in normal DR [dissecting room] sessions;" "[ORDER was] better than [using] prosections." "I loved the session – [I] learnt more than I have before, really understood, love learning this way, felt self-empowered to do things;" "[I] really enjoyed the session - found it a new approach that made me really look and engage with the anatomy – identified what I didn't know;" "Thought this session was very helpful to aid me memorizing anatomy, thank you."

The student perceived value in ORDER for others' learning:

"I feel the tool may be useful for many students, however personally I do not find that it helps me;" "I think [drawing] is helpful for some people but not for me;" "[I] thought it was a good session but it's just not how I choose to learn;" "It is a very good method but it will not be useful for students like me who have absolutely no skill at drawing;" "I understand that showing this to students gives them ideas and techniques on how to study, however personally didn't find it helpful as I spent too much time being concerned about what my drawing looked like rather than actually learning;" "Unfortunately I'm not a drawer or a visual learner so this session wasn't really up my street."

The student perceived no value in ORDER for learning or that standard methods were more valuable for learning

"I don't think that I learned much more than if someone [had] told me the information;" " [I] felt copying diagrams would be more helpful for my learning;" "I find it better if we are all taught and write in revision and then draw in my own time."

Student performance and perceptions using ORDER-IT

Having identified that ORDER-SAP was valuable for a minority of students when compared to standard methods, but that overall students had positive perceptions of ORDER and would value a more accommodating approach to the process with more flexibility in the timing of each step, an online interactive tutorial (ORDER-IT) was designed. This comprised a modified ORDER process delivered as a supplement to learning and was developed without the requirement for including further timetabled sessions in an already congested curriculum. The value of this ORDER-IT format for student learning was then investigated.

Impact of student background on performance using ORDER-IT

Mean improvement in student test scores between pre and post testing with both Control-IT and ORDER-IT was highly significant ($P < 0.001$) in each case. The ORDER-IT tutorial produced a highly significant difference ($P < 0.001$) in the change in pre-post test scores (2.71, ±2.17) of the cohort ($n = 55$) when compared to Control-IT (1.31, ±2.03) (**Figure 4A**). The majority (70.90%, $n = 39$) of these participants improved their score the greatest or same extent when using ORDER-IT, compared to those who improved to the greatest extent when using Control-IT (29.10%, $n = 16$). The difference in mean test performance of students with either a visual ($n = 57$, 2.47, ±2.16) or non-visual ($n = 16$, 2.87, SD =2.26) learning preference when using ORDER-IT was not significant ($P > 0.05$) (**Figure 4B**). Due to the low percentage of participants considered to be non-artistic due to their views on art as a learning tool, (6%, $n = 3$), analysis of the impact of student artistic background on performance with ORDER-IT was not included.

Student perceptions of ORDER-IT

Having shown the value of ORDER-IT experimentally, cohort perceptions of both the ORDER-IT ($n = 65$) and the Control-IT ($n = 73$) interactive tutorials were collected to identify student views in terms of impact on their learning **(Figure 4C)**. Where a mean response > 3 from a five-point Likert-type scale indicated an overall agreement with each statement, the cohort considered that ORDER-IT (4.2, ±0.85) and Control-IT (4.18, ±1.02) were effective techniques for their learning, that ORDER-IT (4.54, ±0.69) and Control-IT (4.51, ±0.58) improved their learning of anatomy, that they would recommend ORDER-IT (4.63, ±0.65) and Control-IT (4.54, ±0.69) to others and that they would use similar tutorials to ORDER-IT (4.77, ±0.46) and Control-IT (4.81, ±0.46) in the future. There was no significant difference ($P > 0.05$) in the mean response to each item with when comparing Control-IT and ORDER-IT. The mean response to the item

"The ORDER technique is a useful method for learning anatomy/ This text based technique is a useful method for learning anatomy" was significantly (*P* < 0.05) or highly significantly (*P* < 0.001) different to all other items for both ORDER-IT and Control-IT. There were no significant differences (*P* > 0.05) in any of the mean responses to each item regarding ORDER-IT when compared to each item regarding Control-IT.

DISCUSSION

Effective learning with ORDER

The findings presented here are supported by previous research that suggests the ORDER process should be capable of enhancing student learning. Studies within the emerging field of educational neuroscience have demonstrated the importance of the visual arts for deep neural integration (Tyler et al., 2012), have proposed a role in altering cognitive abilities and motor skills (Schlegel, et al., 2015) and have identified a positive relationship between observational drawing, motor control and procedural memory (Chamberlain et al., 2014). A recent qualitative study has advocated the inclusion of drawing in anatomy curricula through identifying student perceptions (Bell and Evans, 2014), while other work has identified the value of artistic learning methods in anatomy and medical education for increasing engagement and active participation (Phillips, 2000; McMenamin, 2008). Artistic methods have been proposed to provide visual reminders (Finn and McLachlan, 2010), to activate prior knowledge (Nayak and Kodimajalu, 2010), to improve test scores (Azer, 2011), to influence metacognition and activation of tacit knowledge (Naug, et al., 2011; Lyon, et al., 2013) and to promote knowledge retention (Balemans, et al., 2016) while enhancing student experience (Nanjundaiah and Chowdapurkar, 2012; Noorafshan et al., 2014). Furthermore, the possibility that artistic approaches could replace cadaveric material by providing depth and meaning has also been proposed (Collett and McLachlan, 2005). Previous work has also successfully applied constructivist (Bergman et al., 2013) and experiential learning theory (Plaisant et al., 2004; Bentley and Pang, 2012; Jensen et al., 2013), to anatomy education, concepts that have been incorporated into the design of ORDER.

Picture theory describes how images are not merely visual representations of text, but that they can provide further information to observers above and beyond what can be described with words and have value beyond the visual arts discipline (Mitchell, 1994). This theory supports the use of drawing in the ORDER process as an effective method and approach for anatomical description when time is short and for the representation of anatomical detail. It is interesting to note that the medical cohort found ORDER-SAP more valuable than drawing alone, which suggests there is added value in using ORDER over the process of producing illustrations when learning anatomy. In addition to the theoretical framework of ORDER, this may be because the process provides an explicit structure that promotes the learning process of drawing, as opposed to artistic outputs. Through the marking of single lines by hand as a *denotational cod*e, drawing is proposed to focus on observation, thinking and the creation of ideas, as opposed to alternative visual artistic methods that are regarded as primarily presenting and provoking sensation or emotions (Petherbridge, 2010). This supports the use of ORDER as an appropriate process that emphasizes learning through observation, rather than artistic merit, a focus that has been proposed in previous work (Lyon, et al., 2013). Illustration has been described as the pertinent artistic technique for constructing a sequence or a practical order of development of an idea or process over time (Petherbridge, 2010), which corresponds effectively to the drawing component within the ORDER cycle. Previous work has shown that drawing enhanced student critical observation (Collett and McLachlan, 2005), while drawing can also be a useful tool for communicating with patients (Liou et al., 2014), and art has been used to develop observational (Bardes et al., 2001; Jasani and Saks, 2013; Moore et al., 2011; Shapiro et al., 2006) and diagnostic skills (Dolev, et al., 2001). Future work can explore how ORDER could be adapted as a tool for enhancing these areas of medical education, in addition to further anatomical topics.

An interdisciplinary approach to learning through observation, reflection and drawing

To enhance the use of the ORDER artistic process in a practical teaching session, an environment of interdisciplinary collaboration to support medical student learning was developed through incorporation of facilitation by medically trained anatomy demonstrators, visual artists and postgraduate art students. The importance of transdisciplinary collaborations between art and medicine have been described in terms of specific frameworks for learning, such as the development of arts-based *Visual Thinking Strategies* that apply the procedures involved in the observation of artwork to medical learning and teaching approaches (Reilly et al., 2005), and can provide wider perspectives of anatomy learning (Phillips, 2000; de la Croix, et al., 2011; Liou, et al., 2014). Artists may introduce a subtle presence that offers students a different perspective to conventional classes, and could facilitate activities that may help bring alternative attitudes to the often complex environments where anatomy is taught (Allen, 2014). However, while the unique experience delivered in ORDER-SAP may have provided a distinct and memorable learning encounter, in this case it appears that the presence of artists did not influence improved learning performance for the majority of students and that participants did not indicate that the artist present played a positive role in their learning. Findings here and previous work (Lyon, et al., 2013), would suggest that students would prefer more guidance from and discussion with artists. In this case, the presence of artists may have actually had the unfortunate consequence of detracting from the emphasis on ORDER as a learning process and caused anxiety around the unintended assumption that that students were expected to produce artistic creations. The focus on drawing, rather than on learning, has been previously noted as a potential barrier (Lyon, et al., 2013). It is proposed that any future ORDER-SAP session would benefit from a more structured approach to artist involvement by explicitly incorporating theories of drawing and artistic observation.

An important relationship between the observation of artwork and a reflective thinking approach, where time, scope, clarity, depth and the organization of observation and reflection are described as key processes, has been proposed (Perkins, 1994), aligning with important steps in the ORDER cycle. Furthermore, this relationship is proposed to occur through the processes of metacognition or *reflective intelligence*, and *experiential intelligence*, which is described as building on prior knowledge through experience (Perkins, 1994), thus supporting the cognitivist theoretical basis of ORDER. Moreover, the *inner conversation* of metacognition regarding one's own thinking and reflective processes about the artwork created, the *interpersonal conversation* of assisted metacognition prompted by discussion and creative reflection with others and the *silence* of subconscious cognitive and neural processing have been described as the critical steps that occur during learning that arises from engagement in artistic activities (Catterall, 2005). The ORDER cycle includes opportunities where each of these processes can occur during *Observe*, *Reflect*, *Draw* and *Edit* steps. With greater emphasis, the guiding presence of artists could facilitate the interpersonal conversations that occur during guided and collaborative reflection

(Catterall, 2005; Lyon, et al., 2013) and could lead to improved results when utilizing ORDER-SAP. While the process of *interpersonal conversation* (Catterall, 2005) is not possible in the self-study environment of ORDER-IT, this has not prevented student learning. The steps that constitute the ORDER-IT process can instead be viewed as incorporating the *silence* of subconscious cognitive re-structuring (Catterall, 2005) and may therefore have enhanced learning in this manner. Future work can explore and further refine the specific processes of observation (Bleakley et al., 2003; Boudreau et al., 2008), reflection and drawing to give all students more guidance in performing each step.

Impact of environment and delivery on learning with ORDER

The aim of designing and potentially introducing ORDER was, rather than an attempt to replace standard methods of anatomy learning, to expand upon the variety of methods for students to use as appropriate, to provide a learning strategy that encourages deep understanding and to do so in an efficient and cost-effective manner. It was intended that providing an explicit cognitivist and constructivist framework of learning activities in a cyclical step-by-step format to encourage processes of observation, refection, formation and testing of abstract concepts, as described in experiential learning theory (Kolb, 1984) would enhance learning, while repeated cycles would encourage students to acquire, build upon and retain knowledge (Ausubel, 2012). Due to this strong theoretical basis on which ORDER was designed, and the recent studies that have advocated the use of drawing and visual artistic methods in anatomy learning and medical education (Pandey and Zimitat, 2007; Nayak and Kodimajalu, 2010; Naug, et al., 2011; Nanjundaiah and Chowdapurkar, 2012; Tyler, et al., 2012; Jasani and Saks, 2013; Lyon, et al., 2013; Noorafshan, et al., 2014; Balemans, et al., 2016), the finding here that standard methods were significantly more effective for improving student knowledge test performance in a dissecting room environment indicated that practical and logistical factors in the session had potentially influenced the outcome, rather than the cognitive processes involved in ORDER itself.

Accounting for contextual learning (Clough and Lehr, 1996) and providing a variety of methods (Ward and Walker, 2008) so that students are able to choose their own techniques and environments that have relevance to their own situation and experience, are known to be effective in anatomy learning. Delivering a structured, compulsory ORDER-SAP session to fulfill curricular requirements is therefore unlikely to be the most powerful use of the method, which is confounded by the finding that student performance was significantly greater in Control-SAP, a more flexible session that included a greater variety of resources. Indeed, students themselves perceived that ORDER would be more suitable as a supplement rather than being delivered as a compulsory practical. Despite this, positive overall student perceptions of aspects of ORDER-SAP, but more favorable perceptions of the standard session, coupled with the perceived value of ORDER for their own and other's learning and the finding that ORDER-SAP was at least as effective as standard methods of anatomy learning for 38.31% of the cohort, suggests that there could be merit in continuing to provide ORDER-SAP in the format described here as a non-compulsory session. Furthermore, if these data could be extrapolated to an equivalent proportion of the global population of anatomy students, ORDER-SAP in its current form could be widely valuable. Instead of persisting with the ORDER-SAP format described however, findings here suggest that delivery should be modified to enhance learning for use in other contexts and environments, and to make the process valuable for learning of the largest possible proportion of students. Relative student performances in the compulsory ORDER-SAP session and with the optional ORDER-IT resource suggests that student engagement and motivation could play an important role in the success of each approach.

If ORDER-SAP delivery as a practical teaching session was maintained, some modifications would clearly be required. Because *Timing* was the key theme impacting upon the success of ORDER perceived by the majority of students, this is likely to be an important area requiring adjustment. Learners require all aspects of the experiential learning cycle to be utilized equally for optimal learning (Kolb, 1984), and so depending on the curricular time available, ORDER could be delivered over multiple surface anatomy sessions, with reflective observation encouraged during didactic teaching, that could be followed by sessions for drawing and editing, and the addition of a clinical session where transformation of learned concepts into concrete experience could add an applied and practical element to the process. The additional time available would also allow further opportunities for guiding students through each ORDER step and cycle and further opportunities for collaborative discussion (Lyon, et al., 2013). Feedback from ORDER-SAP however, indicated that students would welcome ORDER as a supplement to learning for occasional use, suggesting that the most suitable learning environment in which to deliver ORDER would not be practical or lecture-based.

It has been proposed that rather than comparing e-learning with standard methods of learning, the effective elements of traditional teaching should instead be incorporated into e-learning used as part of a blended learning approach (Evgeniou and Loizou, 2012). Based on this concept, the development of ORDER-IT was conducted by introducing the successful elements of ORDER-

SAP into an e-learning environment to be used as a supplementary resource that could provide the added flexibility requested by students. The differences in effectiveness of ORDER when delivered as a taught or self-study e-learning approach presented here clearly show that the mode of delivery and learning environment in which ORDER is used is vital. A major advantage of e-learning is accessibility, in that students have wide access to the internet, to computers, tablets and other devices and also possess the ability to effectively utilize them for learning (Link and Marz, 2006; Khan et al., 2009). Although e-learning has been shown to be considered as useful by students, it is not considered to be a replacement for contact teaching, cadaveric material or other anatomy learning resources (Davis, et al., 2014). While a study that evaluated a multimedia e-book for anatomy learning in comparison to traditional practical methods found no significant improvements, it did achieve positive student perceptions and findings indicated that the tool could be an effective supplement to standard methods (Stirling and Birt, 2014). Elsewhere, e-learning tools have been shown to improve assessment results (Choudhury et al., 2010; Webb and Choi, 2014) and student learning (Stewart and Choudhury, 2015). When designing e-learning tools, it has been shown to be important to include features that reduce cognitive load and maintain usability (Van Nuland and Rogers, 2016b), and that simple e-learning tools can be just as effective for anatomy learning as more complex resources (Van Nuland and Rogers., 2016a). Taken together, previous findings suggest that the accessible, simple and supplementary nature of ORDER-IT as an e-learning tool are likely to have contributed to the relative success of this approach. Peer-learning, critical thinking and metacognition are key aspects provided by e-learning in a blended learning environment (Kassab et al., 2015) and e-learning has also been utilized for development of transferable skills in communication and critical analysis (Choudhury and Gouldsborough, 2012). Providing a platform for online peer-peer interactions in a future online ORDER tutorial could further improve learning by providing discussion during the *Edit* step. This would allow the provision of *conversation* (Catterall, 2005) to the ORDER-IT process, while successful integration of tablet technology into an anatomy curriculum (Raney, 2016) suggests a potential route of integration of ORDER-IT into blended learning. While social media has been utilized effectively in anatomy education (Jaffar, 2014; Barry et al., 2016), a current barrier to this approach can be the poor quality and relevance of available learning resources (Raikos and Waidyasekara, 2014), and so ORDER-IT could be a worthwhile future addition to such platforms.

Learning performance with ORDER is independent of learning preference and artistic background

While visualization is a major method for memorization and understanding of anatomy adopted by medical students (Pandey and Zimitat, 2007), by emphasizing ORDER as a learning process and due to the theoretical and evidence-based underpinnings of the approach, it was intended that ORDER would provide an effective framework for all learners independently of their visual artistic ability or visual learning preference. Despite previous work having discredited the idea that students possess a specific learning style (Coffield, 2004; O'Mahony et al., 2016), the concept that individuals are restricted to learning in a particular way appears to remain a strongly held and pervasive belief among students, based on their ORDER-SAP free-text responses here. It is likely that such a belief would impact upon the engagement and therefore possibly the learning of students in any novel learning method. Work presented here however, demonstrates that a non-visual learning preference or a background lacking artistic pursuits does not confer a disadvantage on students when utilizing a process involving observation and drawing. Where new and conflicting knowledge is incorporated into an existing framework during the process of cognitive dissonance, experiential learning can occur (Dennick, 2015). During the ORDER process there are opportunities for cognitive dissonance to arise when drawings produced are not identical to the anatomical images found in text books. This could allow students to appreciate anatomical variations and errors within their own understanding. Having shown that possessing a visual learning preference or an artistic background is not a requirement for effective learning with ORDER, students who do not consider themselves visual learners or capable artistically may also experience cognitive dissonance when they discover that they are able to learn by drawing. This finding may also be consistent with previous work that has identified that while visual perception and graphical representation are vital systems that influence drawing ability during cognitive development, there is likely to be a related but separate relationship between these systems (Guérin et al., 1999; Bouaziz and Magnan, 2007). The strength of the ORDER framework allows the possibility that the process can be expanded to include alternatives to drawing that may also be effective for learning, independently of student artistic learning characteristics. Replacing the *Draw* step with *Do* within an optional ORDER-based resource could facilitate incorporation of alternative artistic techniques such as clay modelling and creative writing which may in turn engage a wider student audience.

Limitations

As there were differences in the delivery and evaluation methods of ORDER-SAP and ORDER-IT, this disparity should be considered as a caveat when attempting to compare findings from the two parts of this study. As the Control-SAP study consisted of a variety of resources and methods, a factor known to positively influence learning (Ward and Walker, 2008), and was compared to the single method utilized in ORDER-SAP, the validity of findings may have been compromised. A future study of ORDER in a taught environment could incorporate ORDER-SAP as one method within a wider practical session or could be compared to a control session consisting of a single method. A limitation of ORDER-IT, like any self-study tool, is that it is difficult to control and identify student use of the resource. A future study could incorporate a more detailed questionnaire instrument that could identify how students used the ORDER-IT tool, how they engaged with the drawing activities and if they used additional resources to complete the tutorial. Differences in terms of the complexity of ORDER-IT, as an instructional video, and Control-IT, as a text and image based tutorial, should not have conferred a learning advantage in either case (Van Nuland and Rogers, 2016a). The educational background of students has been shown to be an important influence on learning performance with a histology e-learning tool (Selvig et al., 2015) and there are likely to be similar factors that have affected student performance with both ORDER-SAP and ORDER-IT. It would have been effective to have investigated the demographics of participants in order to identify any characteristics, in addition to artistic background and learning preference, which may have impacted upon learning performance with ORDER. For example, gender is known to impact upon learning in anatomy and medical education in terms of assessment type (Kelly and Dennick, 2009; Foster, 2011) and spatial ability (Linn and Peterson, 1985; Masters snd Sanders, 1993; Langlois et al., 2013). Unfortunately, informed consent was not provided here for gender data, or the data of non-responders, to be included. As learning performance has been investigated here through immediate post-testing, a longitudinal study may be required to address the enduring benefits of ORDER-SAP and ORDER-IT. While immediate post-testing may have accounted only for short term knowledge acquisition rather than retention and understanding, the accuracy of delayed testing could have been limited by the proximity of revision for assessments and by uncontrolled peer-peer interactions. However, a questionnaire instrument designed to identify the long-term impact of ORDER-SAP and ORDER-IT could be implemented in the future. Repeating investigations with further student cohorts would also strengthen the findings obtained.

CONCLUSION

Findings presented here indicate that with appropriate modifications in terms of timing, structure and delivery, the ORDER process can be effectively utilized in different contexts and learning environments as a widely applicable and valuable supplementary learning method with the advantages of amenability in terms of cost, resources and utility. The strong theoretical underpinnings supporting the design of the ORDER process and the overall positive perceptions of students suggest that findings presented here can be generalized to other student populations. Future work will explore how ORDER can be most effectively refined and delivered to optimize student learning. The finding that learning performance with an artistic learning method is independent of a student visual learning preference and artistic background will be of importance to educators when designing and introducing of novel learning approaches.

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