Drawing in Anatomy Education: Exploring its Roles in Teaching and Assessment

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If you can't fly, then run. If you can't run, then walk. If you can't walk, then crawl. But whatever you do, you have to keep moving forward.

Martin Luther King Jr

Abstract

This thesis consists of an investigation of the current use of visual representations, and drawing in particular, when teaching and assessing within anatomy education in medical studies.

Although we know a lot about teachers' use of visual representations and increasingly drawing, especially in the context of science education, less is known about the use of those tools by educators in the anatomical domain. Drawing is not currently systematically being used within assessment in anatomy education in UK medical schools, and its potential in assessment has not been investigated in depth.

Four studies were conducted to answer the research questions set for this thesis. The first study investigated the way in which the teaching staff understand the use of visual representations in teaching, learning and assessment in anatomy. To answer this, observations of seven anatomy demonstrators were conducted within Year 1 dissection sessions, and interviews were conducted with the same demonstrators. The second study employed a real-world experimental design to explore if students' drawings reveal changes in their understanding after dissection. Drawings from 98 Year 1 medical students were analysed in a within-subject crossover design, where students in the first condition drew the exterior of the heart before dissection in Week 1 and drew the superior mediastinum after dissection in Week 2. The order was reversed for students in the second condition. All drawings were analysed for their content and form with an extensive coding scheme that was developed for this thesis, as the existing coding approaches towards drawings were judged as inappropriate. The third study investigated the use of drawing

to reveal changes in understanding as the medical degree progresses. Drawings of the exterior of the heart from 46 Year 3 students were analysed and compared to drawings from the Year 1 students. Finally, the fourth study investigated the way in which anatomy demonstrators understand drawing in the assessment of anatomical knowledge; eight artefact-based interviews were conducted with anatomy demonstrators.

The findings offer important insights into the way in which visual representations and drawing in particular are being used by anatomy demonstrators within anatomy education and their perspectives on the use of drawing in teaching, learning and assessment. A significant contribution is also made to the knowledge regarding the use of drawing to assess understanding in spatially intensive domains, such as the anatomical one. This thesis also contributes to our knowledge of dissection as a method of teaching anatomy and the need for drawing training within this domain. Finally, the scheme for drawing analysis that was developed, evaluated and employed in this thesis can be considered a methodological contribution to the approaches of analysing drawings in the current literature.

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1. Introduction

There can be little doubt that anatomy has always been strongly associated with visual representations. The domain of anatomy has used visual representations for hundreds of years to visualise both internal and external aspects of the human body. A large amount of the work that Leonardo da Vinci produced was devoted to anatomy (Bay & Bay, 2010) and the aim of his drawings was to reveal structure – and occasionally function – by visually demonstrating the dissected material (Jose, 2001). However, there are still many things that are not known about the way in which visual representations are used in teaching anatomy, especially drawings, nor how understanding of anatomy can be assessed by drawing activities. This thesis is fundamentally concerned with these issues. Moreover, this theme is intertwined with another issue, which is the debate about the use of dissection as a method of teaching anatomy. Thus, this research sets out to examine the role of visual representations and drawing in the teaching and assessment of anatomical knowledge, and to discuss whether dissection changes what students draw in anatomy. To do this, a real-world research approach and a methodology driven by pragmatism were employed to answer four research questions.

Before I describe the content of each chapter, I will start by providing the definitions of some of the core terms that will be used a lot in this thesis. Firstly, as described by Tversky et al. (2006, p. 54), "like written language, visualizations are cognitive tools, designed to augment the capacity of the human mind". They are available in multiple types (e.g. drawings, photographs, maps, and 3D models) and can be used for a number of reasons and in various contexts (see section 2.2 in Chapter 2).

The main focus of this thesis is on visual representation in the form of drawings. 'Drawing' in this thesis is based on the definition by Quillin & Thomas (2015, p. 2), where it is defined as the "learner-generated external visual representation depicting any type of content, whether structure, relationship, or process, created in static two dimensions in any medium". This definition draws a distinction between drawing as a learning and assessment strategy and drawing as an artistic expression, as presented with distinctive characteristics (e.g. words).

This thesis also extensively uses terms from the medical domain. Therefore, the two terms ‘anatomy’ and ‘dissection’ are defined here as well, to establish the foundation of this interdisciplinary research. According to Venes (2017, p. 113), anatomy is defined as “the branch of science dealing with the structure of organisms”. As described in the Chapter 2, the scientific branch of anatomy is considered fundamental within medical degrees, traditionally taught by dissection activities. Dissection is defined by Martin (2015, p. 222) as “ the cutting apart and separation of the body tissues along the natural divisions of the organs and different tissues in the course of an operation. Dissection of corpses is carried out for the study of anatomy”. This thesis sets out to explore aspects related to the use of visual representations and drawing in teaching and assessment in the development of medical students who learn anatomy, as questions around ways of visualising content in anatomy have remained insufficiently investigated for a significant time.

1.1. Summary of the Chapters

Chapter 2 - Literature Review. The first part of the literature review is dedicated to visual representations and drawing. It considers arguments and evidence from the literature on *teaching with visual representations and drawings* and then some arguments from the *drawing to learn* literature are considered as well. Finally, it reviews studies on *drawing in assessment*. The second part of the literature review describes teaching within anatomy education and the emphasis is put on the teaching method of dissection. The chapter then discusses dissection as a controversial method in anatomy education. Lastly, the third part of the literature review considers assessment both generally and specifically within anatomy education.

Chapter 3 - Context. This chapter describes the context in which the studies in this thesis were conducted, and it is also divided into three sections. The first part describes the goals of medical education in the UK and explains the structure and content of a medical degree. Then, emphasis is put on one Year 1 module in the medical degree at the University of Nottingham, where most of the data were collected. The environment of the Dissection Room (DR) at the School of Medicine and the DR sessions of that module in Year 1 are described, along with its aims and the ways in which students are assessed. Finally, a Year 3 session in surface anatomy and its intended learning outcomes are described in the last part of this chapter.

Chapter 4 - Methodology. The first part of this chapter considers aspects of real-world research and the pragmatic approach employed for this research. Then, the methods of data collection and the chosen approach of a multi-strategy design are described, as well as the methods of analysing the data. The next part is dedicated to describing in detail the development of the coding schemes applied for analysing the anatomy demonstrators' observational and interview data, as well as students' drawings from Study 2 and Study 3. In the last part of this chapter, ethical considerations are discussed.

Chapter 5 - Study 1. In order to explore how anatomy demonstrators understand the use of visual representations in teaching, learning and assessment, semi-structured observations and semi-structured interviews were conducted with seven anatomy demonstrators as they briefed students at the introductions of dissection sessions in Year 1. Observations focused on the visual representations and drawings used when the demonstrators gave these introductions. The demonstrators were then interviewed at the end of the semester regarding their beliefs and practices about visual representations and drawing in teaching, learning and assessment. Thematic analysis uncovered how anatomy demonstrators use visual representations when they introduce the Year 1 dissection sessions, and which forms they prefer the most and why. In addition, the results describe their beliefs about visual representations and drawing in teaching, learning and assessment of anatomy more generally.

Chapter 6 - Study 2. In order to explore if students' drawings reveal changes in understanding after dissection, a real-world experiment was conducted with Year 1 medical students who were asked to draw the exterior of the heart and the superior mediastinum (SM) before and after dissection. A coding scheme was developed to analyse the drawings from 98 Year 1 students for their informational content and the students' representational choices. The results revealed whether dissection changed what medical students drew, as it examined the influence that dissection had on their content and form. In addition, the extent to which the drawings of the exterior of the heart and the superior mediastinum showed differences in how their representation was affected by dissections is discussed as well.

Chapter 7 - Study 3. In order to also explore if students' drawings reveal changes in understanding as the medical degree progresses, drawings of the exterior of the heart from 46 Year 3 medical students were compared with some data from Study 2 that was reused here. These students followed the same instructions to draw this human organ in a session about surface anatomy. This study was formed after an invitation to participate in a project that involved Year 3 students and that was entitled "drawing out surface anatomy". Students created drawings by following the same procedure as Year 1 students, with the aim of determining how medical training as the degree progresses can transform this popular representation in students' drawings. The same coding scheme from Study 2 was applied, and the results provided information about the extent to which the representation of the heart changed in students' drawings by Year 3.

Chapter 8 - Study 4. Finally, in order to investigate the way in which anatomy demonstrators understand drawing in the assessment of anatomical knowledge, eight anatomy demonstrators from the dissection sessions of Year 1 were interviewed concerning the students' drawings from Study 2. These interviews focused on their approach to assessing students' drawings of the exterior of the heart and the superior mediastinum. Thematic analysis revealed information about the aspects of those drawings that the demonstrators consider, their beliefs about drawing as an approach for assessing anatomical understanding and, lastly, the extent to which the practitioners' approach to examining those drawings is related to the method of analysis used by researchers in this thesis.

Chapter 9 – General Discussion. The closing chapter discusses the findings of each of the four studies. Then, the limitations of this research and the implications for further research are considered. Finally, the main contributions of this thesis are described as a conclusion to this thesis.

1.2. Research Questions

This section introduces the research questions that four research studies in this thesis aimed to answer. The sub-questions are presented as well below each research question. The next chapter aims to provide the background of those questions and justify why they were considered for investigation.

RQ1 (Study 1): "How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?" It is known that visual representations are strongly associated with anatomy. The first study aimed to investigate predominantly how anatomy demonstrators understand the use of visual representations and drawings in teaching (methods of data collection: observations and interviews) and then secondarily see what they believe about drawing in teaching, learning and assessment (methods of data collection: interviews) by answering the following two sub-questions:

- <u>RQ1, Sub-question 1</u>: "How do anatomy demonstrators use visual representations and drawings to introduce dissection sessions in anatomy?"

This sub-question aimed to explore both the types and the ways they use visual representations and drawings (what they do).

- <u>RQ1, Sub-question 2</u>: "What are their beliefs about using visual representations and drawing in teaching, learning and assessment in anatomy?"

This sub-question aimed to explore the demonstrators' views regarding the use of visual representations and drawing through discussions around their own use of these in teaching and their views concerning the advantages and disadvantages of using them in learning and assessment within this context (what they say).

RQ2 (Study 2): "Do student drawings reveal changes in understanding after dissection?" The second research question aimed to shed light on the use of drawing as a means of assessing whether dissection changes students' understanding, as represented by Year 1 medical students' drawings. This investigation has a dual focus on both dissection as a teaching method and the use of drawing as an assessment tool in anatomy education.

- RQ2, Sub-question 1: "Does dissection change what Year 1 medical students draw in anatomy and do they show improved understanding of the spatial aspects after dissection?"

The first sub-question examined whether dissection changes the informational content that medical students represent in their drawings of the exterior of the heart and the superior mediastinum. It was expected that their drawings after dissection would show an improvement with respect to the number of anatomical features and their shape, location and labelling.

- RQ2, Sub-question 2: "Does dissection change the way that these students draw?"

The second sub-question explored whether dissection changes the way in which medical students depict their understanding of the exterior of the heart and the superior mediastinum with respect to their use of colour and the clarity and the dimensionality of their drawings.

- RQ2, Sub-question 3: "How do different anatomical structures affect student drawings?"

The third and last sub-question in this study discussed whether the exterior of the heart and the superior mediastinum show differences in the way they are depicted by students.

RQ3 (Study 3): "Do student drawings reveal changes in understanding of anatomy as the medical degree progresses?" This study explored the use of drawings to assess changes in students' understanding of the exterior of the heart after more extensive medical education. This study was formed after an invitation for another project that involved Year 3 medical students in a session about surface anatomy.

- RQ3, Sub-question: "Do the Year 3 students show improved spatial aspects of the anatomical structures or different visual characteristic in their drawings of the heart to the Year 1 students?"

Emphasis was put on the way in which Year 3 and Year 1 students show differences in how they represent the spatial aspects of the heart, such as its overall shape, as well as their use of colour and the clarity and dimensionality of the drawings.

RQ4 (Study 4): "How do the anatomy demonstrators understand the use of drawing in the assessment of anatomical knowledge?" This study set out to examine the anatomy demonstrators' perspectives on drawing as an assessment of anatomical knowledge by answering the following three sub-questions:

- RQ4, Sub-question 1: "How do practitioners approach assessment of the students' drawings?"

This sub-question examined the way in which anatomy demonstrators look at the students' drawings (what they do). It aimed to explore those aspects of the informational content that anatomy demonstrators consider in their assessment of drawings and whether students' representational choices influence the demonstrators' decisions about the drawings.

- RQ4, Sub-question 2: "What do practitioners believe about the use of drawing in the assessment of anatomical knowledge?"

This sub-question explored the anatomy demonstrators' views about this aspect of the use of drawing. To better explore this, demonstrators were asked to express their views on its perceived advantages and disadvantages in this context (what they say).

- RQ4, Sub-question 3: “Does the practitioners’ approach to assessing students’ drawings show similarities to the researchers’?”

This sub-question was addressed by comparing the anatomy demonstrators’ approach of assessing students’ drawings, which resulted from the first sub-question that this study aimed to explore, with an approach which developed for research purposes and used in Study 2 and Study 3.

2. Literature Review

2.1. Introduction

As described in Chapter 1, this thesis explores the use of visual representations and drawings in teaching, as well as the use of drawing as an approach to assess understanding within anatomy education (after dissection activities and also as the degree progresses). Therefore, the first part of this chapter is dedicated to visual representations and drawings in teaching, drawing to learn, as well as the use of drawing in assessment. It intentionally excludes the discussion of evaluation approaches for student-generated drawings, as this will be discussed in 4.5.2 (Methodology) to support the reasons for developing a scheme to code medical students' drawings in anatomy. The next part aims to give a brief description of the approaches towards teaching within anatomy education. Here, the emphasis will be placed on dissection as a teaching method within medical education, and the debate concerning whether it is the best method for teaching will be reviewed. This leads to considering assessment both generally and specifically within anatomy education.

2.2. Visual Representations and Drawing

This section of the literature review is dedicated to visual representations and drawing. Before presenting the reviews and arguments regarding the use of visual representations and drawings in teaching and the use of drawing in assessment, this introductory section aims to define visual representations and drawing, as well as build on some fundamental arguments within the literature around them. Tversky et al. (2006, p. 54) argue that

> Like written language, visualizations are cognitive tools, designed to augment the capacity of the human mind (see Tversky, 2001, 2005, for further discussion). Then, as now, they serve myriad purposes: to record information; to lighten the burden of working memory; to convey information to others; to promote discovery, inference, and insight; and to facilitate collaboration.

The purpose that drives this design is the externalisation of thought. Tversky (2011, pp. 500-501) argues that diagrams, like any other type of visual and non-visual representation, externalise thought for a number of reasons, including aesthetic, behavioural, cognitive and communicative reasons or for several of those reasons concurrently.

This thesis aims to offer additional insight into those forms of "externalised thought" and see how these are being currently communicated in the teaching of anatomical knowledge. Furthermore, this thesis examines whether this "externalised thought" in the form of drawings could provide useful information about students' state of understanding. Before presenting the discussion around these issues in this review, some arguments regarding them will be presented to establish context.

First of all, Scaife & Rogers (1996, pp. 188-189) argue that there are three functions of a representation. According to these authors, the first function of computational **offloading** considers: "…the extent to which differential external representations reduce the amount of cognitive effort required to solve informationally equivalent problems." The second function of **re-representation** considers: "…how different external representations, that have the same abstract structure, make problem-solving easier or more difficult." Finally, the function of **graphical constraining** considers: "…the way graphical elements in a graphical representation are able to constrain the kinds of inferences that can be made about the underlying represented world."

However, external representations are not only used in isolation. Ainsworth (2006, p. 187) highlights the interest around the integration of different representations due to the increased availability of multimedia learning environments. Multi-representational environments are already increasingly available in our daily lives, with education considered a domain where such environments are available to a great extent. According to Ainsworth (1999), multiple representations serve three functions: to **compliment**, to **constrain** and to **construct**. The first function (to compliment) refers to the complementary roles of visual representations in terms of their information or the processes that they assist. The second function (to constrain) refers to the role of representations in constraining interpretation. This function includes the use of a representation that the learner understands to aid the interpretation of another abstract or less understood representation. It also considers the constraining of a representation's interpretation by *"exploiting inherent properties"* (p. 139) of another representation. The third and last function (to construct) refers to the role of multiple representations to construct deeper understanding "… in terms of using MERs [multiple external representations] to promote abstraction, to encourage generalisation and to teach the relation between representations" (p. 141).

The perspective advocated by Tversky and Ainsworth is that representations help people learn complex concepts. However, others go further and argue that since professional practices in most disciplines are fundamentally representational, students should be given the opportunity to develop this skill set: representational competence. Representational competence was defined by Kozma & Russell (2005, p. 131) in the context of chemistry, although it has now been generalised across domains, as:

> …a term we use to describe a set of skills and practices that allow a person to reflectively use a variety of representations or visualizations, singly and together, to think about, communicate, and act on chemical phenomena in terms of underlying, perceptual physical entities and processes (Kozma, 2000a, 2000b; Kozma & Russell, 1997).

Thus teaching, learning and assessing with visual representations can be argued as central for anatomy education, as students need to develop their representational competence to reach their full potential in terms of using visual representations in their practice.

When we try to put external representations into categories, there is a diversity of approaches which could be employed to draw distinctions between them. As argued by Ainsworth (in press), an approach would be to taxonomize representations based on their structural aspects (e.g. Mayer, 2005; Schnotz, 2002; Pierce, 1906, Lohse, 1994) or their functional properties (e.g. Cheng, 1996; Levin, 1987; Ainsworth 1999, 2006). For example, Ainsworth (in press) lists some approaches related to the structural aspects of representations such as putting emphasis on the representations' modality (e.g. map *versus* written directions), dynamism (e.g. drawing *versus* video) or abstraction (e.g. sketch *versus* photograph). However, there is no single agreed structural taxonomy and so its remains difficult for researchers to compare across studies, as different researchers could use the word 'picture, diagram, graphic or visualisation' for example and all be writing about the same image.

Consequently, some researchers have avoided the need to categorise representations by structure by instead considering their functional purpose. Two examples of approaches which focus on the representations' functional properties are already described in above paragraphs, the one proposed by Scaife & Rogers (1996) which considers three functions of a representation (computational offloading, re-representation, graphical constraining) and the taxonomy proposed by Ainsworth (2006) which identifies three functions of multiple representations (to compliment, to constrain, to construct). This approach whilst useful for its intended purpose was considered too abstract for this research. Consequently, the representations are grouped into categories based on their structural characteristics. Some dimensions of their categorisation in this thesis are found in the distinctions drawn in the rubric which Ainsworth & Newton (2014) used to code types of representations in publications on visual representations in science education. This was adopted as it used language and terms likely to be familiar to the participants and whose relatively broad categorisation was consistent with the research methodology. The term ***3D Visuals*** is used in this thesis to describe representations with three-dimensional characteristics such as physical models and ***2D Visuals*** consider an umbrella term for all visual representations which are represented in 2D such as photographs and diagrams. ***Drawings*** refer to 2D self-drawn visual representations created in any medium, as defined by Quillin & Thomas (2015) and justified below. ***Drawings*** is distinguished from 2D Visuals in this thesis, as the emphasis is put on its self-constructed characteristic. Finally, ***Text*** describes the external representation of written language.

The representational practice at the heart of this thesis is drawing and its roles within teaching and assessment in anatomy. As presented in Chapter 1, this thesis employs the definition of "drawing" by Quillin & Thomas (2015, p. 2), which describe it as the "learner-generated external visual representation depicting any type of content, whether structure, relationship, or process, created in static two dimensions in any medium". This definition was chosen to illustrate the distinction between drawing as a learning and assessment strategy compared to drawing as an artistic expression. Drawing in this definition serves the purpose of supporting learning or acts as an assessment approach for to-be-learnt content; it can also show distinctive characteristics (e.g. words) that make its nature different from purely artistic constructions.

The next two sections address aspects of *teaching with visual representations and drawing*s, *drawing to learn* and *drawing in assessment*. Although *drawing to learn* is not considered the core focus of this thesis, some arguments around it are presented because some sub-questions in this thesis explore the anatomy demonstrators' beliefs about the use of drawing in learning within anatomy education.

2.2.1. Teaching with Visual Representations and Drawings

This section discusses teaching practices and visual representations by providing and critiquing fundamental arguments from the literature and empirical results. Eilam, Poyas & Hashimshoni (2014, p. 74) express the view that "Knowledge of representations and particularly VRs [visual representations] is one of these rapidly developing areas that teachers need to master, because VRs are relevant to all contemporary educational practices". There can be little doubt that anatomy education is considered a domain in which, like science, technological innovation makes available to the lecturers an increasing number of visual representations with various functions. This section of the review attempts to establish the background for the need to conduct an investigation on the use of visual representations in teaching anatomy.

The role of the teacher in the development of students' representational competence is considered crucial, according to arguments by representational researchers and the empirical evidence. Eilam & Gilbert (2014, p. 3) suggest that teachers need to be competent regarding the use of representations, and must develop skills for students to become representationally competent as well.

A fundamental dimension of the use of visual representations in teaching is the teachers' knowledge and understanding of visual representations. Eilam, Poyas & Hashimshoni (2014) attempted to evaluate teachers' knowledge and understanding of visual representations in the context of science and maths. They attempted to uncover teachers' representational competence (across different grade levels, junior high and high school) by researching 72 science and math teachers' self-constructed and ready-made visual representations of their preference. Teachers were provided with three scenarios and they were directed to represent their content through self-constructed visual representations. They were then asked to choose the most effective from four ready-made visual representations in each of the three scenarios. Finally, these teachers provided written responses, and were interviewed in order to uncover the reasoning behind their constructions and choices of visual representations. The results show that the teachers' representational competence and skills seemed to be limited, and there was a lack of training that characterised both their products and their performance. Based on this study, it could be argued that we should not take for granted that educators will have always achieved the required level of representational competence and skills to effectively use visual representations in teaching.

Cook (2011b) seems to contradict the recommendations by Eilam, Poyas & Hashimshoni (2014). Cook conduced a layered case study to discover the ways in which seven high school teachers use visual representations in science, with regard to course content, student characteristics and availability of resources.

The courses of earth sciences, biology, physics and chemistry were covered in the study. Classroom observations across six weeks were employed to answer the research questions, and interviews with the teacher participants were conducted at the start and end of the semester. Overall, the results of this study show that teachers in science consider a variety of aspects in their use of visual representations, such as prior knowledge and ability level among students, and it is recommended that teachers' use should be considered in the design principles of graphics. One interesting finding of this study is the teachers' preference for real images of tissue cross-sections when delivering anatomy and physiology in biology classes; diagrams were used only when the represented content could not be depicted by a real image. As technological development has rapidly increased the availability of visual representations in education, it is worth providing additional evidence about practitioners' preferred types of visual representations in anatomy education to uncover the reasons for those preferences in their day-to-day practice.

It is worth seeing whether practitioners within anatomy education use multiple representations in their practice; it is also worth understanding more about the types of visual representations they employ in those situations. In the same vein as above, a study by Ainsworth & Newton (2014) explores the gap between aspects considered important by teachers and those by educational research in terms of visual representations in STEM. The authors researched journal publications in STEM for the period between 2010 and 2012. Their research resulted in 401 abstracts that were coded for a) their research questions, b) the representations employed by the study, c) their methodology, and d) the domains that those abstracts referred to. In addition, they interviewed 6 teachers in science who taught the 11–18 age group regarding their views on research on visual representations in science education. Generally, it becomes evident from both the journal publications and the teachers' interviews that visual representations are considered important in teaching and learning in science and a number of visual representations were coded in both. Multi-representational use, implied in the abstracts to a great extent, was also mentioned in the teachers' interviews. The types of visual representations that were of interest in research and that were coded in the teachers' interviews shared some common ground. However, an interesting result for this thesis was that four out of six of the teachers referred to drawing, which was coded in only 10% of the journal publications examined. This evidence suggests that it is worth looking at the practitioners' perspectives regarding the use of visual representations in teaching, as this can guide further research to answer questions that can support day-to-day instruction in the real world.

In teaching anatomy – a course that is visually demanding and for which various representational tools are available – it seems reasonable to examine whether the lecturers use visual representations, and what forms they prefer and consider important in the dissection laboratory environment, especially when the empirical evidence shows contradictory results. Part of RQ1 ("How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?") aims to provide recommendations about the types of visual representations and the ways in which these are being used by demonstrators in the introduction to dissection sessions in anatomy.

Although this thesis will not attempt to dig deep into such relationships, it is worth exploring whether how anatomy demonstrators use visual representations and their beliefs regarding their use influence medical students' engagement with learning using visual representations. Such an investigation was considered important, as there is contradictory evidence about the ways in which teachers use representations to influence students. Schroeder et al. (2011) explore teachers' beliefs and their instructional behaviour when using text with pictures; they also explore students' engagement with learning from the texts in this display. 108 teachers in biology, geography and German and their 5th to 8th grade students participated in this study. The authors found a positive relationship between the teachers' beliefs about the need for students to be taught strategies for learning from such displays; however, associations between students' engagement and teachers' beliefs were not generally significant. Moreover, the results show that teachers' instructional behaviours mediated the relationship between student engagement and teachers' beliefs.

However, Nitz et al. (2014) contradict the above recommendations. This team conducted a study with 931 secondary education students to explore the relationship between representational competence and content knowledge. They also explored what students believe about their teachers' representational practices and whether these practices influence students' representational competence and content knowledge after they have been taught photosynthesis. The teachers were advised to teach as they normally do and no special treatment was administered. Students' representational competence and content knowledge were assessed before the teaching unit and at the end. In addition, the authors also scored, at the end, the representational features that the teachers employed in their instruction. The results generally show an interactive relationship between representational competence and content knowledge. Furthermore, they show that representational features appeared only in moderation in teachers' instructions, with little influence on students' representational competence except that the time spent in class in interpreting representations was positively associated with learning. These studies are reported here to highlight the need for further research into the way in which teachers use visual representations. As stated earlier, although this study uses a very different method to Nitz et al., it will attempt to provide some recommendations as to how visual representations are used in anatomy education with respect to teachers' use and beliefs concerning visual representations.

A study by Coleman, Tigue & Smolkin (2011) explored 388 elementary teachers' self-reported instructional practices involving graphical representations. Briefly, the researchers attempted to investigate the types of graphical representations that are mostly used in science compared to other content areas and whether specific types are employed more than others., as well as show their teaching practices and activities with interpretation and construction of graphical representation. They examined all these across the elementary grades. Some of the results worth focusing on for this thesis are the following: a) the most recurrent practice was to point/refer to a graphical representations in a book, b) a very small minority reported drawing and labelling details as a graphical practice, c) specific types of graphical representations were linked with science teaching but little efforts were made by teachers to develop students' skills to interpret or construct so as to communicate science, and d) in science, elementary teachers did not reach the full potential of graphical representations' use. This thesis investigates anatomy demonstrators' preferred types of visual representations and the nature of their representational practice (interpretation or construction); it seems likely that the students arriving in medical school will not have had explicit education on the representations they will face in this course.

As our knowledge of teachers' use of visual representations is increasing, this thesis attempts to explore anatomy demonstrators' use of visual representations in a setting that is dominated by various forms of them and the debate on the best practices to communicate anatomical knowledge to students in medicine. In the busy environment of a dissection laboratory, anatomy demonstrators have several representational tools available. However, RQ1 ("How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?") aims to investigate if they use representational tools and which ones (what they do) when they teach the highly visual course of anatomy; it also aims to explore their beliefs (what they say) about these tools in teaching, and generally in learning and assessment in this context.

2.2.2. Drawing to Learn

Before reviewing drawing as an approach in assessment, this section of the literature presents some fundamental arguments from educational and psychological (main cognitive) researchers around *drawing to learn*. There is evidently some recent progress in this literature; however, there are still gaps about the views on the *drawing to learn* approach within anatomy education.

Prain & Tytler (2013, p. 69), through their framework of representation construction affordances, argue for the potential of learning by generating representations in science. The three dimensions of their framework are: a) the **semiotic** dimension, "…where learning is understood as students developing the capacity to recognize and use key features of generic and science-specific material and symbolic tools to interpret/explain phenomena"; the **epistemic** dimension, "…where knowledge building in science is understood as the use of a broad range of material and symbolic practices for undertaking and communicating science inquiry, and our argument that these practices should be strongly reflected in classrooms"; and c) the **epistemological** dimension, "…where student reasoning and learning in science can be enhanced by the process of constructing and negotiating their own representations". These are presented here as introductory arguments regarding the practice of having students construct their own representations, based on arguments from science education.

In addition, drawing is argued to be a generative learning strategy and is included among the eight strategies listed by Fiorella & Mayer (2015, p. 1) that are said to promote generative learning: "…the process of transforming incoming information (e.g., words and pictures) into usable knowledge (e.g., mental models, schemas)." For these authors, drawing promotes generative learning as it intends, along with the other proposed strategies in that review article, to "…actively make sense of to-be-learned information during learning by selecting the most relevant information, organizing it into a coherent mental representation, and integrating it with their existing knowledge" (Fiorella & Mayer, 2015, p. 4). However, they stress that the learner needs to concentrate their efforts on the to-be-learnt content and not be possibly distracted by the mechanics of drawing; this could be minimised when the learners are additionally supported in this process in several ways.

With regard to the body of literature on drawing, the increasing number of publications provides evidence of a growing interest in the topic. According to the review paper by Van Meter & Garner (2005, p. 286), drawing as a strategy caught the interest of researchers in 1970s (mid to late) but this was lost by the mid-1980s due to the variable results of the studies and the *"rather disappointing"* research body. They emphasise the gap in the learner-generated drawing literature that exists between the "anecdotal" recommendations and the insights based on empirical evidence. However, in the last 10 years, there is once more a growing interest in researching drawing. A reason for this is the large amount of available recommendations for teachers about the use of learner-generated drawing. It is not implied, by any means, that these recommendations are certainly incorrect, but they are mostly unsupported by evidence-based findings (Van Meter & Garner, (2005).

A domain in which drawing has been claimed to be of vital importance is science. Ainsworth, Prain & Tytler (2011), based on arguments from the literature on science practice and science education, suggest five key reasons that drawing in science education should be considered a fundamental practice for students. They argue that drawing in science can increase students' engagement, develop their representational competence in the domain and help them in scientific reasoning using representations. Moreover, they emphasise the use of drawing as a strategy for learning and for assessment of student understanding. They also highlight that many research questions around this topic should be answered by the growing empirical evidence. Although they make their argument specifically for science, many of their findings are likely to apply to medical education, especially the preclinical aspects of medicine where anatomy is being taught. This thesis is predominately interested in the ways in which drawing can be used to assess medical students' understanding in anatomy, and the views of anatomy demonstrators on the use of drawing as an approach for learning is only considered through two research sub-questions.

Tippett (2016) employs a thematic analysis of 80 relevantly recent research studies (2000–2014), with one of the main purposes being to investigate tendencies within this body of literature. Tippett reports a shift in the way in which representations are used: recently, the focus of the studies on the use of diagrams in the context of learning science is moving from the interpretation of visual representations to the construction of them. The paper also emphasises that further investigations are needed to determine aspects of learning with diagram construction, such as the influence of prior and domain knowledge, research in the real world and the connection between context, task, form and function in such practices. This growing research interest in *drawing to learn* enhances our understanding of aspects related to the implementation of such practices; however, there are not many things known about real-world practitioners' beliefs regarding the use of visual representations in general and drawing in particular when learning in different contexts.

A sub-question for RQ1 ("How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?") explores practitioners' beliefs regarding the use of visual representations and drawing in learning within anatomy education, as there are not many things currently known about what educators believe regarding this learning strategy within the anatomical domain.

2.2.3. Drawing in Assessment

In this thesis, emphasis is given to the functions of drawing to support assessment. This section aims to present empirical studies that explore this function of drawing, and attempts to present the progress in evidence regarding the use of this strategy. This general and concise review of the evidence will present examples of empirical recommendations on drawing's effectiveness as an assessment tool in various contexts. This section puts the emphasis on drawing. The issue of assessment, in general and within anatomy education, will be considered later in its own part of this literature review.

There is a growing number of empirical studies that explore drawing's effectiveness as an assessment tool. Köse (2008) examines drawing as a tool to explore students' misconceptions of plant photosynthesis and respiration in biology. The participants in this study were 156 third-year undergraduate students in primary education who were taught primary biology in their first year of training. After they received some training about drawing mixed with practical activities, they were directed to construct a drawing of what photosynthesis and respiration in plants consists of; the level of conceptual understanding that the students demonstrated was scored and analysed. The results show that these students hold a substantial number of misconceptions about the examined concepts, as a substantial number of drawings for both contents were judged as having misconceptions. Interview data that was collected from some of those 15 students reaffirmed many misconceptions identified from the drawings. Another study by Dikmenli (2010) in biology education, which used drawing to reveal students' misconceptions, concluded with similar results regarding the effectiveness of drawing to reveal misconceptions. Therefore, this evidence recommends that drawing can be used as an approach to uncover university students' understanding.

Cooper, Williams & Underwood (2015) argue that students' drawings are better at uncovering their understanding in spatially intense topics. These authors explored university students' understanding in a general chemistry course by analysing both their written responses and drawings of intermolecular forces (IMFs). Two cohorts of 94 and 160 students for replication purposes constructed drawings of IMFs and provided written explanations using the beSocratic drawing assessment software; responses were collected both on iPads and tablets. Both data were analysed by the same coding scheme, and reveal that the greater number of students' drawings show a misunderstanding about the IMFs location. Drawings of IMFs promoted unequivocal interpretation, which the written responses did not; thus, assessment of the written responses only could, at times, lead to misinterpretations about students' understanding. It was also argued by the authors that assessment with the use of multiple modes could reveal different points of view about students' understanding.

Although these studies provide a reason to be optimistic about the use of drawing for assessment in this thesis, there are, however, many things that are not known about the use of drawing as an approach to assess understanding in the spatially intense domain of anatomy. An exception to that claim is a study by Osório, Rodrigues, Garcia & Costa (2013) on cellular anatomy in medical education, which supports the finding that drawings reveal students' understanding and misconceptions about the structure of a cell. 120 medical students were asked to complete two drawing tasks at the beginning of their first practical session. As claimed, the scores show that all the drawings have, at the minimum, one misconception, and students' drawings show unpredicted and generalised misconceptions. However, the full paper of this study is not available/published and, of course, it is not possible to get all the information about the design and analysis of this study just from the available version that was found.

A recent study by Slominski, Momsen, & Montplaisir (2017) states: *"*Drawings are an underutilized assessment format in Human Anatomy and Physiology (HA&P), despite their potential to reveal student content understanding and alternative conceptions." It investigates the use of drawing to uncover university students' understanding in neuroanatomy and neurophysiology, by recruiting HA&P students from diverse majors. The content involved the concept of *"chemical synapses between neurons"*. A drawing task before instruction in neuroanatomy and a drawing task after instruction in neuroanatomy but before instruction in neurophysiology were administered. Drawings from 352 students were coded for the first drawing task, where 261 of those students completed both drawing tasks and were coded for structural accuracy/neuroanatomy (Drawing 1 and Drawing 2) and functional accuracy/neurophysiology (Drawing 2). The results reveal the diversity of ideas that students carry before instruction in both the anatomy and physiology of the neuron. Students produced more accurate drawings before instruction for the task on neuroanatomy than for the task on neurophysiology. Moreover, the drawings of the neuron anatomy were better after the students received instruction. Therefore, this paper argues that drawing can be considered a useful form of formative assessment in this domain. However, it can be argued that the nervous system is an abstract concept, and is not comparable with other more visible concepts in anatomy. Consequently, an investigation of what drawing can offer as an approach to assessment in anatomy is required in order to better understand its utilisation within such a spatially intense area.

In addition to the use of drawing in assessing students' understanding, there is some evidence about the way in which various levels of expertise can be revealed in drawings. This is considered particularly important in this thesis, as, if it is generalised to this domain, it could provide information about the way in which medical students' understanding changes throughout the whole period of their training and could inform us about critical aspects of their progress. For example, a study by Hay, Williams, Stahl & Wingate (2013) investigates how the neuron is represented in drawings that were created with various levels of expertise: in 126 undergraduate students, in 50 trainee scientists (PhD students and postdoctoral researchers) and 8 lab leaders. The results of the drawing analysis reveal that most of the undergraduate students, irrespective of the stage of the module they were at when they created their single drawing (the beginning, middle or end), reproduced the textbook archetype. Trainee researchers created drawings that were close to the textbook archetype or drawings that were related to what might be seen in "nature". The lab leaders' drawings, instead, were neither related to the textbook archetype nor to the form observed in nature (except one). Their constructions were recognised more as schematic sketches, which seemed to relate to aspects of each of the lab leaders' interest and status as principal investigators. Furthermore, two teaching interventions were conducted with 48 undergraduate students. The post-intervention drawings, where the intervention was targeted to have an effect on the perspective that the students draw, show that students' representations tend to be identified as closer to the lab leaders' representations of the neuron. Finally, this study also involved drawing sorting tasks with 36 undergraduates, 10 trainee scientists and 6 lab leaders; an undergraduate subgroup, which reproduced the textbook archetype in drawings, could identify the experts' constructions. This provides a rationale for considering the different representations that can be constructed by students with various levels of expertise within medicine, specifically from students in different years of the medical degree, and to see whether particular patterns are observed within the years of medical education.

It can be suggested by the limited empirical evidence on drawing as an assessment approach within anatomy education that many aspects of drawing as assessment still need further examination or are not investigated at all. Therefore, based on those empirical recommendations, it was considered valuable to examine the ways in which drawing can be used to assess medical students' understanding in the spatially intense domain of anatomy. Based on the above arguments on drawing as assessment, this investigation considers the assessment of understanding within a dissection session with RQ2 ("Do student drawings reveal changes in understanding after dissection?"), which examines how dissection changed Year 1 students' drawings in anatomy. In addition, RQ3 ("Do student drawings reveal changes in the understanding of anatomy as the medical degree progresses?") explores drawing as an approach to reveal understanding between two stages of the development of expertise within a medical degree by comparing Year 3 and Year 1 drawings of the same structure. Moreover, this thesis takes *drawing in assessment* a step further, as it also provides initial recommendations on the way in which real-world practitioners understand students' drawings in anatomy with RQ4 ("How do the anatomy demonstrators understand the use of drawing in the assessment of anatomical knowledge?"). It executes this by asking practitioners to assess some of the drawings that Year 1 students constructed to answer RQ2.

Finally, as with *drawing to learn*, there are not enough recommendations on what practitioners believe regarding the use of visual representations and drawing in particular when learning within different domains. Therefore, a sub-question for RQ1 ("How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?") and a sub-question for RQ4 ("How do the anatomy demonstrators understand the use of drawing in the assessment of anatomical knowledge?") explore practitioners' beliefs regarding the use of drawing in assessment within anatomy education, to provide evidence on what is believed about this practice within anatomy education.

2.3. Teaching in Anatomy Education

There is little doubt that anatomy has been always considered fundamental in medicine. Stabile (2015, p. 87) illustrates its importance in this quote:

> Anatomy is important in almost everything we do in medicine. It is the basis of clinical examination, and also of the increasingly important diagnostic technologies which enable imaging of the living body, such as ultrasonography, CT scanning, NMR, fMRI, and virtual 3D reconstruction. Anatomy for surgery is paradoxically the least important. Nevertheless, forgetting (or worst still, never knowing) the path of the accessory nerve in the posterior triangle of the neck while excising a sebaceous cyst may have unintended consequences. Whether it is the "safe" location for an intramuscular injection or the interpretation of the Psoas muscle stretch, knowledge of the underlying anatomy is essential.

The topic of anatomy attracts a great degree of attention in the medical curriculum, and so it is unsurprising that there should be much discussion around how much of it should be included and in which ways it should be taught (Stabile, 2015). It has been argued that a thorough grasp of anatomy is required early in medical training, due to the necessity of extreme precision in medical procedures (Older, 2004). However, Turney (2007) notes when discussing anatomy in the modern medical curriculum that, although anatomy has been a very important feature of medical training for hundreds of years, this has gradually changed. Anatomy is still treated by medical schools as a fundamental subject. However, as Turney states, its curriculum has diminished in the last decades. Anatomy has come to be regarded as a course that focuses on detail, but it does not put emphasis on the relevance of the to-be-learnt content and has not been successful in quickly adapting to modern learning methods. Turney (2007, p. 106) also argues that teaching in anatomy does shift in the direction of delivering "functionally and clinically relevant courses irrespective of the method of teaching". He also claims that further improvement is still needed to establish what should be required for all students as fundamental knowledge, what should target specialist training, and where the anatomical knowledge should be assessed in the medical degree. It seems that the anatomical domain within medical education has shifted direction, and things that were considered established are now being reconsidered in light of the modern curriculum that medical schools aim to deliver to the health professionals of the 21st century.

Several methods are used to teach anatomical knowledge within medical degrees. Some of them have a long history behind them and so are considered “traditional” in the field (e.g. cadaveric dissection); others are considered “modern” approaches (e.g. computer-assisted learning) due to technological improvements in more recent times. This section of the literature review is dedicated to discussing dissection as a method in teaching and learning in anatomy. Of course, there are several methods for teaching anatomy (e.g. prosections, medical imaging, computer-assisted learning, plastination, and living anatomy). However, in this thesis, the method of dissection will be mostly focused on in the context and scope of the studies conducted.

2.3.1. Dissection in Anatomy Education

Considering the number of methods available for teaching and learning in anatomy and the transformation taking place within the medical curriculum in the past few decades, the notion of a “traditional” method of dissection has received some attention recently, especially with regard to its effectiveness and applicability in medical training in the 21st century. This availability of teaching methods has informed a debate on what the best practice is and whether dissection is automatically the best choice.

Older (2004, p. 90) strongly supports cadaveric dissection in anatomy education, and argues for the benefits resulting from experiencing dissection as part of medical training. The author of this opinion paper argues that

> Dissecting is the most important procedure at the threshold of medical undergraduate education and training. To have access to his or her own cadaver is a unique opportunity and privilege. It is an early encounter

> with mortality; often it is the first time that the students confront death. In the process their manual dexterity and bonding by team work will develop and improve; a direct encounter with active and not passive learning. The students will have verification of facts from the primary source, will enjoy the art of discovery and check the interpretation of others. They will gain a three-dimensional understanding of the body, its variation and pathology. They will also begin to acquire communication skills. This will give them confidence and enrich their clinical competence.

All these claims present cadaveric dissection as a multipurpose experience in medical training. In addition to the above claimed benefits of dissection in medical training, Rizzolo & Stewart (2006) also argue that problem-solving tasks in the dissection environment support the establishment of the usual way of thinking in clinical practice, as the rhythm of the dissection environment is the same as the one in clinical practice. They argue that required spatial reasoning competencies for practice in the field are developed when dissection works in alliance with imaging approaches, and that these spatial skills are essential to allow communication between healthcare professionals and between clinicians and patients. Finally, they suggest that self-reflection and a combination of essential cognitive and affective skills are promoted by dissection activities as well as professionalism. However, it is debatable whether all these claims regarding dissection's effectiveness are supported by robust evidence.

Lempp (2005) interviewed 29 medical students from the Years 1–5 to gain an insight into medical students' perceptions of dissection and the learning outcomes that they report. Students considered dissection to be vital to gain anatomical knowledge; only three did not hold positive opinions about dissection activities. Student interviews revealed that they perceived the following learning outcomes to result from dissection: 1) value and experience of practical skills, 2) becoming familiar with the human body, 3) facilitation of combining theory with practice, 4) developing respect for the human body, 5) usefulness of dissection as preparation for clinical work, 6) recognition of the status of dissection, and 7) development of teamwork skills. They supported the view that dissection develops the skills expected for the accomplishment of the medical degree and for their career beyond it (Lempp, 2005). This insight into the students' beliefs about the learning outcomes that dissection supports seems to be in alliance with many of the claims made by supporters within anatomy education.

It is also interesting to consider surgeons' views on dissection in this debate, as their specialisation requires sound anatomical knowledge. Sheikh et al. (2016) collected questionnaires from 48 surgeons. In one of the questions, the surgeons were asked to choose the method they considered the best for teaching in anatomy. The findings of this research show that, no matter their level in the hierarchy, the majority of surgeons considered cadaver/prosection demonstration to be the best. In addition, a fair number of them supported its strengthening within anatomy education. However, complementary research with more participants across all career stages and specialties would provide wider recommendations in this matter. In addition, an investigation with more participants who have received their training more recently and who have experienced contemporary learning approaches might reveal another insight into practitioners' beliefs about the best method for teaching anatomy.

On the other hand, Ross (2015) argues that dissection is a time-consuming procedure that requires too much organisation and stresses the process over the content, with few opportunities for critical analysis. Thus, students focus their efforts on practical decisions rather than improving their understanding of anatomical principles (Ross, 2015). Concerns about the value of dissection were expressed by McLachlan et al. (2004) in comparison to the use of living anatomy and medical imaging. Due to the fundamental characteristics of dissection, it is less suitable for the training of living anatomy. In terms of medical imaging, knowledge of cross-sectional views is not easily fostered through dissection because aspects of what the students learn in dissection do not directly relate to cross-sectional views; this is important, as cross-sectional views are considered a lot in medical imaging. Moreover, not only is the surface of the human tissues – i.e. the colour and the feel – changed to a great extent post mortem, but also those haptic experiences are more appropriate to the students who are likely to become surgeons, as dissection is considered vital for training in this specialty. However, only a small number of those students will continue towards a career in surgery. Furthermore, there are issues about the integration of anatomical knowledge into a clinical context, as dissection is usually taught in the preclinical setting (as it is in Nottingham University). In addition to these potential disadvantages, the authors of this paper argue that the stress caused to students when they encounter death should be considered. Along with those disadvantages of training students with dissection, practical drawbacks related to ethics, cost and hazards should be considered as well.

Rizzolo & Stewart (2006) point out that some medical schools have chosen to replace full dissection classes in their curriculum with prosection classes or they offer dissection as an elective module. However, a sizeable proportion of these medical schools then went back to reinstating teaching with full dissection. This reinstatement of full dissection likely resulted from the ineffectiveness of prosection-guided teaching (in terms of their cost of preparation as compared to the short time that they last for in classes with large numbers of students), the poor performance of students as the degree progressed, the number of students choosing the elective full dissection, or worries related to what relevant medical education establishments would think and students' limited exposure in small-scale teaching settings. This implies that decisions taken about the delivery of anatomical knowledge must be comprehensive, and many aspects of dissection as a teaching method in anatomy and its purpose/power must be considered, along with the design and effectiveness of any other methods employed instead.

But are all those arguments about dissection supported by evidence other than lecturers' beliefs and is the claimed evidence enough to support decisions in medical schools that must, in other aspects, use evidence-based practice? It is very important in this debate to realise that there is a lack of empirical results for supporting or abandoning dissection as the best method to convey anatomical knowledge.

A study by McLachlan & Patten (2006) in medical education reviews the history of both dissection and living anatomy, as well as arguments about using dissection for teaching anatomy (as compared to living anatomy and medical imaging). These authors emphasise the need of future research to investigate which is the best approach in anatomy teaching to make the most successful clinicians, as this gap clearly exists in evidence-orientated recommendations for teaching anatomy literature. Bergman (2015, p. 212) comments when discussing dissection in anatomy education that

> …in medical education today, the key question regarding anatomy education increasingly focuses on how education can be made as effective as possible. Therefore, it is important that future research investigates what and how students learn from dissection and other teaching methods, in order to provide teachers (and students) with information on which they can base their choices.

The lack of evidence-based outcomes within anatomy education in the past becomes apparent in a study by Vorstenbosch et al. (2011). They searched four databases for English publications between 1985 and 2009 on anatomy in medical education. Here, 525 papers were identified and a representative subset of 100 of those publications were analysed. Some of the results of this study are presented in detail below to illustrate better the differences between the codes that were identified in the data and to show the lack of evidence-based results. Their analysis reveals that anatomists authored a sizeable percentage of anatomy education papers (60%) and educationalists only authored 5% of them. The perspective given in 50% of the papers authored by anatomists was their own, whereas, in educationalists papers, claims were based on data from participants. An analysis of 797 identified statements within those papers (i.e. statements that employed supportive arguments about anatomy education and which included the words “anatomy” or “anatomical” or “anatomist”) revealed some concerning results. A worrying aspect of this review was that 56% of these statements did not have a foundation, 27% were supported by references and only 17% were evidence-based. Statements by anatomists were less likely to be supported by references or evidence.

In addition, 35% of the analysed papers were categorised as viewpoint publications (no set research questions). However, it is promising to note from Vorstenbosch et al. (2011) that, out of the full set of identified 523 publications, the number of papers in anatomy within medical education has roughly double in size every five years. In addition, statements about teaching methods have increased significantly, with a rise to 53% of the corpus for statements published between 2005 and 2009, compared to only 10% of the statements published between 1985 and 1989. There was also a most welcome decrease in the statements without foundation to 47% in the period of 2005–2009, compared 84% for 1985–1989; this shows that the focus on empirical evidence is rising in the field.

Limited evidence-based recommendations are a concern for curriculum redesign, as such redesign seeks to find a new direction towards those ongoing changes. Of course, it is not claimed here that either the arguments supporting or rejecting dissection as the best practice to teach anatomy are wrong. It is the lack of evidence characterising many of those claims that is of concern. It seems that, in recent years, this has started changing, with more evidence-based claims reported within medical education publications. RQ2 ("Do student drawings reveal changes in understanding after dissection?") aims to add to this discussion by examining the way in which dissection changes medical students' understanding as depicted in their drawings.

2.4. Assessment

Pellegrino (2002, p. 48) describes assessment as

> a process of gathering information for the purpose of making judgments about a current state of affairs. In educational assessment, the information collected is designed to help teachers, administrators, policy makers, and the public infer what students know and how well they know it, presumably for the purpose of enhancing future outcomes.

The discussion around assessment in this thesis includes both formative and summative assessments. Pellegrino, Chudowsky & Glaser (2001, p. 37) describe *formative assessments* as situations where teachers employ forms of assessment to either provide interim feedback on students' progress, increase their motivation, or decide on their further instruction. They describe *summative assessments* as an approach to assessment that is employed to consider if, at the end of a stage of education, individuals have succeeded in achieving a specific degree of competency.

2.4.1. Assessment in Anatomy Education

There is a diversity of assessment instruments used in anatomy for formative and summative assessments, depending on the educational objectives. Brenner, Chirculescu, Reblet & Smith (2015, p. 105), when discussing assessment in anatomy, argue that

> There is no golden rule, which type of assessment instrument or format will be the best in measuring certain educational objectives; but one has to respect that there is no assessment instrument, which is capable to assess educational objectives from all domains of educational objectives.

Therefore, it becomes reasonable that various assessment tools exist and are being used in anatomy education, which is considered a complex and demanding course within the medical degree. Brenner et al. (2015) discuss examples of different types of assessment in anatomy education, and these are listed and briefly described here to stress the variety of the foci within assessment tools and to highlight the unsystematic use of drawing for assessment within the domain, as well as the lack of recommendations about areas that could particularly benefit the process of collecting information about students' understanding.

The assessment tools listed by Brenner et al. (2015) include the following. 1) ***Written Exams***: The authors used a description of the various possible questions in a written exam found in Chollet (2009), where the four possible question types and their emphases were described as: a) *memorization*, where a fact has to be recited by students, b) *pathway*, where a blood or nerve's path has to be traced by students, c) *spatial*, where a spatial relationship between structures has to be described or a specific structure depicted in a diagram has to be recognised by students, and d) *analytical*, where a problem/clinical scenario has to be answered by students by incorporating material. 2) ***Multiple Choice Questions (MCQ)/Multiple Answer Questions (MAQ)***: This assessment tool is formed by an introductory stem that gives students the topic and information they will need to answer, and then the question or request and the answer options are given. A clinical vignette or an image (e.g. schematic drawings, photographs, x-rays) could also be used as a stem. Students have to tick the correct answer; while MCQs have only one correct answer, MAQs have more than one correct answer but at least one distraction. 3) ***Extended Matching Questions (EMQ)***: Two or more questions, which have at the beginning display a general introduction or theme before the question or request, and then have the same list of answers, which are not limited in length, one of a kind and cue-free. One answer is the correct one in each question, while the others serve as distractors. Moreover, the answers could be the correct ones in multiple questions. However, developing these questions is difficult, and also not many pieces of software are able to use EMQs. 4) ***Spotter/Tag Tests***: In these assessments, students are presented with prosected or pre-dissected materials and the structures are tagged on them. Students then have to work on tasks; they usually answer short-answer questions or, in some cases, multiple-choice questions related to these materials and their indicated structures. 5) ***Oral Exams***: This form of assessment can measure a student's performance related to the cognitive and meta-cognitive objectives within the setting of a structured oral examination. 6) ***Online Assessments***: For this description, the authors use an example of a study by Morris & Chirculescu (2007) on an eight-hour daily three-week course in clinical anatomy. At the end of each week, the students' progress was assessed using an online test. The conclusions that were drawn highlight, among others, that the differences between examiners' approaches or within the same examiner's approach are fully eliminated in online assessments and that the students' results are made available very quickly after the end of the assessment. 7) ***Structured Observations***: This form of assessment considers the contributions of individual students and the quality of the dissected result, along with techniques or anatomical principles related to clinical skills. 8) ***Portfolio***: This refers to the assessment of a product coming from an individual student or a group of students on a dissection table. The portfolio can consider a first-hand display of the students' performance and provide a window into their abilities regarding team-working or ethical considerations, for example, among the other things that can be assessed by this form of assessment. 9) ***Students' Self-Directed Learning and Assessment***: According to the example that Brenner et al. (2015) use, these could involve self-directed learning approaches undertaken by a small number of students in an informal setting and in which the learning materials and assessment instruments are in the hands of the students. The role of the lecturer is restricted only to moderating these assessment sessions

This brief description of assessment tools within anatomy education makes evident the variety of objectives that these forms of assessment target, as well as the variety of settings that must be considered. It also becomes evident that drawing is not currently used in a systematic way within assessments in anatomy education. The target objectives, intended settings, form and interpretation of the use of drawing to assess understanding in anatomy are not thoroughly investigated within a real-world context as yet.

Pellegrino, Chudowsky & Glaser (2001, p. 3) argue that advances in knowledge within cognitive science should inform the current assessments being used:

> Contemporary theories of learning and knowing emphasize the way knowledge is represented, organized, and processed in the mind. Emphasis is also given to social dimensions of learning, including social and participatory practices that support knowing and understanding. This body of knowledge strongly implies that assessment practices need to move beyond a focus on component skills and discrete bits of knowledge to encompass the more complex aspects of student achievement.

As there is a growing body of knowledge on the use of drawing as an approach for learning and assessment, it is reasonable to invest on exploring how our increasing evidence-based understanding about the use of drawing in assessment could inform current assessment approaches and provide some recommendations to steadily consider this method in a more systematic setting within the practice. We do know, based on evidence by Pandey & Zimitat (2007), that visualisation is considered an essential approach by students when they learn in anatomy. However, drawing doesn't seem to be currently used systematically within anatomy education, although the arguments and evidence-based results that were presented earlier (e.g. Ainsworth et al., 2011; Cooper et al., 2015) suggest that drawing could be considered a powerful tool for students to make their thinking visible and for teachers to assess their students' understanding of the to-be-learnt content. Consequently, questions about its application within this domain remain unanswered. Such basic exploratory questions include the implementation of drawing to assess students' understanding of a concept (e.g. Cooper et al., 2015) or how the representation of a concept is altered by the development of expertise (e.g. Hay et al., 2013). Not only that, some evidence-based recommendations on the kind of information that practitioners could extract from a student's drawing in anatomy add to any discussion on the use of drawing in assessment.

Consequently, research questions in this thesis were set to examine these fundamental aspects of drawing as an approach to assessment in anatomy by answering the following three questions: RQ2 (Study 2) explores the way in which drawing can be used to assess students' understanding after dissection activities by asking Year 1 medical students in the first condition to draw the exterior of the heart before dissection in Week 1 and the superior mediastinum after dissection in Week 2 and vice versa for the second condition. RQ3 (Study 3) explores the way in which drawing can be used to assess students' understanding in anatomy as the degree progresses by comparing drawings of the exterior of the heart from Year 3 medical students with drawings from Year 1 students (as reused data from Study 2). RQ4 (Study 4) investigates how anatomy demonstrators understand the use of drawing for assessment in anatomy by asking practitioners to assess the students' drawings that students created in Study 2.

3. Context

3.1. Introduction

This chapter aims to describe the real-world context in which most of the data were collected for this research, in a medical school where dissection sessions are still being delivered (for the debate regarding dissection in anatomy education see Chapter 2). Studies 1, 2 and 4 (Chapter 5, Chapter 6 and Chapter 8) were conducted in the Dissection Room (DR) sessions which form part of the Year 1 curriculum of the BMedSci degree (Medicine BMBS) at the University of Nottingham. Study 2 was conducted with Year 1 medical students and Study 1 and 4 were conducted with anatomy demonstrators within these DR sessions of Year 1. Study 3 was conducted in a Clinical Phase 1 surface anatomy session of Year 3 that was specially designed to involve life drawing activities.

Firstly, the goals of medical education in the UK, the years and the stages of the medical training are presented in this chapter. Secondly, the usual student activities and the modes of assessment in these sessions from the Year 1 module that was at the center of most of the research in this thesis are described. In addition, the Year 3 session in surface anatomy is described, as well as the learning outcomes that it was hoped that the students wouldachieve. Details about the researchers' involvement in the sessions for the purposes of data collection will be specified in each of the chapters describing specific studies.

3.2. The Goals of Medical Education in the UK

The General Medical Council (GMC) in the UK has set the goals of medical education and the stages of becoming a doctor in the UK. These learning outcomes of medical education are listed in this section as given by the GMC and cover three themes: a) the doctor as a scholar and a scientist, b) the doctor as a practitioner, c) the doctor as a professional.

The first, overarching outcome was described by GMC (2015, p. 2) as follows:

> Medical students are tomorrow's doctors. In accordance with good medical practice, graduates will make the care of patients their first concern, applying their knowledge and skills in a competent and ethical manner and using their ability to provide leadership and to analyze complex and uncertain situations.

The first outcome considers the theme of the doctor as a scholar and a scientist and is considered by the following elements, as outlined from GMC (2015, pp. 2-4): 1) "The graduate will be able to apply to medical practice biomedical scientific principles, method and knowledge relating to: anatomy, biochemistry, cell biology, genetics, immunology, microbiology, molecular biology, nutrition, pathology, pharmacology and physiology". 2) "Apply psychological principles, method and knowledge to medical practice". 3) "Apply social science principles, method and knowledge to medical practice". 4) "Apply to medical practice the principles, method and knowledge of population health and the improvement of health and healthcare". 5) "Apply scientific method and approaches to medical research".

The second outcome obtained from GMC (2015, pp. 4-7) considers the theme of the doctor as a practitioner: 1) "The graduate will be able to carry out a consultation with a patient". 2) "Diagnose and manage clinical presentations". 3) "Communicate effectively with patients and colleagues in a medical context". 4) "Provide immediate care in medical emergencies". 5) "Prescribe drugs safely, effectively and economically". 6) "Carry out practical procedures safely and effectively". 7) "Use information effectively in a medical context".

The third and last outcome retrieved from GMC (2015, pp. 7-9) considers the theme of the doctor as a professional: 1) "The graduate will be able to behave according to ethical and legal principles". 2) "Reflect, learn and teach others". 3) "Learn and work effectively within a multi-professional team". 4) "Protect patients and improve care".

3.3. Medical Degree at the University of Nottingham

According to GMC (2017), medical courses in the UK, which are recognized by the GMC, usually offer five year degrees/four year degrees (for graduate entry courses). These courses provide the fundamental medical sciences education and clinical training. The post-graduate training includes a two-year foundation programme, where the graduates hold a provisional GMC license, until they are fully registered after they finish the first year of the course.

The University of Nottingham provides three routes into the Bachelor of Medicine Bachelor of Surgery (BMBS) degree: 1) the five year BMBS Medicine, 2) the four year BMBS Graduate Entry Medicine, and 3) the 6 year BMBS Medicine with Foundation Year ("Medicine, University of Nottingham," n.d.).

In the Year 1 and Year 2 of the five-year BMBS Medicine degree at the University of Nottingham, students undertake basic medical training as it is organized into four themes: a) molecular/cellular aspects of medicine, b) human structure and function, c) healthcare in the community and d) early clinical and professional development. In Year 3, the students need to conduct a research project to be awarded with a BMedSci and move into the clinical phases within teaching hospitals and community care across Nottinghamshire, Derbyshire and Lincolnshire. After completion of the five year BMBS degree, a compulsory two year post-graduate foundation doctor training follows to get the GMC full registration after the graduates finish the first year ("Medicine BMBS, University of Nottingham," n.d.).

3.3.1. Dissection Room

The medical degree at the University of Nottingham is taught in a Medical School that still provides within its curriculum, full-body dissection classes. As advertised in the programme’s website, this course is one of the few in the UK that provides medical students with the opportunity to perform exploratory dissection ("Medicine at the University of Nottingham," n.d.). Most of the data collection for this thesis was conducted in this learning environment within the ongoing curriculum of the Year 1 students.

Figure 1. Interior of the dissection room prior to dissection sessions (view 1).
Photograph taken by Dr. Peter Wigmore

Figure 2. Interior of the dissection room prior to dissection sessions (view 2).
Photograph taken by Dr. Peter Wigmore

3.3.2. Human Development: Structure and Function (Year 1)

The Dissection Room (DR) sessions taught in Year 1 and which mostly used in this thesis were part of the Human Development: Structure and Function (HDSF) module that is taught in Years 1 and 2 of the medical degree. According to the virtual learning environment's online specification, this module intended to "…develop a working knowledge of human development and clinical anatomy of the thorax, neck, upper limb and lower limb" and "…there is an opportunity to consider the basic mechanism of disease development for some common conditions." This was a student-centred module with anatomy tutorials, supporting lectures and microscopy practicals (retrieved from Moodle's description of this module). The dissection sessions of this module were delivered in the DR of the School of Life Sciences. The HDSF module was delivered in parallel with the Structural Correlates of the Systems of the Body part of the Systems Curriculum. Two of the dissection sessions of the 2nd semester in Year 1 concerned those topics.

The main aims of the HDSF module, the modes of delivery and assessment are presented in this chapter. Any specific learning objectives of the involved sessions, where needed, are presented in the studies' chapters.

3.3.2.1. Aims of the module

As described in one of the DR workbooks of the module (Pratten & Loughna, 2013), the HDSF module aimed to a) give students an understanding of topographical anatomy, b) enable them to explore functional and clinical anatomy through student-centered tasking, Computer Aided Learning (CAL) and dissection activities, c) enable students to approach some clinical examination methods through surface anatomy and radiographic images and d) offer a learning environment where they develop group work skills, employ anatomical terminology appropriately and practice a certain degree of autonomy in practical work. In the 2nd semester of Year 1 the HDSF sessions covered the Thorax, Neck, Upper Limb and the Lower Limb. HDSF was delivered in parallel with two sessions of the Structural Correlates of the Systems of the Body, part of the Systems Curriculum. In the 3rd semester of

Year 2 the HDSF sessions covered the Abdomen, Pelvis, Perineum, Back and Head. The module was delivered by both lectures and practicals in the DR and in Multi-Disciplinary Labs (MDLs). In addition, the students could attend an optional session once per week (on the majority of the weeks). In these sessions cadavers were not available, although the students had the opportunity to complete any tasking, discuss any issues with demonstrators, initiate tasking preparations for the next week's topic and find areas that they may want to bring up for discussion in the next sessions. The students could retrieve the learning outcomes and objectives of each session from before in their workbooks.

3.3.2.2. Dissection Room Sessions

In this section, the way that the Year 1 sessions' rota was carried out in the DR is explained. The expected learning outcomes, duration, subject rota (Table 1) and the ways of assessment for these sessions is described after the description of the way that the sessions were performed in the DR. Each of these sessions normally lasted for three hours and follow introductory lectures and recommended independent study. There were four tasking rooms and in each a cohort of around 30-34 students firstly attended a briefing from a qualified demonstrator before they split the rest of the session between multi-tasking within a tasking room and exploratory dissection in the main part of the dissecting room. Four tasking rooms were adjacent to the main DR. Students in each tasking room were then divided into two groups, with one group staying in the tasking room to interact with a variety of learning materials (workbooks, prosections, physical models, computer learning packages etc.) whilst the other carried out the dissection activities in the main DR and then the groups swap, as they spent half of their time in each of these learning environments. Those students in the tasking rooms were supported by one demonstrator and specially designed workbooks. In the main DR, the other group conducted the planned and supported hands-on dissection activities in small groups. They were supported again by the relevant materials and demonstrators' help where needed ("Anatomy Teaching in the School of Life Sciences, Faculty of Medicine & Health Sciences, University of Nottingham, UK," n.d.). Data for Studies 1, 2 & 4 were collected within this learning environment of the 2nd

semester dissection sessions of the Year 1 through various methods, as described in the Methodology (Chapter 4) and in each of these studies (Chapters 5, 6 & 8).

Table 1. Semester 2, Year 1 dissection sessions in order

Subject of the session
Thoracic Wall, Pectoral mm, Pleural Cavity & Lungs
Respiratory System
Heart & Pericardium
Mediastinum
Triangles of the neck
Root of the Neck, Axilla and Shoulder
Flexor Compartments of Arm and Forearm & Cubital Fossa
Anterior of Wrist and Hand
Extensor Compartment of Upper Limb, Wrist, & Elbow Joint
Thigh Anterior & Medial Aspects
Gluteal Region & Posterior Thigh
Leg, Popliteal Fossa, Ankle & Foot
Joints of the Lower Limb

3.3.2.3. Assessment

Students are evaluated in HDSF module using four assessments during the 2nd semester of Year 1:

1) Online multiple-choice questions (20% of the final mark): It is conducted at the end of the semester and lasts for 45 minutes. These are questions with regard to factual knowledge and do not involve any visual representations in either question or answer forms.

2) Online exam with 2 clinical problems (20% of the final mark): This exam is conducted at the end of the semester and lasts 90 minutes It is worth noting that visual representations that (2D visuals e.g. diagrams, x-rays, photos of bones) were used in the multi-format clinical problems. For example, students had to drag and paste labels on features that were numbered on the 2D visuals.

3) Spotter exam (50% of the final mark): This was a specimen-based exam at the end of the semester and lasts 40 minutes. In this exam students were expected to identify and explain the functional and clinical importance of a specific structure on a prosection or pre-dissected material.

4) In-course assessment (10% of the final mark): Regarding the unit of in course assessment in the 2nd semester of the Year 1 HDSF module, all questions were pre-set and given to all groups. As described in one of the DR workbooks of the module (Pratten & Loughna, 2013), a group mark based upon the quality of dissection contributed 30%, the individual students' mark based on their answers to questions contributed 40% and lastly, the mean mark from all the students on the table contributed 30%. For the group dissection mark, usually students' groups were dissecting the left and right side of the cadavers, unless it had been agreed to focus in one side to preserve structures on the contralateral side. Students were given a list with structures that they would be questioned on. In some cases, for the structures that lacked the desired quality or had been employed in other dissection activities students were not assessed on these topics. In addition, for those students that did not get consent to be absent from a dissection session, 10% of their final mark was

subtracted. The assessment of the students' own performance was conducted at the end of each dissection session, where students in their groups are asked one pre-allocated question each. 2D visuals are being used in those questions like x-rays, surface anatomy pictures, as well as 3D visuals like bones, the skeleton and of course, the cadaver. For the final unit of assessment, each session's mark was considered to the same extent. In addition, students had the option at the semester's end to rank the other members of their group for their contribution to their team work and moderate to a certain extent their group mark, if more than 50% of each group agreed. The marking criteria for both group and own performance marks were available in their workbooks. The first session of dissection was not considered for coursework assessment, as it was treated a practice for the students.

As for the sessions on the Structural Correlates of the Systems of the Body that run in parallel, those sessions' in-course assessment does not contribute to the mark of the module that they belong to, as they only consider formative assessments. These two sessions are assessed with the rest of their module in a 90-minute exam, which has a range of questions such as MCQs, drag and drop labelling, hot spots and involved visual representations as well.

3.3.3. Drawing out Surface Anatomy (Year 3)

As part of another project, I was invited to the surface anatomy session "Drawing out surface anatomy" to collect data for Study 3 (Chapter 7). This study was not originally planned to be part of this thesis, but the opportunity was taken when it came up as an invitation to participate in this workshop. As described in the session's materials that were provided by the session's Surgical Teaching Fellow in charge, David (pseudonym), this workshop was meant to be an alternative and innovative learning experience that involved the topics of the Cardiovascular System and Abdominal Examination. It took place at the Clinical Skills Centre of the Medical School and lasted 3 hours, and was repeated once. It was designed as an "innovative teaching session" for the Clinical Phase 1 Year 3 students, in which life drawing activities were involved. Surface anatomy was drawn on a model who later posed for drawings by the students. It was aimed at enabling students to achieve learning objectives with regards to developing an understanding of the way that internal organs can be visualised on the surface of the human body by life drawing.

As described in the same materials, the session involved the thematic tasks associated with the cardiovascular system and the abdominal examination. For the first task, which was on the cardiovascular system, the students had to complete two activities. The first was to provide drawings of the exterior of the heart that could be used for Study 3 of this thesis. For the second activity of the first task, the students could draw referring to the life drawing model. For the second task, the abdominal examination, students could draw on a black paper with a chalk. The emphasis was given here to the location of abdominal planes which mark the location of specific organs and the drawing of a 3D human body on a piece of paper (2D by its nature). Some fine arts students also attended the session.

The Surgical Teaching Fellow in charge described the intended learning outcomes for the part regarding the cardiovascular system as:

> 1) Make general observations about the appearance of the patient relevant to the cardiovascular system. 2) Examine the major peripheral pulses and be able to identify a bruit (vascular sounds) over the carotid, femoral and renal arteries. 3) Locate the cardiac apex beat and recognise an abnormal location in relation to surface landmarks. 4) Auscultate the heart, positioning the patient appropriately to facilitate cardiac sounds. 5) Demonstrate the presence (or absence) of the superficial peripheral pulses. 6) Recognise varicose veins and describe their anatomical distribution. 7) Outline the normal venous physiology and describe the roles of superficial, deep and perforating veins and venous valves in the scheme of venous blood flow.

For the part of the session regarding the abdominal examination, the intended learning outcomes were:

> 1) Describe the appearance of the abdomen in relation to scars, distension or visible masses. 2) Palpate all areas of the abdomen lightly and more deeply, avoiding hurting the patient. 3) Systematically examine for enlargement of the liver, spleen, kidneys and abdominal aortic aneurysm. 4) Correctly examine hernial orifices. 5) Define the terms reducible, irreducible, incarcerated and strangulated with respect to hernias. 6) Discuss the differential diagnosis of patients presenting with abdominal pain and the acute abdomen.

As fine arts students were involved in this session as well, the session materials described that it was intended to help these students develop skills related to their knowledge and understanding of anatomy, and also intellectual, practical and transferable skills. The detailed list of the learning outcomes for the fine arts students is not given here, as this chapter is intended to make a case of the context that relates to the medical students or the anatomy demonstrators that were involved in the research studies of this thesis.

3.4. Conclusion

In this chapter, the general goals of medical education have been presented and the specific Year 1 Dissection Sessions of the medical degree at the University of Nottingham have been described. It is important to note here that although current assessment involves a variety of multi-modal assessments (e.g. talking, reading, writing, interpreting 2D visualizations and 3D artefacts), a notable absence is that students are never asked to construct visual representations through drawing. The absence forms the focus of the research studies that were conducted for this thesis.

4. Methodology

4.1. Introduction

This chapter aims to describe the methodological considerations and justify the purpose of the undertaken approaches in this thesis. Firstly, this chapter explains the reasons for undertaking real-world research and the pragmatic approach that was followed to answer the research questions. Secondly, it describes and justifies the methods of data collection and the methods of analysis in the context of a multi-strategy design. Then, a detailed account is provided on the development and use of a coding scheme to analyse learner-generated drawings for two of the four studies in this thesis. The last part of this chapter describes how the ethical considerations were addressed. Further information about the methods of data collection (including any materials that were used) and the methods of analysis will be described in each of the studies' chapters (Chapters 5, 6, 7 & 8).

4.2. Real-World Research

To reach deeper insight on the issues under investigation, this research was conducted in the real-world educational environment described in Chapter 3. According to Robson (2011, p. 4), real-world research is characterised as "…applied research projects which are typically small in scale and modest in scope. They tend to be related to change and/or policy, often seeking to evaluate some initiative, service or whatever". This project was conducted within the "small scale" real-world setting of the ongoing curriculum in a medical school, with the main purpose of "the evaluation" of the role of visual representations and drawing in the teaching and assessment of anatomy education, alongside aspects of dissection as a method of improving anatomical understanding. Robson & McCartan (2016, p. 11) list some of the real-world researchers' aspects of emphasis in their work. Four priorities should be highlighted here, as they are considered important dimensions of this thesis's approach and reflect aspects of its epistemological identity: the "interest in solving problems", the "generalist researchers", the "strict time constraints" and the “need for well-developed social skills”. The “interest in solving problems” applies here, as there is not much known about the practitioners’ use of visual representations in anatomy teaching, especially of drawings. In addition, there is even less known about the use of drawing to assess medical students’ understanding of anatomy. The point of “generalist researchers” is relevant here, as the approach that was undertaken does not put emphasis on one methodology, but values the use of a multi-strategy approach that is dependent on the research aims of each of the four studies. The “strict time constraints” applies due to the effort of this project to work under the limited time available to conduct data collection within the natural setting of an ongoing curriculum of a medical degree. Finally, the last point with regard to the “need for well-developed social skills” highlights the skills that are required to conduct research within the real-world setting of an ongoing anatomical curriculum of a medical school.

4.3. Pragmatic Approach

The principles of the pragmatic approach have been described in the literature by Tashakkori & Teddlie (1998, p. 23) with an epistemology that is considered to have “both objective and subjective points of view”, an axiology where “values play a large role in interpreting results” and an ontology that allows us to “accept external reality” and “choose explanations that best produce desired outcomes”. This philosophical approach was followed to answer the set research questions. Johnson & Onwuegbuzie (2004, p. 17) argue that this approach

> … offers an immediate and useful middle position philosophically and methodologically; it offers a practical and outcome-oriented method of inquiry that is based on action and leads, iteratively, to further action and the elimination of doubt; and it offers a method for selecting methodological mixes that can help researchers better answer many of their research questions.

This approach was followed as this thesis employed a multi-strategy design (see section 4.4.4). The research methods chosen were considered the most appropriate to answer the research questions, irrespective of the philosophical positions with which they are typically associated. Itwas judged as mostly suitable for the complexity of the research questions, as "its logic of inquiry includes the use of induction (or discovery of patterns), deduction (testing of theories and hypotheses), and abduction (uncovering and relying on the best of a set of explanations for understanding one's results)" (Johnson & Onwuegbuzie, 2004, p. 17).

4.4. Methods of Data Collection

The research questions that each of the studies investigate and the methods of data collection for each are described in this section. Further details about the sampling, tasks and procedures are explained in each study's chapter.

4.4.1. Study 1

Study 1 aimed to answer the RQ1: "How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?" Semi-structured interviews were employed to answer the research question of Study 1 (Chapter 5) and they were combined with semi-structured observations. The decision to conduct interviews was based on their fundamental role in the qualitative methodology, as they allow us to understand the opinions and explanations given by people on a topic (Punch, 2009). According to Robson (2011, p. 280), in a semi-structured interview,

> The interviewer has an interview guide that serves as a checklist of topics to be covered and a default wording and order for the questions, but the wording and order are often substantially modified based on the flow of the interview, and additional unplanned questions are asked to follow up on what the interviewee says.

Study 1 employed semi-structured interviews due to this "structured flexibility" that they offer, which could support the investigation of this study's complex topics. One interview guide was developed, piloted and employed in Study 1 to interview anatomy demonstrators (N=7) regarding their use of and beliefs about visual representations and drawings to teach anatomy. These interviews were conducted in the facilities of the medical school; they were audio recorded and full transcripts were produced thereafter. The interview guides and details about the samples and the procedures for Study 1 will be described in Chapter 5.

Semi-structured observations were the second method employed to collect data for Study 1. Anatomy demonstrators were observed while they were giving the introductions of the Year 1 DR practical sessions in order to explore their use of visual representations and drawings. Observation is characterised as a direct way to find out what people do and say instead of asking them, according Robson & McCartan (2016). This was one of the fundamental reasons to choose this method in Study 1 – i.e. to directly see how seven anatomy demonstrators used visual representations, especially drawings, in their teaching practice – and it complements data from the semi-structured interviews to answer the research questions of Study 1. A semi-structured observation was employed, pre-defined particulars were the focus (e.g. use of visual representations). However, freedom was provided so that other information that was relevant for the aims of this study could also be recorded. For this reason, an observation schedule was designed, piloted and implemented to observe the way in which visualisation is being used by anatomy demonstrators when they teach Year 1 medical students. The observation schedule used in Study 1 will be described in Chapter 5. It is worth noting that the anatomy demonstrators were not observed at an equal number of times. The key reason for that was availability as different demonstrators taught more or less frequently. In addition, four demonstrators taught at the same time in each session, thus making impossible the observation of multiple demonstrators at once.

4.4.2. Study 2 and Study 3

Study 2 explored RQ2: "Do student drawings reveal changes in understanding after dissection?" and Study 3 explored RQ3: "Do student drawings reveal changes in their understanding of anatomy as the medical degree progresses?" Learner-generated drawings (see the definition in Chapter 1 or Chapter 2) were collected and analysed for both studies. Study 2 involved a quasi-experimental design, where 98 Year 1 students' drawings before and after dissection were analysed. These students' drawings were of the anatomical content being studied that week (the heart and the superior mediastinum). Study 3 compared the drawings of the exterior of the heart from 46 Year 3 students with the same drawings of the Year 1 students (which were reused from Study 2). Year 3 students followed the same drawing instructions and time limit as the students in Year 1. The collection of students' drawings for analysis constitutes a large amount of the collected data for this thesis.

4.4.3. Study 4

Finally, Study 4 aimed to answer the RQ4: "How do the anatomy demonstrators understand the use of drawing in the assessment of anatomical knowledge?" Semi-structured (as explained in section 4.4.1) and artefact-based interviews were employed for Study 4. One interview guide was developed, piloted and employed to interview eight anatomy demonstrators. For this reason, the anatomy demonstrators were presented and directed to go through Year 1 drawings from Study 2. These interviews were conducted in the facilities of the medical school; they were audio recorded and full transcripts were produced thereafter. The interview guides and details about the sample and procedures for Study 4 will be described in Chapter 8.

4.4.4. Multi-Strategy Design

In this thesis, a multi-strategy approach was used to answer the research questions presented above. Data were collected by both qualitative and quantitative methods, depending on each study's research questions. Each of the studies employed the methods of data collection that were judged as the most appropriate to answer the research questions presented in Chapter 1.

Robson & McCartan (2016) list and describe the multi-strategy design's potential benefits (partially based on Bryman, 2006). From these, five potential benefits make this approach the most appropriate for this research. They are:

1) **Completeness**: A multi-strategy design was involved to achieve a fuller insight into the complex and broad topics under investigation.

2) **Offsetting weaknesses and providing stronger inferences**: The weaknesses of the methods employed in the studies were balanced out by the strengths of the other undertaken approaches, which resulted in stronger conclusions. For example, the analysis of the observations of the anatomy demonstrators' practice in Study 1 was complemented by semi-structured interviews of those participants. Similarly, the researchers' coding of drawings in Studies 2 and 3 was complemented by semi-structured interviews with anatomy demonstrators approaching the assessment of students' drawings in Study 4.

3) **Answering different research questions**: The multi-strategy design is ideal for investigating the diverse and broad set of research questions in this thesis.

4) **Ability to deal with complex phenomena and situations**: This design has proven very useful for investigating the complex topic of this thesis within a real-world setting.

5) **Instrument development and testing**: The effectiveness of the coding scheme developed and applied to quantitatively analyse students' drawings in Studies 2 and 3 was supported by the interviews with anatomy demonstrators approaching the assessment of learner-generated drawing in anatomy in Study 4.

4.5. Methods of Analysis

4.5.1. Thematic Analysis

The thematic analysis, as described by Braun & Clarke (2006), was used to analyse the observational and interview data for Study 1 and the interview data for Study 4. Braun & Clarke (2006, p. 79) define thematic analysis as "…a method for identifying, analysing and reporting patterns (themes) within data. It minimally organizes and describes your data set in (rich) detail. However, frequently it goes further than this, and interprets various aspects of the research topic (Boyatzis, 1998)". Various considerations discussed by Braun & Clarke (2006) were taken into account before the analysis and were reconsidered during the process: a) the prevalence of the themes was considered with flexibility and continuous judgement, b) the analyses approached a rich account of the data set, and c) the undertaken approaches were driven by theoretical interests (a deductive approach) but space was also available for emerging patterns to fit into the analyses (an inductive approach). The thematic analyses of the data in this thesis followed the recommendations and the six steps of performing thematic analysis as described by Braun & Clarke (2006). Firstly, after the transcription of the interviews and the familiarisation with the data, the initial codes were generated. Then, the codes were sorted into the first themes, which were reviewed to end up with the definitive version of the "thematic map" and the defined themes. In section 4.5.1.1 and section 4.5.1.2 below, the themes, codes and sub-codes of the observation and interview analysis for Study 1 and the interview analysis for Study 4 are presented and defined where needed.

4.5.1.1. Study 1

The analysis process described in 4.5.1 concerning the observational and interview data in Study 1 resulted in the themes and codes that are presented in Table 2. For the observational data, the codes of ***Drawings***, ***2D Visuals***, ***3D Visuals*** and ***Text*** belong to the theme **External Representations in Teaching**, which partially answered the RQ1: "How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?" The code of ***Drawings*** refers to drawn 2D constructions, ***2D Visuals*** refer to any type of visual representation which is depicted in 2D (e.g. illustrated diagrams, photographs), the ***3D Visuals*** consider any type of visual representation with 3D characteristics (e.g. physical models). Lastly, ***Text*** refers to the external representation of written language.

Table 2. Theme and codes of the observational data in Study 1.

Theme	Codes
External Representations in Teaching	Drawings
	2D Visuals
	3D Visuals
	Text

Three themes are reported in the interview data of Study 1 and are presented in Table 3. These two themes added to the answer of RQ1: "How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?" The first one, ***External Representations in Teaching*** and its codes ***Drawings, 2D Visuals***, ***3D Visuals*** and ***Text*** refer to same aspects as in the analysis of the observational data that is described above. All four codes in this theme were divided into two sub-codes of the ***Usefulness*** and ***Disadvantages***. The sub-codes ***Usefulness*** and ***Disadvantages*** of each code refer to the aspects related to each of the external representation's reported usefulness and its disadvantages when is used in teaching. The code of ***Drawings*** includes also the two additional sub-codes of ***Construction Time*** *and* ***Types***. ***Construction Time*** is related to the construction of the drawings before or during the DR sessions and the ***Types*** to the form of those constructions (e.g. schematic drawings).

The second theme that is reported in Table 3, ***External Representations in Learning*** is consisted by the same sub-codes of ***Drawings***, ***2D Visuals***, ***3D Visuals*** and ***Text*** in learning practices. Those four codes in this theme refer to the same aspects as in the analysis of the observational data and in the first theme of the interview data, ***External Representations in Teaching***, it is aspects concerning learning and assessment were captured here. All those four codes again are subdivided into ***Usefulness*** and ***Disadvantages***.

The third theme that is reported in Table 3, ***External Representations in Assessment*** is consisted by the codes ***Drawings***, ***2D Visuals***, ***3D Visuals*** and ***Text*** in learning practice. The codes of this theme are not sub-divided like the codes in the other two themes, as the analysis did not reveal deeper elements for sub-categorisation.

Table 3. Themes, codes and sub-codes of the interview data in Study 1.

Themes	Codes	Sub-codes
External Representations in Teaching	Drawings	Usefulness
		Disadvantages
		Construction Time
		Types
	2D Visuals	Usefulness
		Disadvantages
	3D Visuals	Usefulness
		Disadvantages
	Text	Usefulness
		Disadvantages
External Representations in Learning	Drawings	Usefulness
		Disadvantages
	3D Visuals	Usefulness
		Disadvantages
	2D Visuals	Usefulness
		Disadvantages
	Text	Usefulness
		Disadvantages
External Representations in Assessment	Drawings	
	3D Visuals	
	2D Visuals	
	Text	

4.5.1.2. Study 4

Three themes are reported in the interview data for Study 4 and are presented in Table 4. These three themes answered the RQ4: “How do the anatomy demonstrators understand the use of drawing in the assessment of anatomical knowledge?” The first theme of ***Anatomical Knowledge*** describes the demonstrators’ comments regarding the informational content the students were expected to depict in their drawings. This theme consisted of the two codes of ***Content***, which refers to the anatomical content depicted in the drawings, and ***Accuracy***, which refers to the demonstrators’ comments regarding the anatomical accuracy of the represented structures. Specifically, ***Accuracy*** consisted of three sub-codes: the accuracy of ***Shape***, ***Location*** and ***Labelling***. The second theme referred to ***Representational Choices***, which concerned the demonstrators’ comments on the representational choices that the students made in their drawings. Specifically, this theme consisted of the codes of ***3D***, which referred to aspects related to the dimensionality of the drawings, and ***Colour***, which concerned aspects related to the use of colour in the students’ drawings. All of these codes are also present in the extended rubric for drawings used in the thesis and are, therefore, explained in detail with examples in section 4.5.2.2. The third and last theme, ***Functional Aspects of Drawing***, consisted of the codes of ***Drawing in Formal Assessments***, ***Drawing in Teaching and Learning*** (as assessment was the focus of these interviews, there was insufficient data on this two justify separate codes). In addition, the code of ***Drawing in Formal Assessment*** consisted of the two sub-codes of the ***Advantages*** and the ***Disadvantages*** related to the use of drawing in formal assessments in anatomy.

Table 4. Themes, codes and sub-codes of the interview data for Study 4.

Themes	Codes	Sub-codes
Anatomical knowledge	Content	
	Accuracy	Shape Location Labelling
Representational choices	3D	
	Colour	
Functional aspects of drawing	Drawing in formal assessments	Advantages Disadvantages
	Drawing in teaching and learning	

4.5.2. Drawing Analysis

The analysis of students' drawings for Studies 2 and 3 comprises the quantitative analysis of this thesis. Drawing data can be considered quite complex, depending upon the context and purpose for which the drawings are being constructed. In this thesis, the collected drawings were considered as complicated data, as these constructed visualisations communicate diverse sets of characteristics of anatomical knowledge. For example, they provided information not only on names and locations, but also on shapes and conventions in the domain. The amount of information and detail that the students put into their drawings and the required level of precision in evaluating these constructions statistically led to the need to develop a coding scheme that quantitatively analysed the messy and subjective content the drawings represented. This coding scheme followed the principles found in verbal analysis, defined by Chi (1997, p. 2) as the "methodology for quantifying the subjective or qualitative coding of the contents of verbal utterances". The reasons for developing a novel approach and the actual coding scheme will be presented below. Data produced by the application of the developed coding scheme was analysed statistically in Statistical Package for the Social Sciences (SPSS) for the hypotheses of Studies 2 and 3 (see Chapters 6 and 7 for more information about the statistical tests and considerations).

4.5.2.1. Development of the Coding Scheme

The dominant element of the learner-generated drawings that is usually assessed in *drawing to learn* and *drawing in assessment* literature is undoubtedly *accuracy*. As Van Meter & Garner (2005, p. 299) comment in their review, accuracy is defined as "the degree to which completed drawings resemble the represented object(s)". However, there are various ways in which accuracy can be scored for learner-generated drawings. For example, starting from the simplest approach, Van Meter (2001) coded 5th and 6th grade students' drawings of the central nervous system when reading science text. The author developed a 1-to-4-point general rubric and then constructed specific tools for each of the three content areas of text to score the accuracy of the structures and their connections. Dove, Everett & Preece (1999) coded 9–11 year olds' drawings in a study investigating their understanding of the hydrological concept of the river basin through drawings. They analysed children's drawings for understanding, orientation and their content. Firstly, the drawings were coded into five categories for the level of understanding they depicted, according to the criteria they satisfied. Any identified misconceptions were noted. Secondly, with regard to the orientation, the direction of the river in the drawings was coded into eight categories. Thirdly, the content of the drawings was coded as well. In each drawing, each presented feature was coded and thus a list of the presented features was formed. Then, the researchers identified the content of the drawings that was mostly coded to form three groups of features, which included majority of the features presented in the drawings. It seems that an even more complex approach was employed by Bobek & Tversky (2014), who coded 7th and 8th grade students' visual (drawings) and verbal explanations of the bicycle pump and chemical bonding. For example, for the explanations of how the bicycle pump operates, the structure and function were coded by giving a maximum of 12 points for including and labelling 6 structural part. Information about any part's function or movement and the interaction between parts were coded as functional (no maximum). Essential information about the function was coded by the number of presented functional information content (maximum 4 points). The researchers also coded and counted three ways of using arrows and, lastly, the number of steps shown on the produced explanations.

There is also evidence from Osório, Rodrigues, Garcia & Costa's (2013, pp. 1120-1121) study on cellular anatomy in medical education that supports the idea that drawings revealed the students' understanding and misconceptions about the structure of a cell. 120 medical students were asked to complete two drawing tasks at the beginning of their first practical session. They were asked to make: a) "the scheme of an animal eukaryotic cell" and b) "their vision of an epithelial human scrub slide under the microscope". These drawings have been coded for a) "the number and organisation of the cells", b) "the presence of entities that have sizes below the optical microscope detection limit", c) "the position of the nucleus within the cell" and d) "odd representations". The authors claimed that the scores showed all drawings to have, at the minimum, one misconception, and students' drawings showed unpredicted and generalised misconceptions. However, the full paper of this study is not available/published and, of course, it is not possible to get all the information about the design and analysis of this study just from the available 500 words abstract.

The above examples of the coding schemes' scored accuracy aspects of drawings were judged appropriate for the age, level of knowledge and research aims that the studies addressed, but they seem to be insufficient for coding these drawings in the context of this thesis and the research questions it sought to answer. Analysing these rubrics, it was decided that the majority were too simple for the complexity of the content of the drawings in this thesis and that something more detailed would need to be attempted. Thus, the codes in the thesis approach with regards to informational content were based on the coding approaches of drawings found in this literature (Ainsworth, Galpin &

Musgrove, 2007; Bobek & Tversky, 2014; Dove et al., 1999; Van Meter, 2001; Van Meter, Aleksic, Schwartz & Garner, 2006).

The analysis of this thesis also aimed to cover the representational choices that the students included in their drawings. With regard to the representational choices, not many papers were identified that deal with aspects of the drawings' form. However, there is a study by Ainsworth, Galpin & Musgrove (2007) that is coded on a 5-point scale regarding the extent to which students' drawings of the circulatory system were abstract or realistic. In the same paper, the clarity of the drawings was coded on a 3-point scale. The coding scheme by Gan (2008) was developed to analyse drawings of the *light* created with the use of an online multimedia environment. Amongst all 7 dimensions that included in the scheme, the author considered the dimension of *aesthetics/clarity*, which scored in a 3-point scale a number of aspects related to the diagrams' aesthetic result (e.g. use of colour, rendering etc.) and aspects related to the extent that they employed successfully tools to make the drawing understandable to the reader and of course, correct (titles, labels etc.). Given the previous successful if limited use as illustrated in these studies, it was decided to adopt similar approaches to deal with the students' representational choices.

The development of the coding scheme in this thesis was based upon the *verbal analysis* paradigm as described by Chi (1997, p. 2), in which "… one tabulates, counts, and draws relations between the occurrences of different kinds of utterances to reduce the subjectiveness of qualitative coding". In addition, drawings of the exterior of the heart and the superior mediastinum were created by two expert anatomists and a list of features was provided from a third expert anatomist, to see which features the teaching staff expects to see depicted on students' drawings (similar approaches undertaken in Leopold & Leutner, 2012; Leopold, Sumfleth, & Leutner, 2013; Van Meter, 2001). Lastly, the recommended student textbook, *Essential Clinical Anatomy* (Moore, Agur, & Dalley, 2011; 2015), was consulted for the same purpose.

4.5.2.2. Coding Scheme

The coding scheme was created in consultation with a learning scientist and an expert anatomist (the two research supervisors of this thesis). Due to the level of knowledge that this drawing analysis aimed to score, *accuracy* of the constructions involved four distinct aspects of the information content: the presence of anatomical features, the accuracy of shape, the accuracy of location and the correctness of labelling. Furthermore, due to the nature and the conventions of the anatomical domain, three representational choices were considered in the employed coding scheme: the use of colour, the clarity (the extent to which they drew clear representations) and the dimensionality of the drawings (the extent to which students gave three-dimensional characteristics to their drawings).

Twenty-eight anatomical features in total for each structure (Table 5, Table 6) were identified as the content that the experts would like to see depicted in students' drawings; these were included in the coding scheme.

Table 5. List of the coded anatomical features of the exterior of the heart in alphabetical order

Exterior of the Heart	
anterior interventricular artery	left subclavian artery
arch of aorta	left ventricle
atrioventricular sulcus	pulmonary trunk
brachiocephalic trunk	right atrium
great cardiac vein	right brachiocephalic vein
inferior vena cava	right common carotid artery
interventricular sulcus	right coronary artery
left atrium	right marginal artery
left brachiocephalic vein	right pulmonary artery
left common carotid artery	right pulmonary veins
left coronary artery	right subclavian artery
left marginal artery	right ventricle
left pulmonary artery	small cardiac vein
left pulmonary veins	superior vena cava

Table 6 . List of the coded anatomical features of the superior mediastinum in alphabetical order

Superior Mediastinum	
arch of aorta	pulmonary trunk
brachiocephalic trunk	right brachiocephalic vein
left brachiocephalic vein	right common carotid artery
left common carotid artery	right internal jugular vein
left internal jugular vein	right lymphatic duct
left main bronchus	right main bronchus
left pulmonary artery	right phrenic nerve
left phrenic nerve	right pulmonary artery
left recurrent laryngeal nerve	right subclavian artery
left subclavian artery	right subclavian vein
left subclavian vein	right vagus nerve
left vagus nerve	superior vena cava
ligamentum arteriosum	thoracic duct
oesophagus	trachea

The coding started from the informational content of each drawing and, for each presented feature, its accuracy of shape and location was coded. If the feature was labelled, the extent to which the label was correct was also coded. That process was repeated for all 28 anatomical features of each drawing under examination. Moreover, notes were taken of any identified misconceptions, the features that were unknown from the construction, and any other comments about the drawing. These notes assisted the coding process but were not considered in the analysis as individual codes. After the coding of informational content, the representational choices made by the students were scored, independent of content. Lastly, the overall shape of the heart drawings was measured and coded. The reason for this was that the anatomical structure of the heart can be considered more dynamic due to the different shapes it can take inside or outside of the human body. The superior mediastinum does not respond in this way, and its drawing is not easily reduced to an overall shape code.

All this information was imported directly to a template specifically designed for this purpose on Microsoft Excel. To minimise typing mistakes and assist the process of coding, drop-down lists were applied to the cells of the pre-defined codes. Any required formatting before importing the data into SPSS used formulas to transfer and edit the data with accuracy.

One key issue that needed to be resolved was an anatomical feature's accuracy of shape and location in relation to the others around it. It was not easy for the raters to decide which of the features the student had intentionally shaped/located incorrectly and which had become inaccurate since their related features were incorrectly shaped/located. If, for example, one of the presented features was intentionally mislocated by the student, it could make several features that were spatially related to it seem mislocated as well and they would have been coded as inaccurately located.

Consequently, it was important that a drawing not be judged as lacking multiple times for a single mislocated feature. To resolve this issue, principles developed from string similarity were used, specifically an *Edit Distance Algorithm* was applied. As cited in the literature of string matching by Navarro (2001), a common distance function is the Levenshtein (1965) edit distance algorithm, which is the minimum number of editing operations (insertions, deletions, substitutions) than can be made for two strings to be considered identical. Table 7 shows an example of the edit distance algorithm in this typical application – spell checking, the idea being to compute the minimum number of transformation used to turn one word into another one.

Table 7. Basic examples of the Edit Distance Algorithm principles

Edit distance between the words “HEAVEN” and “EVEN”	Edit distance between the words “AGRO” and “ERGO”
Steps	*Steps*
1. Delete “H” (1st edit) 2. Keep “E” (no edits) 3. Delete “A” (2nd edit) 4. Keep “V” (no edits) 5. Keep “E” (no edits) 6. Keep “N” (no edits)	1. Delete “A” (1ST edit) 2. Insert “E” (2nd edit) 3. Replace “R” (3rd edit) 4. Keep “G” (no edits) 5. Keep “O” (no edits)
Total= 2 edits	Total= 3 edits

In the thesis, a similar approach was taken to quantify the minimum number of “editing operations” required to transform a student drawing into the ideal. For example, on the drawing below (Figure 3), the left brachiocephalic vein has been placed behind the aortic arch and, consequently, behind the brachiocephalic trunk, making all these features “mislocated”. By using the concept of the edit distance algorithm, we could place the left brachiocephalic vein (the feature not accurately located) on the front of the aortic arch and then all of the above mislocated features become accurately located. Thus, by making only one edit on the diagram, it becomes “accurate” in terms of the features’ location. We could possibly change the location of the aortic arch and the brachiocephalic trunk, but that means we make two edits and we “punish” the drawer twice by coding two features as “mislocated” instead of coding one (the left brachiocephalic vein). Clearly, this approach also makes assumptions and may “reward” a student inappropriately when they perhaps did have multiple misunderstandings. However, its main advantage is that it provides a systematic approach that can be applied consistently across the hundreds of drawings in the dataset, rather than leaving a coder to make arbitrary judgments on each one.

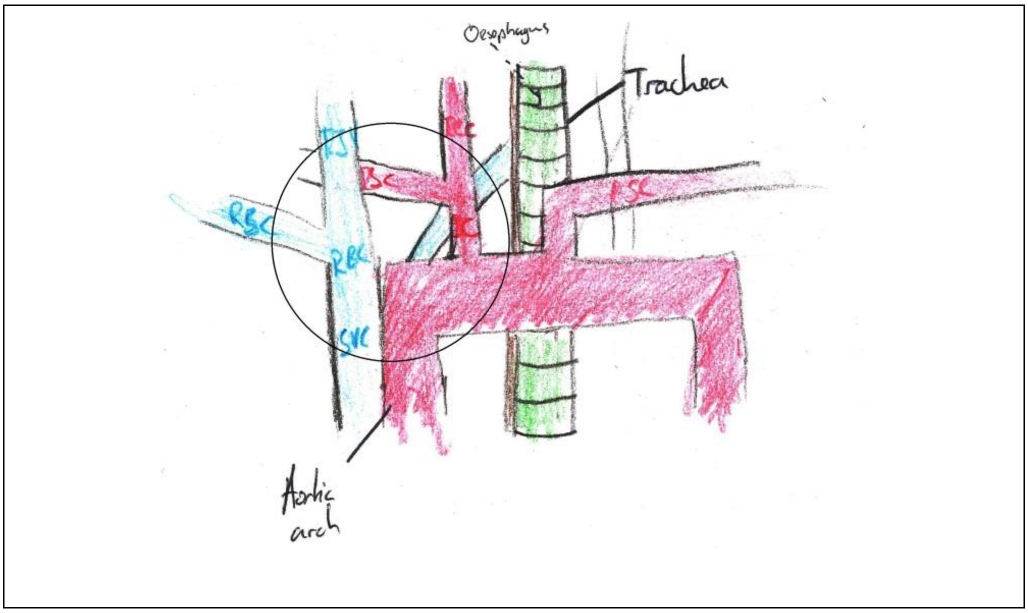


Figure 3: Example in which these principles have applied when scoring the accuracy of features' location

A further issue that needed to be resolved was how to decide between mislabelling versus mislocation. The example below (Figure 4) illustrates how a feature that could have been coded as either mislocated or mislabelled was coded as mislabelled. The student labelled the right internal jugular vein as the "right brachiocephalic vein". It could be argued that the student provided either a) an incorrect label of the particular feature or b) a fully correct label provided, by coding the feature as mislocated. As it was impossible to determine which the correct interpretation would be without speaking to the student, it was decided to treat all examples of this type as "0: labelling provided, but incorrect". This decision was taken as the task instructions did not require students to provide labels, so the coding emphasis was put on the visual feature and not on the written label.

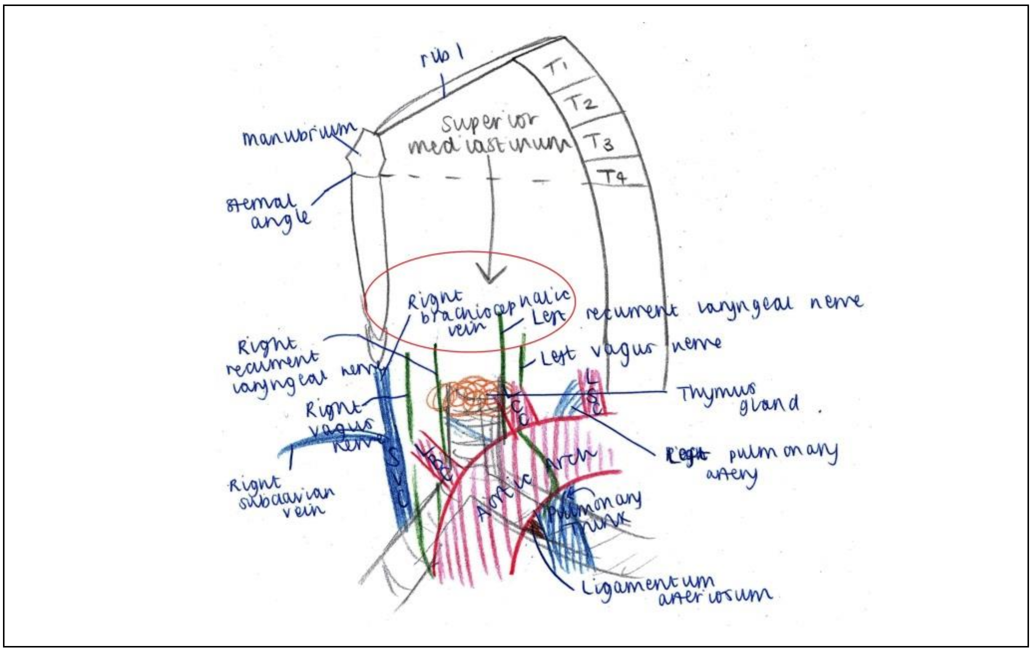


Figure 4: Example of a feature's labelling coded as “provided but incorrect"

4.5.2.2.1. Description of the Informational Levels of the Scheme

To perform the statistical tests in the analysis, all the assigned numerical scores in the codes for the presented features and the accuracy of shape, location and labelling were turned into percentages by dividing their sum for the full drawing by the total number of the drawings’ anatomical features identified in this coding scheme (28).

Presented features

The first information that was coded for each of the 28 anatomical features for each structure was the presence on the drawing or not and it was coded as:

- ***Not presented (score: 0)***: The feature was not constructed on the drawing or not enough evidence to be recognised as present (e.g. Figure 5).

Anatomical feature: **left coronary artery** Score: **0**

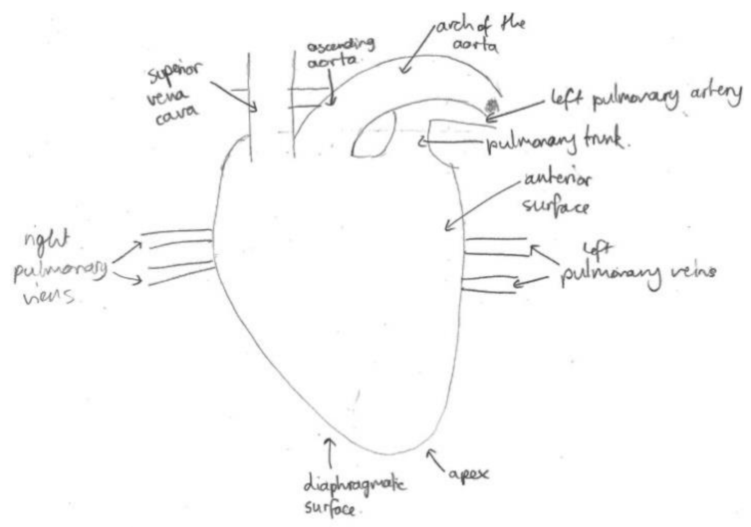


Figure 5: Example of a feature coded as “not presented”

- ***Presented (score: 1)***: Enough evidence was provided to recognise the examined feature as present (e.g. Figure 6).

Anatomical feature: **oesophagus**	Score: **1**

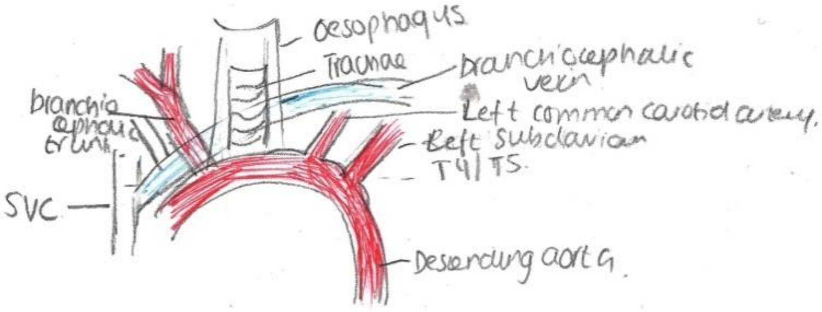


Figure 6: Example of a feature coded as "presented"

Accuracy of shape

For each individual feature, the second coding decision was for the accuracy of the constructed shape and it was coded as:

- ***<u>Feature was not represented (score: N/A)</u>***: The feature was not constructed on the drawing or not enough evidence to be recognised as present (e.g. Figure 7).

Anatomical feature: **brachiocephalic trunk**	Score: **N/A**

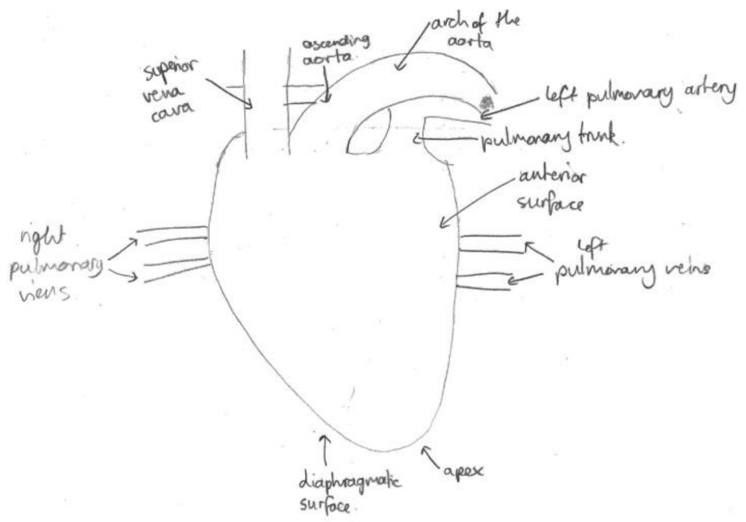


Figure 7: Example of a feature coded as "not represented" (shape)

- ***<u>Feature was not accurately shaped (score: 0)</u>***: The examined feature was presented, but its shape was not satisfactory enough to be coded as accurately shaped (e.g. Figure 8).

Anatomical feature: **oesophagus**	Score: **0**

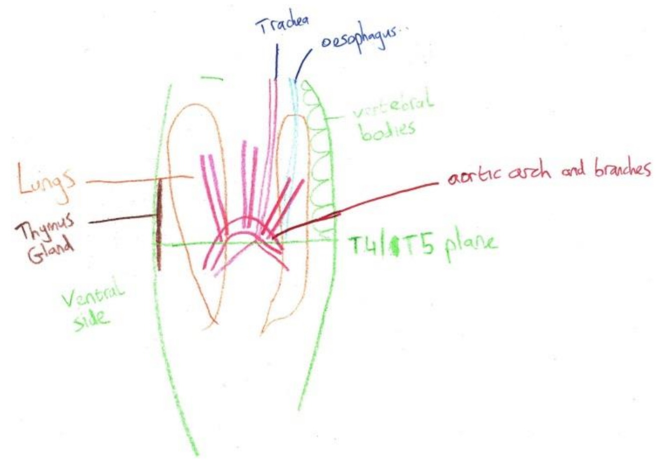


Figure 8: Example of a feature coded as "not accurately shaped"

- ***<u>Feature was accurately shaped (score: 1)</u>***: The shape of the feature was represented accurately (e.g. Figure 9).

Anatomical feature: **superior vena cava**	Score: **1**

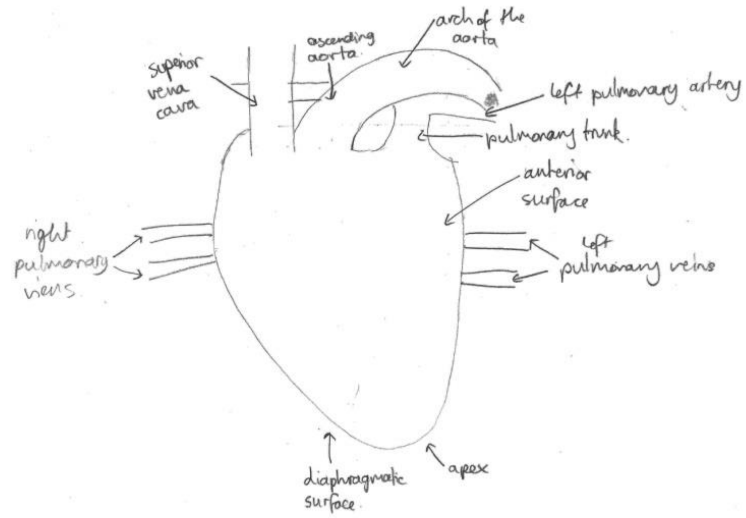


Figure 9: Example of a feature coded as "accurately shaped"

Accuracy of location

Thirdly, for each individual feature out of the 28 under investigation the accuracy of its location was coded as:

- ***<u>Feature was not represented (score: N/A)</u>***: The feature was not constructed on the drawing or not enough evidence to be recognised as present (e.g. Figure 10).

Anatomical feature: **left recurrent laryngeal nerve**	Score: **N/A**

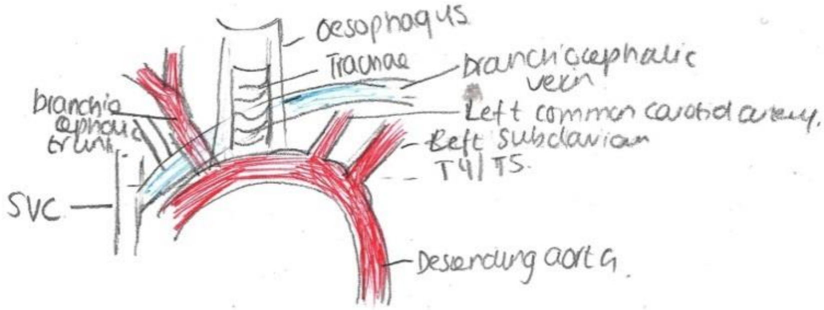


Figure 10: Example of a feature coded as "not represented" (location)

<u>Feature was not located with accuracy (score: 0)</u>: The examined feature was presented, but its location is not satisfactory enough to be coded as accurately located (e.g. Figure 11).

Anatomical feature: **pulmonary trunk**	Score: **0**

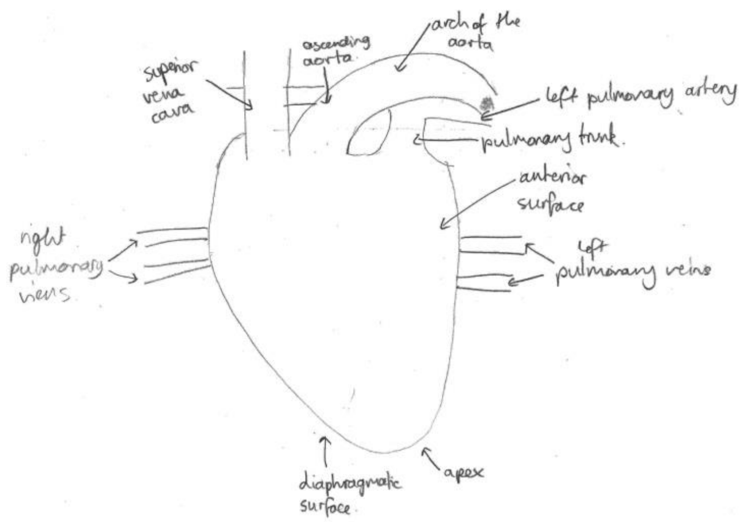


Figure 11: Example of a feature coded as "not located with accuracy"

- ***Feature was accurately located (score: 1)***: The location of the feature was represented accurately (e.g. Figure 12).

Anatomical feature: **arch of aorta**	Score: **1**

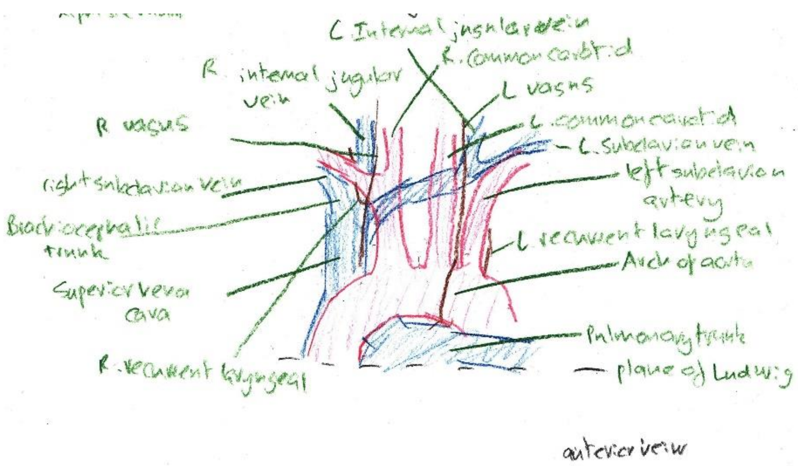


Figure 12: Example of a feature coded as "accurately located"

Labelling

The last coding decision for the informational content was the assessment of each feature's label, if provided on the drawing. In terms of coding the labelling, up to 3 decisions could be made to describe the observed performance for each particular feature:

- ***<u>Feature was not provided (score: A)</u>***: The feature was not constructed on the drawing or not enough evidence to be recognised as present (e.g. Figure 13).

Anatomical feature: **brachiocephalic trunk**	Score: **A**

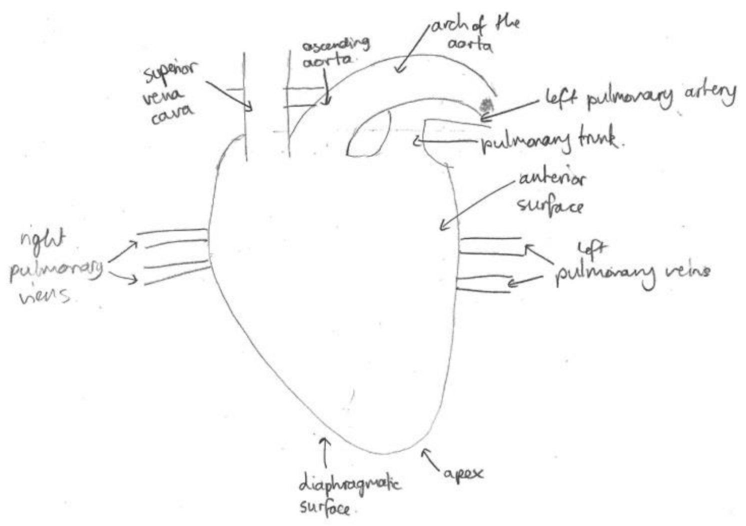


Figure 13: Example of a feature coded as "not provided" (labelling)

Labelling was not provided (score: B): The examined feature was not labelled at all (e.g. Figure 14).

Anatomical feature: **right subclavian artery**	Score: **B**

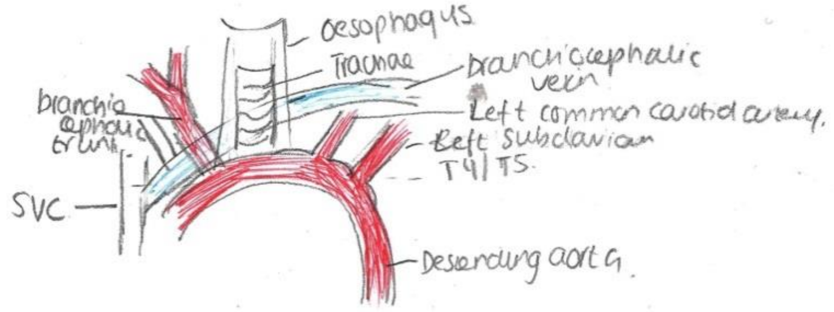


Figure 14: Example of a feature coded as "provided, but labelling was not"

- ***Labelling was provided but incorrect (score: 0)***: The examined feature was labelled, but the label was not correct (e.g. Figure 15).

Anatomical feature: **Left common carotid artery**	Score: **0**

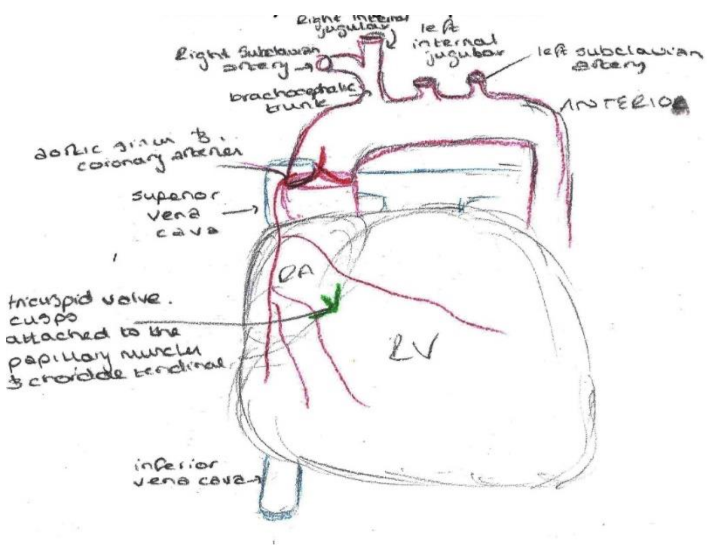


Figure 15. Example of a feature's labelling coded as “provided but incorrect"

- ***Labelling was provided but partially correct (score: 1)***: The provided label was either containing some incorrect parts or some important parts of it were missing (e.g. Figure 16).

Anatomical feature: **right subclavian vein**	Score: **1**

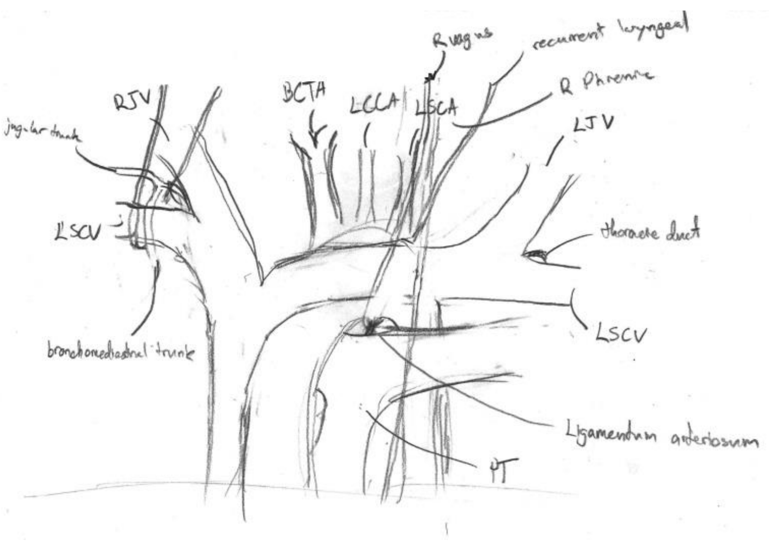


Figure 16: Example of a feature's labelling coded as “provided but partially correct"

- ***Labelling was provided and fully correct (score: 2)***: The provided label was correct and full or even if some parts of it are missing, the student have shown enough evidence to assume from the peripheral and related features that has chosen to skip some parts of it, but still awareness of their full information is supported on the drawing (e.g. Figure 17).

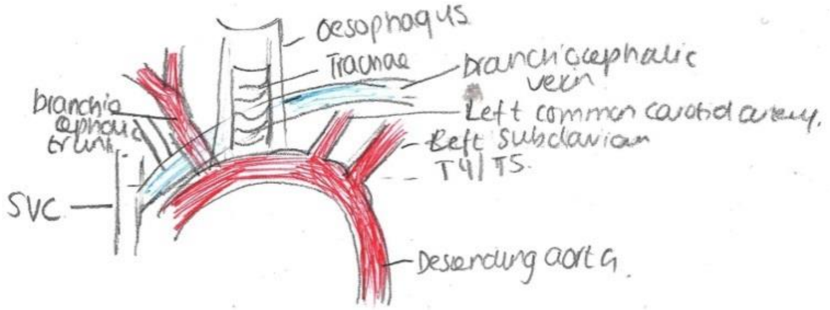
Anatomical feature: **oesophagus**	Score: **2**
	

Figure 17: Example of a feature's labelling coded as "provided and fully correct"

Overall shape

Due to the different nature of structure in the two classes (heart-human organ *versus* superior mediastinum-collection of structures), it was not sensible to talk about "overall shape" for the superior mediastinum. However, it was decided to code the overall shape of the heart as this was a pedagogical objective of that dissection session. The overall shape was coded by a) *dividing width by height* (a human heart in its natural state is about 20% wider than higher), b) *measuring the point of maximum width* (around 60% down is reality) and c) *measuring the point of maximum height* (around 40% to the right/left in anatomy):

- ***Overall shape by dividing width by height***: *the percentage of the maximum width divided by the maximum height.*

- ***Point of maximum width***: the percentage of the maximum width placed from the top divided by the maximum height (e.g. Figure 18).

Score: (max. width P/max. height) X 100

Example: (2.4/7 x 100) = **34.286**

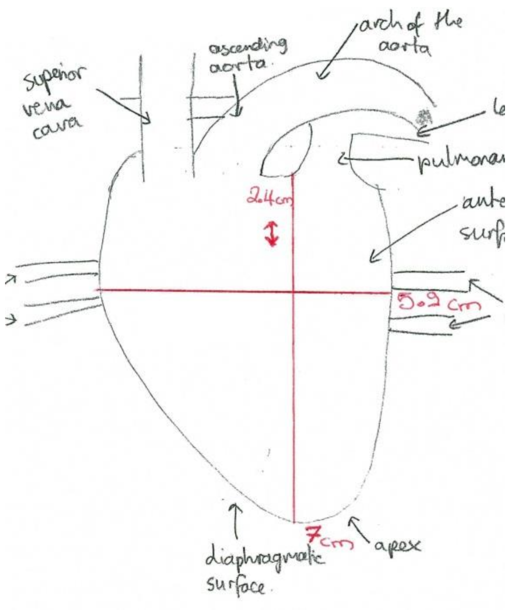


Figure 18. Example of measuring the point of maximum width

- ***Point of maximum height***: the percentage of the maximum height placed from the right divided by the maximum width (e.g. Figure 19).

Score: (max. height P/max. width) x 100 Example: (3.9/5.9 x 100) = **66.102**

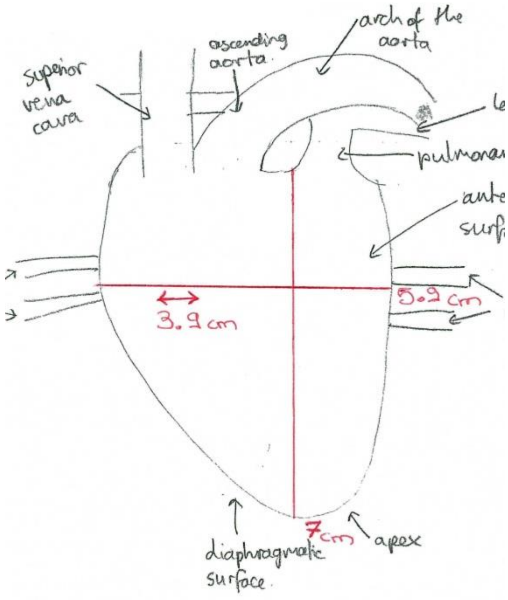


Figure 19. Example of measuring the point of maximum height

4.5.2.2.2. Description of the Representational Levels of the Scheme

Use of colour

The first of the representation choices was examined whether the student used colour semantically on the drawing or not used colour at all. The use of colour on the drawings was coded as:

- ***No use of colour (score: A)***: Colour has not been used on the drawing or has used a single coloured pencil to create the overall drawing (e.g. Figure 20).

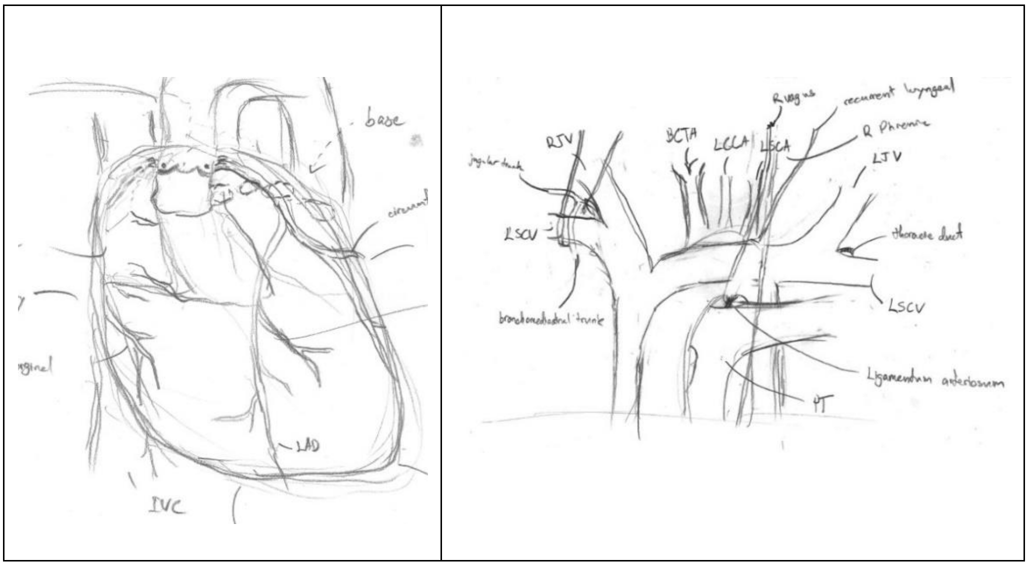


Figure 20: Example of drawings coded as "no colour used"

- ***<u>Used colour (score: B)</u>***: Specific colours have been paired with specific features (e.g. Figure 21).

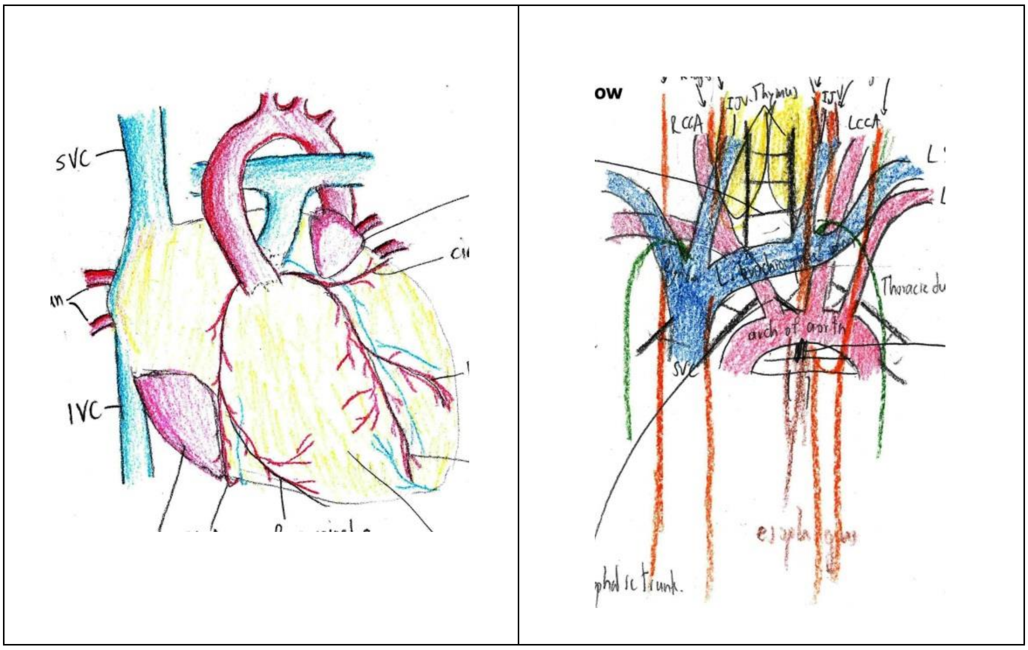


Figure 21: Examples of drawings coded as "used colour"

Clarity

The degree which the drawings were understandable by others was coded as:

<u>Very unclear representation (score: 1)</u>: Difficulties to understand a fair part of the drawing. There was a large amount of scribbles and the majority of the drawing was not clearly constructed (e.g. Figure 22).

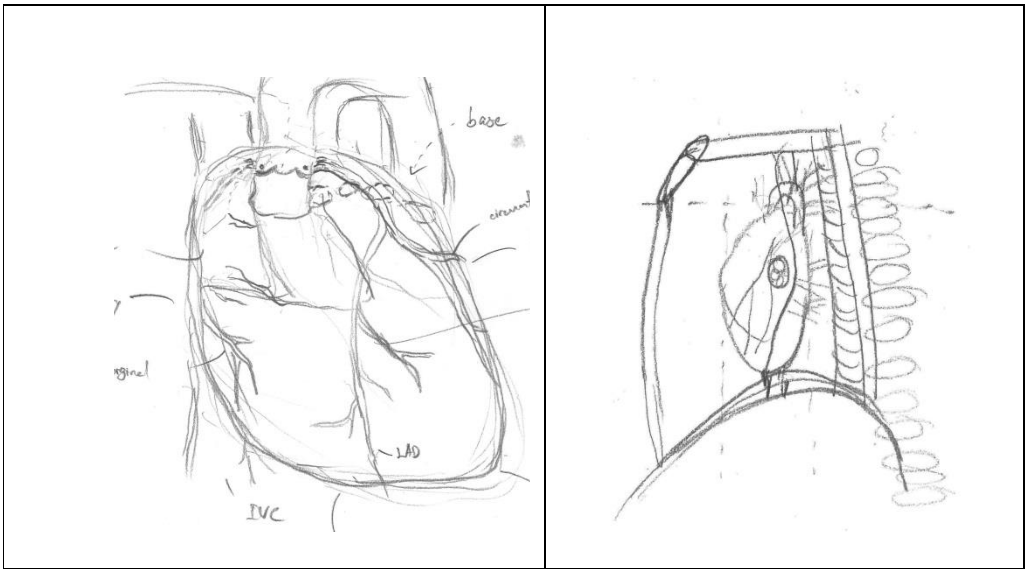


Figure 22: Example of drawings coded as "very unclear representation"

- ***Partially clear representation (score: 2)***: It has been difficult to understand some parts of the drawing, but a reasonable part is clear and understandable. Some parts included a fair amount of scribbles but other bits of it are clear (e.g. Figure 23).

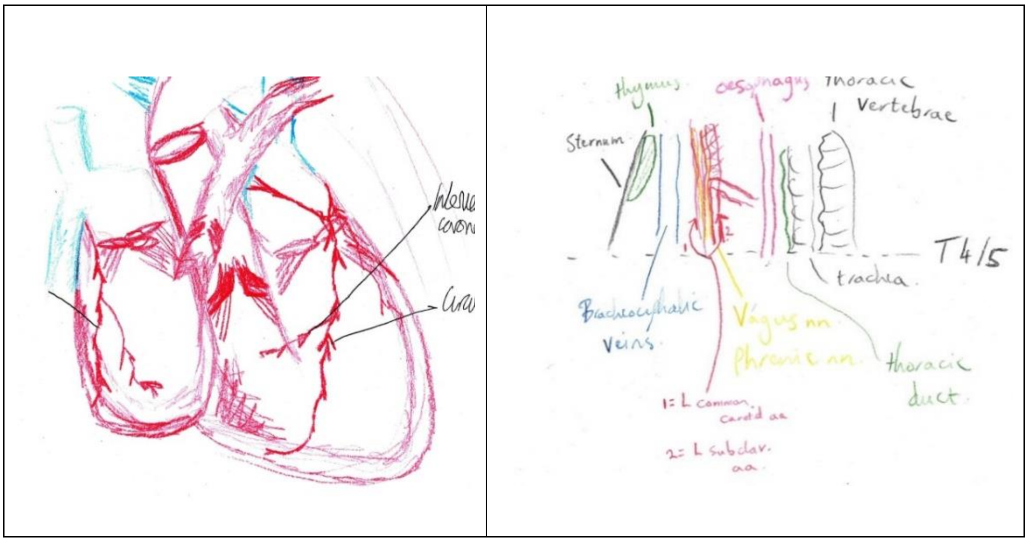


Figure 23: Examples of drawings coded as "partially clear representation"

- ***Very clear representation (score: 3)***: Drawing was completely understandable and clear. Very clear construction, not any unclear parts or scribbles have been identified (e.g. Figure 24).

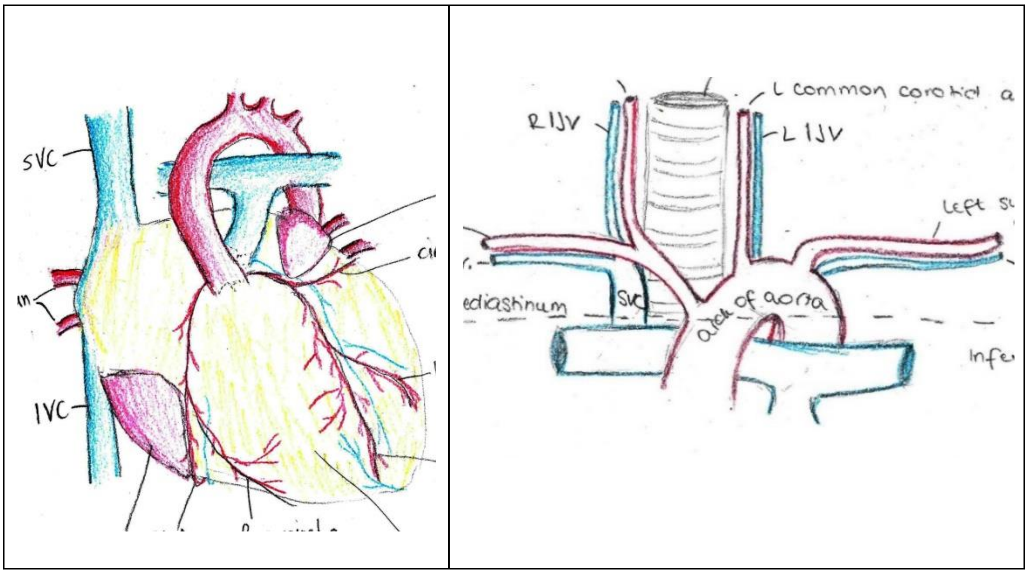


Figure 24: Example of drawings coded as "very clear representation"

Dimensionality

The attempt to represent reality was coded as:

- ***Sketch/highly abstract representation (score: 1)***: The construction did not strongly represent the physicality of the represented object. The construction did not show spatial relations of the represented features and three-dimensional characteristics were not identified (e.g. Figure 25).

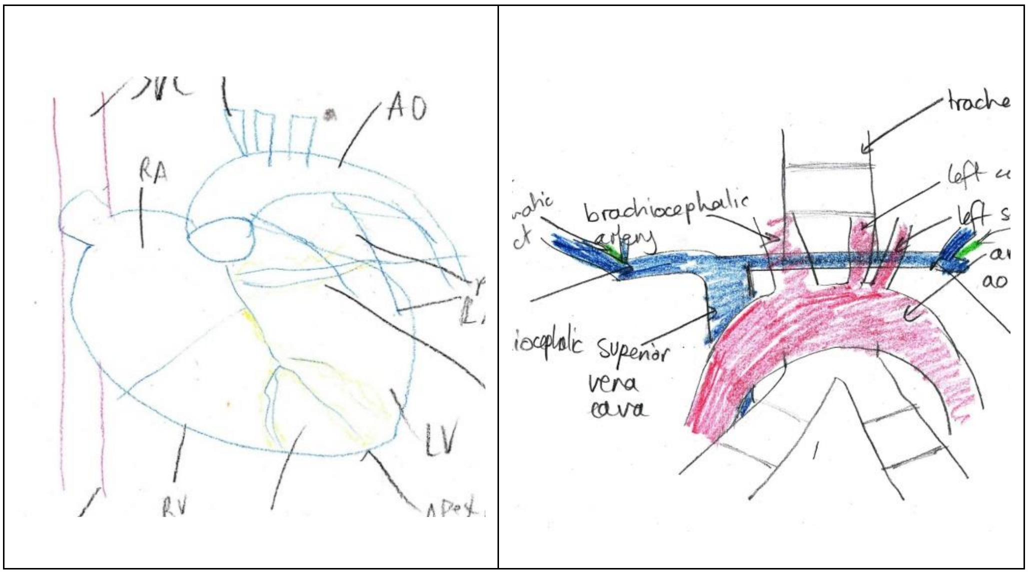


Figure 25: Examples of drawings coded as "sketch/highly abstract representation"

Abstract representations, limited attempts to present things realistically (score: 2): There were not high levels of realistic resemblance, though limited attempts have been made to represent some parts as they would be in real world. The drawing revealed the spatial relations of the features but three-dimensional characteristics were limited (e.g. Figure 26).

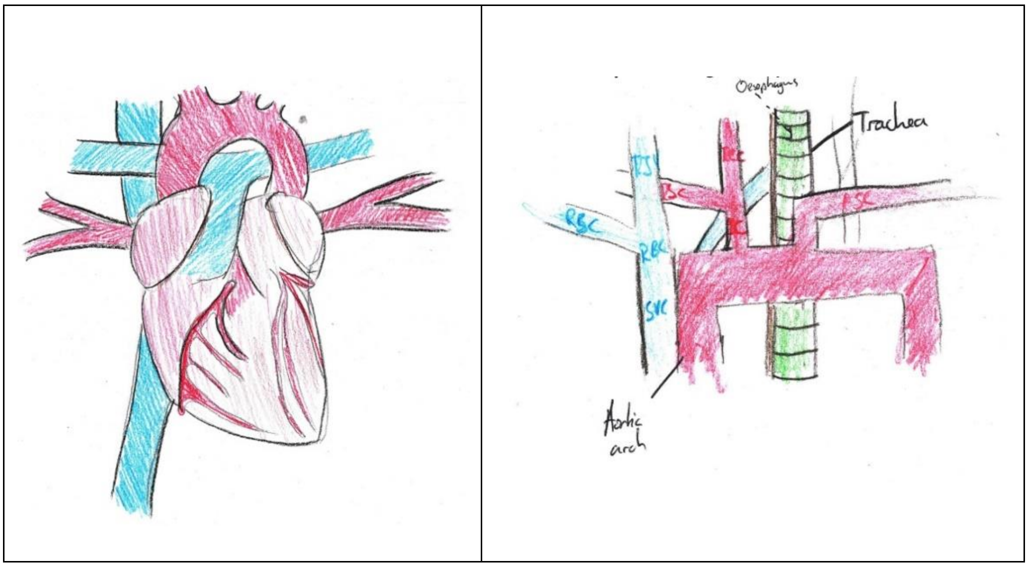


Figure 26: Example of drawings coded as “abstract representations, limited attempts to present things realistically"

- ***<u>Attempting to present features with 3D characteristics (score: 3)</u>***: Attempts to represent features realistically on the drawing. The drawing has revealed the spatial relations of the features and three-dimensional characteristics have been given (see Figure 27).

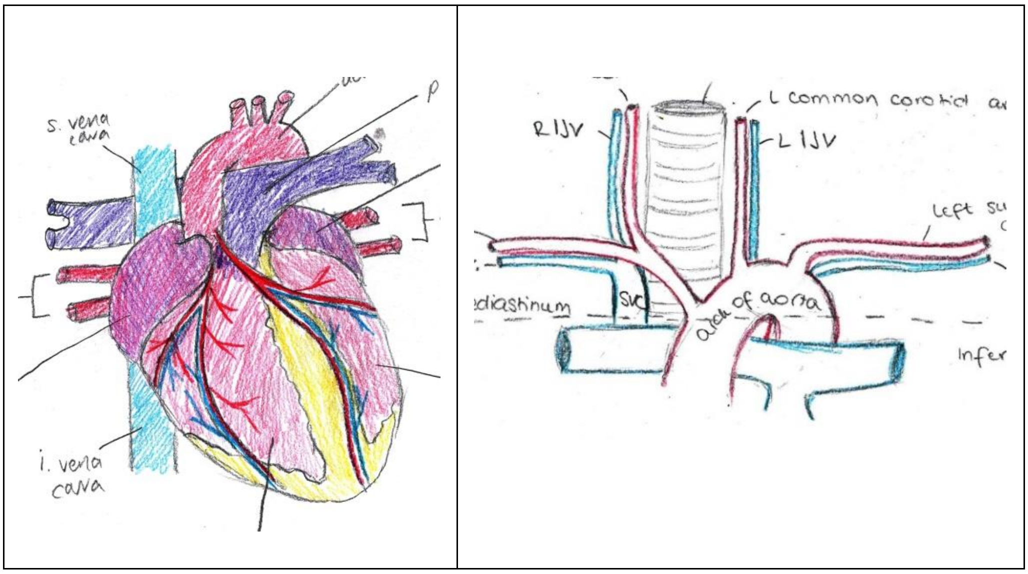


Figure 27: Example of drawings coded as "attempting to present features with 3D characteristics"

4.5.2.3. Reliability of the Drawing Scheme

The first author coded all drawings and 10% were checked for inter-rater reliability. An anatomical expert scored the informational features (number of anatomical features, location and shape accuracy, labelling) and the use of colour. The representational choices of the clarity and dimensionality were checked for inter-rater reliability by a postgraduate researcher in Social Sciences. Both were blind to condition.

For the inter-rater reliability analysis, to examine if agreement between the raters was established, the Kappa statistic was used for the informational content codes of the rubric (number of anatomical features, accuracy of shape and location, correct labels) and for the use of colour code as well. For the other two codes for the representational choices, the clarity and dimensionality codes, the Spearman’s rho was used as the appropriate statistical test to determine inter-rather reliability agreement as the data are rank.

Information codes achieved the following inter-rater agreements. For the number of anatomical features that the students included in their drawings, the agreement between the raters was Kappa= 0.851, $p<0.001$; for the features' accuracy of shape the Kappa was 0.746, $p<0.001$; for the accuracy of its location, Kappa= 0.714, $p<0.001$ and lastly, the established agreement for the appropriate labels was Kappa= 0.812, $p<0.001$.

Representation coding achieved the following agreement. The use of colour had an agreement of Kappa= 0.714, ($p<0.001$). For the clarity code, the Spearman's correlation was $r_s=0.673$, $n=25$, $p<.001$ and finally the raters' scores for the dimensionality code of the drawings was very strongly correlated, $r_s= 0.852$, $n=25$, $p<001$.

In summary, reliability analysis results showed that the consistency between the raters has been established for all the applied codes in the scheme. Because of the variety of research methods used in this thesis, further issues concerning validity and generalizability will be discussed in the relevant chapters.

4.6. Ethics

This thesis followed the ethical procedure that complies with Code of Research Conduct and Research Ethics of the University of Nottingham which is informed by the principles of the British Educational Research Association's Revised Ethical Guidelines for Educational Research (2011). The Research Ethics Approval Procedure for Postgraduate Research Students was followed for obtaining permission to conduct the data collection of this research.

For all the parts of data collection, ethical approval was obtained by the Ethics Committee of the School of Education in advance. Then for all studies, participants gave informed consent for their data to be collected and analysed by the researcher of the studies. Students and anatomy demonstrators were reassured that their data is anonymous, information that may be published will not reveal their identity, personal results will remain confidential and would not influence their performance in those modules involved in the research studies. They were informed that they could withdraw from the study at any point and without any consequence. They agreed that they understood that their data will be held according to the Data Protection Act. Their right to approach the researchers if more information is needed or to express any complaint to the Research Ethics Coordinator of the School was made clear (contact details of all included on both the Information Sheet and the Consent Form).

In Study 1, anatomy demonstrators agreed to be observed relating their use of visual representations in the introductions of the Year 1 DR sessions and to be interviewed for the aims of this research study. In Studies 2 and 3, the students agreed for their drawings to be digitalised and analysed. Lastly, in Study 4 anatomy demonstrators teaching the introduction of the Year 1 DR sessions gave consent to be interviewed regarding their approach of assessing students' drawings from Study 2.

As a large part of the data collection was conducted in the real-world setting of the DR, a significant effort was made by the researchers to not distract the students or the anatomy demonstrators from their usual activities or make them feel uncomfortable at any point when the research team was present in the DR for any activities related to this research. Furthermore, as the DR of the Medical School had its own ethical code of conduct, every effort was made to respect and follow the regulations of the DR and maintain good practice.

4.7. Conclusion

This chapter firstly described the dimensions of the real-world research approach and the pragmatic epistemology employed in this thesis. Secondly, the methods of data collection used and the approach of the multi-strategy design were presented, along with the methods of data analysis. In addition, the themes, codes and sub-codes of the thematic analyses for Study 1 and Study 4, and the coding scheme that was used in the analysis of learner-generated drawings in Study 2 and Study 3, as well as the process of its development, were described in detail. Lastly, the ethical considerations with regard to the data collection process for each of the four studies were described in the last part of this chapter.

5. Study 1

5.1. Introduction

The first exploratory study aimed to answer RQ1: "How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?" Due to the various approaches to using visual representations observed in the demonstrators' introductions of the dissection sessions in Year 1, it was considered valuable to explore the way in which anatomy demonstrators use visual representations when they introduce these sessions. Semi-structured observations were conducted during the short introductions prior to the dissection activities of the Year 1 medical students. To complement this data, after the end of the semester, semi-structured interviews were conducted with the anatomy demonstrators to further explore the way in which they approach these introductions, their use of visual representations and drawings in particular when they talk in these sessions, and their beliefs about learning and assessment with visual representations and drawing. This chapter describes the design of the study, provides an account of the findings and summarises the main point. In line with all the empirical studies in this thesis, a discussion of the findings, their implications and links to the wider literature is reserved for the single integrative discussion chapter, Chapter 9.

- RQ1, Sub-question 1: "How do anatomy demonstrators use visual representations and drawings to introduce dissection sessions in anatomy?"

This sub-question aimed to explore the different ways in which demonstrators use visual representations and drawings when they give short, 30-minute introductions in weekly dissection sessions for Year 1 medical students.

- RQ1, Sub-question 2: "What are their beliefs about using visual representations and drawing in teaching, learning and assessment in anatomy?"

The second sub-question set out to explore the anatomy demonstrators' beliefs about visual representations and drawing in particular in the teaching, learning and assessment of anatomical knowledge through discussions around demonstrators' own use of these in teaching and their views concerning the advantages and disadvantages of using them in learning and assessment within this context.

5.2. Methods

5.2.1. Design

Semi-structured observations were conducted with anatomy demonstrators in the Dissection Room (DR) sessions of the Year 1 medical curriculum at the University of Nottingham. An observation schedule was developed for this purpose (see Appendix 1). After the end of the semester that those observations were conducted in the DR, semi-structured interviews (see Appendix 2) were conducted with anatomy demonstrators as well. All observations and interviews were audio-recorded and conducted in the Medical School of the University of Nottingham.

5.2.2. Participants

Seven anatomy demonstrators who give the introductions to the Year 1, Semester 2 dissection sessions curriculum participated in this study. All participants that were approached agreed to be observed and interviewed. Two out of seven were female and the majority of them (4/7) were academic staff in the School of Life Sciences. Demonstrators' anonymity was protected as their real names were replaced with pseudonyms.

5.2.3. Observations

According to Newby (2010), direct observation of the participants' actions, behaviours and attitudes is an alternative to asking them about something. An observation schedule was developed to be used in the context of the 30-minute introductions to the weekly dissection sessions of the second semester in Year 1. This schedule aimed to capture the demonstrators' use of visual representations by collecting information about their representational activities' duration, the constructive or interpretative nature of the activity, and the type of representation they used (e.g. photograph, drawing, physical models); it also left some freedom for the observer to comment on the observed activities. Photos were taken as well of the observed visual representations that the demonstrators used in their introductions. The observation schedule (see Appendix 1) was piloted in these targeted sessions. The number of sessions observed differs for each participant (ranging from one to four sessions) and was dependent on the researcher's convenience and the rota of the DR sessions.

5.2.4. Interviews

In addition to the observational data, semi-structured interviews were conducted with the anatomy demonstrators concerning the way that they used visual representations and drawings to introduce the dissection sessions of the 2nd Semester in Year 1 and their beliefs about them in teaching, learning and assessment of anatomical knowledge. The interview questions (see Appendix 2) covered 3 areas of interest: a) general questions about teaching approaches to the introduction of the Year 1 DR sessions; b) questions about their use of visual representations in their own teaching; c) questions about their beliefs in using visual representations and drawing in learning and assessment in general.

5.2.5. Thematic Analysis

The principles provided in Braun and Clarke (2006) and which are described in the Methodology (Chapter 4) were used to analyse both the observational and the interview data. The themes, codes and sub-codes are presented in Table 2 (observational data) and Table 3 (interviews) in 4.5.1.1. In some cases, aspects of the data were coded in more than one codes/sub-codes. NVivo 11 was used to code and visualize the data.

5.3. Findings

The results of the observations and the interview analysis are presented in this section and they are complemented by quotes from the participants' interview data. Those behaviours or views that were identified in more than one of the participants are summarised together.

5.3.1. External Representations in Teaching

All anatomy demonstrators discussed the teaching methods with external representations in the DR sessions, and this is the theme that is the most appropriate to answer the relevant research questions. Apart from the types of visual representations, this theme also included references to the representation of text. All anatomy demonstrators used, in their practice, at least one of the external representations in the form of drawings, 2D visuals, 3D visuals or text. A decision was made concerning the code of 3D visuals to also include the coding of real bones or skeletons, as they are considered materials that are not prepared for limited use and could be used interchangeably with physical models. In the interviews, demonstrators also discussed the use of these four types of external representations in teaching. In each sub-code, the results of the observations are first reported and then the results of the interviews.

5.3.1.1. Drawings

Observations

The results from the observations make evident that drawings were used by the majority of the anatomy demonstrators, as five out of seven (Simon, Luke, Dexter, Monica and Robert) used drawings in their practice (Table 8) although as can be seen they varied considerably in how frequently they used them.

Table 8. Number of the DR sessions that the demonstrators were observed and times that they used drawings across the sessions.

Demonstrator	Number of sessions observed	Frequency of drawing use
Simon	3	9
Monica	3	1
Dexter	2	5
Robert	2	13
Luke	4	11

Of those five demonstrators, Simon and Monica constructed their drawings during the sessions. Simon constructed seven drawings (e.g. Figure 28) whereas Monica constructed only 1 drawing.

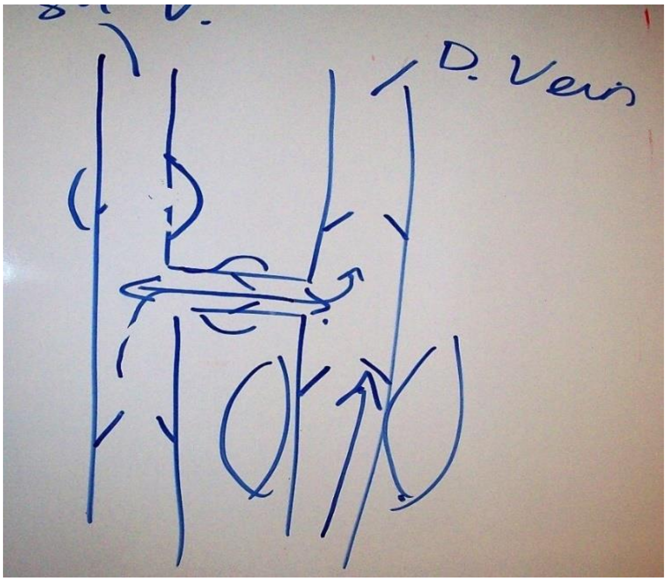


Figure 28. Drawing that was constructed and interpreted by Simon in a session about the Thigh Anterior and Medial Aspects.

On the other hand, both Dexter and Robert created their drawings before the dissection sessions. Dexter made three drawings and Robert constructed nine drawings (e.g. Figure 29 & Figure 30).

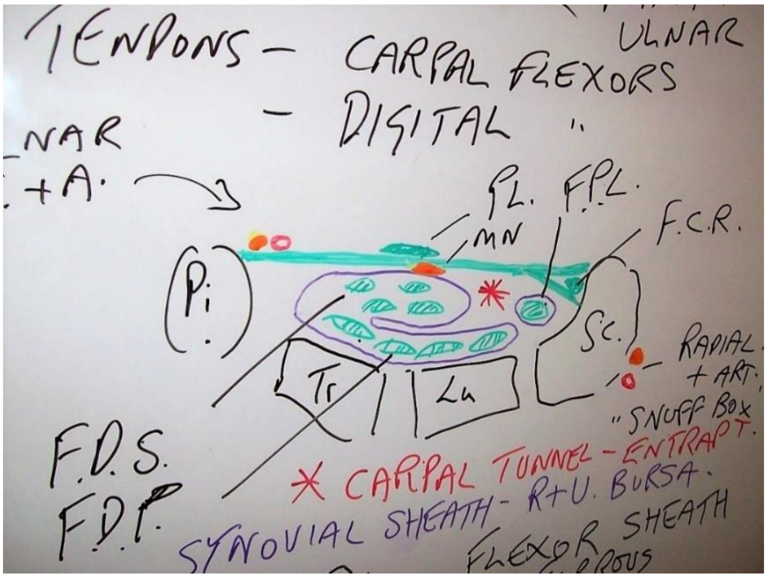


Figure 29. Drawing that was constructed before and interpreted by Robert in a session about the Anterior of Wrist and Hand.

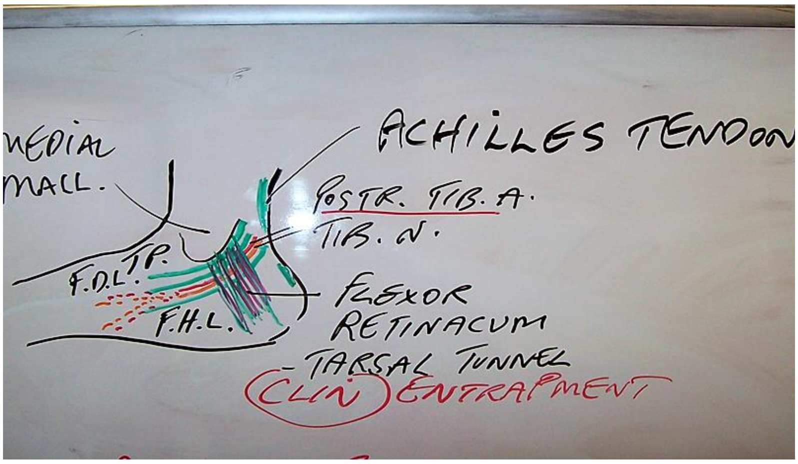


Figure 30. Drawing that was constructed before and interpreted by Robert in a session about the Leg, Popliteal Fossa, Ankle and Foot.

Interestingly, one of these five demonstrators that used drawings, Luke, did not construct any drawings but used quite a lot the drawings that were constructed by another demonstrator in the sessions of the previous days. He used seven drawings from the sessions of the previous days that were constructed by another demonstrator, Robert (e.g. Figure 31). An issue that might occur from this behaviour that was observed relates to the potential of this re-use, as those drawings were created by another person to be communicated to another group. Also, if Luke did not have access to Robert's drawings to reuse, he might have used no drawings in his introduction, as he stated in the interviews that generally he does not draw.

Finally, it is worth mentioning that Robert used at least once a 3D visual with a drawing (multi-representational use).

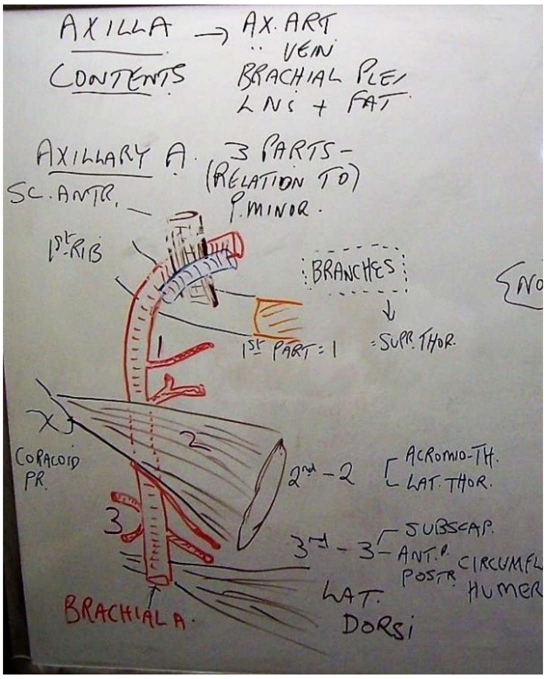


Figure 31. Drawing that was used by Luke in a session about the Root of the Neck, Axilla and Shoulder but was constructed by Robert for the previous day's session.

Interviews

All anatomy demonstrators discussed drawing as a teaching method. However, only three out of seven demonstrators (Simon, Dexter and Robert) reported that they generally create their own drawings for the introductions to the dissection sessions. The other two demonstrators who were observed as using drawings (Luke reused others' drawings and Monica created one) reported that they generally do not draw. Of the demonstrators, four (Luke, Max, Emily and Monica) reported that they generally do not create drawings in their introductions. Although Monica does not generally draw, she reported that she uses other forms of visual communication.

> So I'm not great at drawing but I do a lot of visual stuff, but far more on the models that we have, 3D or the prosections.

Data extracts have been coded in four sub-codes for the code of ***Drawings*** in the theme of ***External Representations in Teaching***: 1) ***Time construction***, 2) ***Type***, 3) ***Usefulness***, and 4) ***Disadvantages***.

Time of Construction

Anatomy demonstrators who generally draw discussed the time when they prefer to create their drawings, either before or during the introductions to dissection. Interestingly, from those three demonstrators who draw, only one (Simon) creates his drawings during the introduction and justified why he does so.

> I do it during the sessions because I think the process of watching somebody do it helps to learn and it also forces you to give time to the students to reproduce it. If I have produced all the diagrams before, let's say spent half an hour producing diagrams, they are not going to have time during my talk to copy those diagrams; they don't have half an hour just to draw off the board. So for me to draw them, limits what I can do but makes sure that there's time for them to copy it.

He also compared the advantage of drawing in the classroom to projecting an illustrated diagram:

> I like to create them myself. Partly because I quite enjoy drawing, but also I think the process of actually doing it is part of the teaching process. If you just flash up a fancy diagram on a PowerPoint it looks very nice, often too complicated for students to copy down, they don't have time to copy it because you are flashing onto the next one. But if I physically draw it, then I know they have got the time to draw it as well and I know that it is possible to draw it relatively simply. If I can do it standing up they can do it in their workbooks, so that's a way of doing it.

The other two anatomy demonstrators who generally draw (Dexter and Robert) prefer to create their drawings prior to the DR sessions:

> Dexter: But I think you have seen that also that I always prefer to draw and I draw it before they come, I don't want to lose that half an hour time by drawing at that time. So, I want to draw it beforehand.
>
> Robert: No I need time before. I usually come in the day before because it takes time, there is simply not enough time in these brief introductory talks at the beginning of each dissection session. There would be nothing like enough time to do the drawing. I would spend the whole time doing the drawing. So I come in beforehand and put the basic things on the board.

Thus, although for one demonstrator creating a drawing in front of the students is considered key for the potential that it is targeted to be achieved, for two others it is to be avoided due to the time constraints in those brief introductions. It is worth mentioning here that out of the total number of demonstrators, two (Luke and Dexter) suggested that they could use existing drawings in the tasking room, although it is worth reminding that Dexter created also his own drawings, as reported above.

> Luke: I mean, I must say, as I said, I almost never actually draw diagrams from the outset. I will take advantage of a drawing, if it's already there. But just don't think it's worth the time and the effort to actually do the drawing. But if someone has done the illustration, the diagram, yesterday, I think it's quite good to go through it again with the students as it's there. There are all the facts, but the ones that I'm underling in red are the really important.

Type

The type of the drawings that anatomy demonstrator prefer was also discussed in the interviews. All these three demonstrators who generally draw stressed that the drawings which they construct should be simple:

> Simon: I think it's very important that the drawings are relatively simple, we are not trying to produce three-dimensional artistic works here, we are trying to use a visual aid for learning. And students aren't going to be able to reproduce very complicated visual information, what they are wanting is a cut down simplified version that they are going to be able to take away and use for learning.

> Robert: I produce them myself, very simple diagrams. Simple diagrams are the important thing and what we haven't got time to do is real artistic efforts, there isn't the time to do it anyway, even if you have got the ability and many haven't. So mine are very basic line drawings, which I think get over the basic points.

Specifically, Dexter described his drawings as schematic:

> Apart from that, because we have our half an hour time to talk about that dissection, so apart from that I use, to some extent, drawing, schematic diagram of this topic.

And also, he expressed the view that even the simplest one could be of help in anatomy:

> I don't think there are because as I said, it is a visual subject and so even the simplest diagram should, and it's the way it is drawn, but even the simplest diagram should help.

Max said also that strong drawing skills are not needed to make a general principle with a drawing and although he does not generally draw during the introductions, he said that a whiteboard in the main DR would be helpful for simple drawings:

> I'm not a good artist, so my diagrams are very perfunctory. But you don't, you know, if you just try to make a general principle, you don't need to have a fantastic diagram.
>
> The other thing that I like is to have a… one thing I find difficult and would prefer it if we had a whiteboard outside, because I like to draw quick diagrams. I don't mean great artistic… just quick sketches on the board to say, well look, this is what we see in the body, this is the skeleton, this is what we feel. Now let's go and have a little look on the board just to demonstrate some features. So it's that. Having a whiteboard available, which I wish we'd got one in there, because in the old days you used to have a blackboard and you could draw on it.

Consequently, it is the "simple" or "schematic" form of drawings that the anatomy demonstrators prefer to use when they introduce dissection sessions. As their comments suggest, it is the simple drawings that the students are able to comprehend, and these drawings also do not require strong drawing skills.

Usefulness

In this sub-code, the demonstrators' comments on the usefulness of drawings were included. Firstly, the anatomy demonstrators commented on the students' engagement with their drawings. All three who draw (Simon, Dexter and Robert) reported that the students tend to engage with their drawings, as the students draw or take notes based on them:

> Dexter: And I've seen them, that they also love to draw from my diagram, because most of the time it is not a beautiful one but a schematic diagram and it is quite useful one. So, they love this drawing as well. So…

> Simon: And students tend to copy those drawings down; you see them reproduced in exams and so forth later on. So hopefully they're of some use to understanding what is going on.

Thus, the action of the students seems to acknowledge the usefulness of those drawings which anatomy demonstrators employ in the sessions. In addition, it is interesting that the students reproduce the constructions that they got engaged during those brief introductions.

Other aspects of the usefulness of drawings during their introductions to the dissection sessions were discussed by Robert and Simon. Robert expressed the opinion that the purpose of the drawings is to help them understand anatomy prior to dissection:

> The intention is that it will help them to understand the anatomy, before they go into the dissecting room.

He also said that he uses drawings when he talks for structural aspects:

> I use… I simply use drawings in particular to try and summarise the basic features, rather than writing down a great list of structures, because anatomy is both…well two aspects of anatomy; one is a visual element, a structural element and the other element is function; functionality is terribly important. So I use a drawing, basically to summarise the basic features of a particular part or region. It is the easiest way, it is a visual way and as I have just said, a lot of anatomy is visual.

Luke also expressed the position that using a drawing in the introduction could be useful for ensuring that students will see what they want them to see:

> Well, in a way I think it can. Because I keep assuming, I keep telling them, there is no point in me drawing, making a detailed drawing of this because it's on page fifteen of your textbook. But of course, I know that a large proportion of them will never study page fifteen on their textbook. Therefore, if I've got them here as a group you could make a case for saying "that's why I do it", because at least I know that they've seen it, they physically have been shown where that nerve runs. Whereas, if I simply say to them "there's a beautiful diagram in your textbook", I've no control over whether they will eventually. That's the defect in my way I approach it. I assume that they will actually, they will fill the gaps themselves. Whereas, I suspect if you spend time drawing something on the board, then at least they've been forced to take that in. That's what I think.

These points above show that drawings are seen as particularly useful when teaching structural aspects of anatomy before the students go to perform dissection activities themselves. Moreover, a drawing construction during the sessions could work as a reassurance for the demonstrator that the students have access to the key points, something that the simple act of directing them to look at textbook illustrations cannot do.

In addition to the above arguments regarding the usefulness of drawings, the usefulness of a multi-representational use was also reported. This aspect was discussed by Simon, who commented on the multi-representational use of a drawing and a model in order to help students understand three-dimensional aspects. He illustrated this with an example about the shape of the pelvis.

> You can say here is the shape, its V shaped at this point, these are the points that it attaches and so on, so a model is very useful. If you can take then the model and then use a diagram, perhaps of different positions, work what the shape is and you can relate the diagram to the model.

Therefore, although only one demonstrator emphasised this in the interviews, the multi-representational use of drawings with other types of visual representations is also considered in those brief introductions.

Disadvantages

This sub-code included the demonstrators' comments on the disadvantages of drawings in teaching. Before the actual disadvantages of this type of representation, the reasons that demonstrators provided for not drawing are discussed. Firstly, Max and Monica mentioned their lack of drawing skills, as illustrated by Max's comment:

> Because I have no artistic talent myself, okay, if possible I like to use prepared material.

In addition to that, Max and Emily stated that are not creating drawings as that is not part of the purpose of those introductions.

> Max: No, I know that some people … I know that Robert does. He does a lot of diagrams. The reason I don't do that is because it doesn't…, and I think you may find that Luke has a much similar view. That's alright if the idea is that you're teaching them from scratch.

> Emily: I very rarely use diagrams or drawings. […] It would be an exception if I did that. I don't use PowerPoint at all because I don't think that's what those introductions should be about. I think they should be brief and to the point, pointing out things that they might have a problem with when they are dissecting, highlighting important facts and highlighting important clinical facts, so they have a motive for learning if they know it's clinically important. But I don't think that introductions should be like a lecture because that's not its purpose.

Lastly, an issue identified by two demonstrators who draw (Dexter and Robert) and one who generally uses existing drawings (Luke) was the limited time that is available for these introductions to the DR sessions, as illustrated in Luke's comment:

> Well, there's definitely. The time, there's the time factor. I don't think that any, where they already have such a compressed course, I think to spend ten minutes of the twenty minutes that I've got with them here on

> drawing something is not a cost-effective way of using my time nor of their time.

Timewise, Luke expressed the view that the aspect of lecturers draw in anatomy is not efficient when good quality illustrations are available:

> So, that's why, I mean I literally almost never physically draw on the whiteboard now. […] But I'm afraid this, as I am concerned, this skill of actually physically drawing on a board is, has gone. We used to have lecturers who could draw with both hands. Who could draw a three-month embryo there and then a six months old embryo there. […] No, it was very impressive, but it's a very inefficient, it's not an efficient way to use the time of a very experienced, competent person. Why ask him to spend half an hour doing this beautiful illustration just to look impressive, when you can actually project it and look at a textbook and say there is this, there…

To sum up the stated reasons for not drawing, it was suggested by the demonstrators that their drawing skills, the time constraints of those brief introductions and their beliefs about the pedagogical purpose of those introductions were why some demonstrators prefer not to draw. It is also evident that the availability of other visual resources makes drawings not as irreplaceable for them.

Regarding the disadvantages of drawings as a type of visual representation, Monica compared a drawing with other teaching methods:

> And I think what the drawing misses out on is looking at relationships of layers on top of each other. So in a textbook, they might reflect something back and say this has been lifted, or they'll show a muscle reflected back and then show what's supposed to be linked to it. But obviously it's much better seeing that in the real prosection itself.

This comment refers not only to the disadvantage of the 2D nature of drawings, but also to the more abstract constructions that could be represented on a pen and paper drawing by someone who does not have the skills to depict such a drawing with the characteristics that Monica described.

5.3.1.2. 2D Visuals

Observations

Observations revealed a quite limited use of 2D visuals in other forms than drawings, as illustrated in Table 9. It is worth remembering here that the term ***2D Visuals*** in this thesis refers to any type of visual representation which is depicted in 2D (e.g. illustrated diagrams, photographs), but not to drawings.

Table 9. Number of the DR sessions that the demonstrators were observed and times that they used 2D visuals.

Demonstrator	Number of sessions observed	Frequency of 2D visual use
Simon	3	1
Luke	4	2

Simon used 2D visuals in the form of illustrated diagrams on a piece of paper and Luke used 2D visuals in the forms of an illustrated diagram on a piece of paper (e.g. Figure 32) and an x-ray.

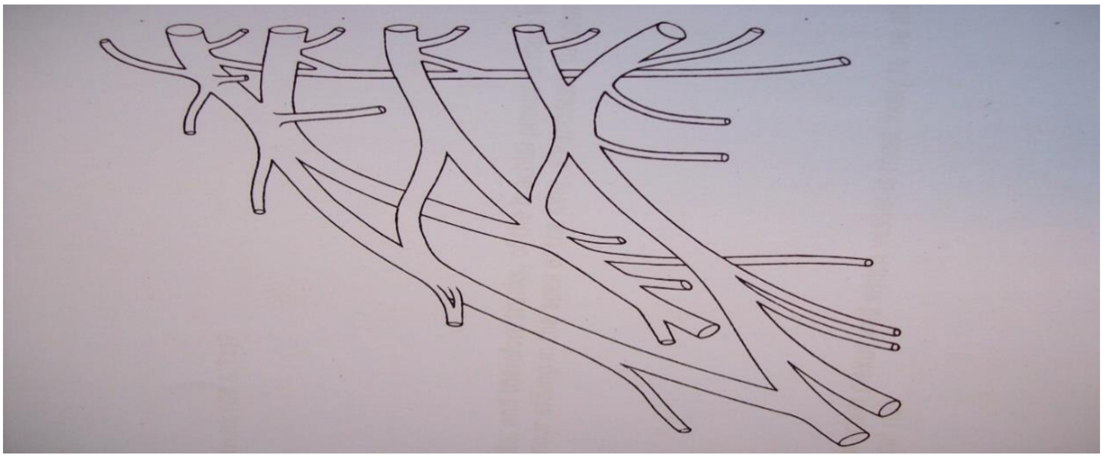


Figure 32. Diagram from the students' workbook that was used by Luke in a session about the Root of the Neck, Axilla and Shoulder.

Interviews

Five out of seven anatomy demonstrators (Simon, Luke, Max, Emily and Dexter) referred to 2D visuals in teaching anatomy. The types of 2D visuals that were identified more or less in the interviews were images, illustrated diagrams and x-rays. The sub-codes of 1) ***Usefulness*** and 2) ***Disadvantages*** were included in this code concerning 2D Visuals of the theme of ***External Representations in Teaching***.

Usefulness

Some of the demonstrators' comments about 2D visuals in teaching referred to aspects around their usefulness. To start with images, Luke and Emily referred to them in the methods that they could use in the introductions:

> Emily: So I expect them to try and think of the answer for themselves if it's possible. If not, I will point things out to them, probably on a, you know like on real bone or on the prosection or on the image. Rather than just give them a straight sort of verbal answer at that stage, once the class is underway I would use the materials around me really.

> Luke: What I prefer is to start off with reality. In other words, a clinical photograph or a clinical story. This is what, and then related to what they are doing in the dissection today.

The second type of 2D visual that was coded under this theme was the illustrated diagram. Dexter made a positive comment on illustrated diagrams as a type of visual representations. He considers them important parts of teaching and learning in anatomy as well as drawings:

> It is in my opinion. I don't, someone may differ about this, but diagrams and drawings at least.

Lastly, the third type of 2D visual that was coded in an interview was x-rays. Luke seemed to be very passionate concerning the use of X-rays in his introductions and explained the reasons why:

> And also, because I'm a trained clinician, a trained surgeon, I also use x-rays you see, I use x-rays in great deal to illustrate... I would now rather show them an x-ray of the scalp to point out certain important features. I would say this is better even, in some circumstances than the actual scalp itself. Because it's relevant for the…, that's how they are going to see a scalp when they become doctors. You know that, they are going to see a fracture of the vault of the scalp. Now you can show them on the scalp and say that's where it is. But unless you become a neurosurgeon, you'll never actually going to see the fracture, but you are going to see the fracture on the scalp x-ray.

Therefore, the 2D visuals in teaching that were identified in the interviews were useful to the teachers in terms of pointing out things for explaining to the students, to initiate the introduction by showing the real thing. It's worth highlighting also that a demonstrator used a 2D visual (x-ray) that is particularly useful in the medical students' future practice.

Disadvantages

In addition, demonstrators also discussed the disadvantages of the 2D visuals. Before the actual disadvantages of this type of representation itself, the reasons that demonstrators provided for not using 2D Visuals are presented. As with drawings, Emily is not using illustrated diagrams often:

> I very rarely use diagrams or drawings. […] It would be an exception if I did that. I don't use PowerPoint at all because I don't think that's what those introductions should be about. I think they should be brief and to the point, pointing out things that they might have a problem with when they are dissecting, highlighting important facts and highlighting important clinical facts, so they have a motive for learning if they know

> its clinically important. But I don't think that introductions should be like a lecture because that's not its purpose.

She does not consider 2D visuals (and drawings as well) in her brief introductions, as she thinks that they do not really fit well with the pedagogical purpose of these sessions.

Luke made a comment that implied the challenges of finding very informative illustrations nowadays. He also puts emphasis on directing the students to identify the clinically important aspects that they will need on those "busy" illustrations. In discussing textbook illustrations, Luke's comment reflects the need for the students to be directed in reading them:

> I think it's important to emphasize the clinically important parts of it. And that's sometimes the problem. The illustrations in the textbooks for instance. They are so good they contain all the information. I think our point is to say yes they're lots, lots, but the four really important parts, points for you today are that. I think that's. In the past, we didn't have illustrations of that quality. We just had to read it from the text on the printed thing of it. That's what I think. And that's why I think that very often the best mixture of illustrative material is to have a true photo of it. That's what it actually looks like. And it is very complicated. Anatomy and surgery are very complicated. But there is a little schematic drawing, a little line drawing, showing you which are the really important points about that photograph of that. And in fact, I've never mastered it, but I think now you can do that electronically, digitally, where you could actually project the cadaver on a clinical photograph on the screen. And then you'd have the ability to draw round it and highlight the important points of it. But I've never been sufficiently keen or skilled in IT work or computer work to deal with that.

It should be noted here that this demonstrator talked positively about a possible projection of a real image and live-annotation on that, although the lack of technical skills makes him consider such an approach too difficult for him.

Another drawback of a type of illustrated diagrams came from Max, who commented on the effectiveness of the anatomy charts:

> Okay. Again, these little charts are okay, but again you can only use them in a small group, sort of thing. My approach would be different, you know.

Simon also referred to illustrations by describing a drawback of projecting one in the introduction:

> If you just flash up a fancy diagram on a PowerPoint it looks very nice, often too complicated for students to copy down, they don't have time to copy it because you are flashing onto the next one. But if I physically draw it, then I know they have got the time to draw it as well and I know that it is possible to draw it relatively simply. If I can do it standing up they can do it in their work books, so that's a way of doing it.

The reported disadvantages of the 2D visuals in the form of illustrated diagrams focus on the number of students participating in a session and also on the speed involved in projecting one, as compared to drawing in front of the students so as to give them time to engage with the visual.

5.3.1.3. 3D Visuals

Observations

3D visuals were used quite a lot by all the demonstrators, as they all used 3D visuals in the form of physical models, bones or skeletons (Table 10).

Table 10. Number of the DR sessions that the demonstrators were observed and times that they used 3D visuals.

Demonstrator	Number of sessions observed	Frequency of 3D visual use
Simon	3	7
Luke	4	7
Max	1	6
Dexter	2	6
Emily	1	1
Monica	3	5
Robert	2	10

In terms of multi-representational usage, Luke, Max and Monica were observed at least once to attach and interpret together two 3D visuals. Also, Robert was observed at least once in interpreting a 3D visual together with drawings or text.

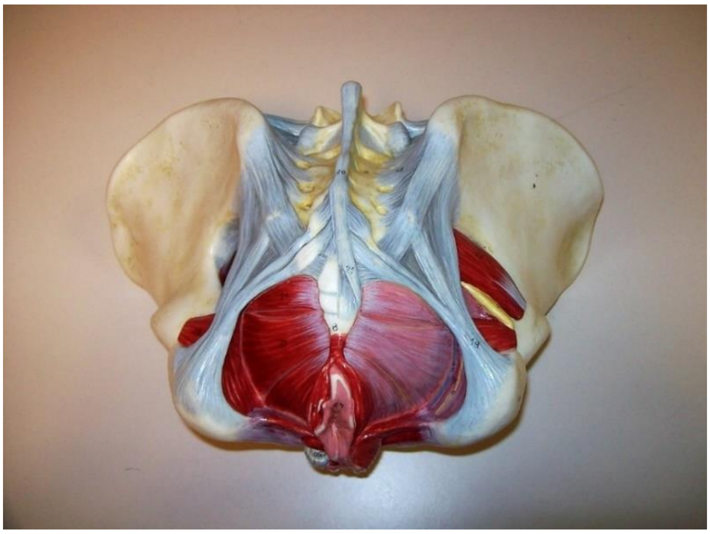


Figure 33. Physical model that was interpreted by Simon in a session about the Gluteal Region & Posterior Thigh.

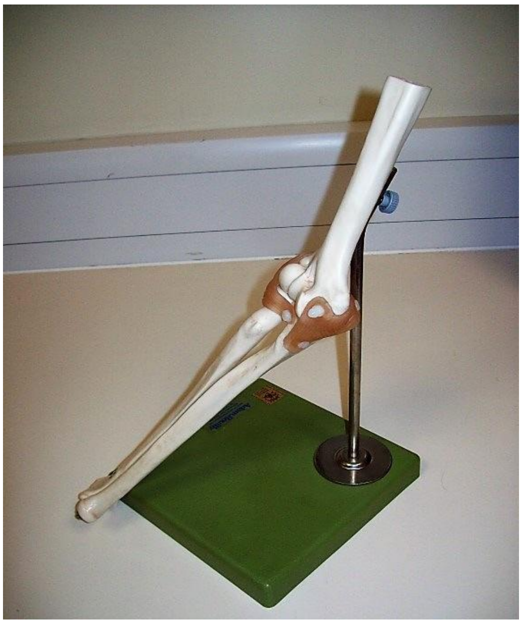


Figure 34. Physical model that was used by Monica in a session about the Flexor Compartments of Arm and Forearm & Cubital Fossa.

Interviews

All the demonstrators mentioned 3D visuals in their interviews as well discussing both their usefulness and disadvantages.

Usefulness

Demonstrators provided quite a few comments on the usefulness of the 3D visuals in teaching. Six out of seven anatomy demonstrators (Simon, Luke, Max, Dexter, Emily, Monica) referred to 3D visuals in their methods that they use and highlighted the reasons for considering them useful:

> Simon: But using actual material, bones, models to point at things to actually show them, to rotate them and show them three dimensional and then also to actually draw on the board.
>
> Emily: So I might have the skeleton, I might have a model or something to point at [..].

Monica: I think what we also try and get them to do is, by saying it, you can learn it, and by pointing it out. I think visual learning is essential with anatomy. So I'm not a big believer in just getting a textbook out, and look at a textbook. You can do that at home. If that's the way you want to learn anatomy, why come to a dissection room? So I try and get them to look at a bone, because a picture of a bone drawn in a textbook is very different to a bone in your hand. And if you have a bone in a text book, you know the left and the right, you know the surface. Whereas if I give you a bone and say, right, which is the anterior surface, which is the inferior surface, is it a left bone or is it a right bone? Is it from your left arm is it from your right arm? And they can look at it and find it very difficult. Because unless you know the different grooves and the different nodules, and you know what to look for, it's quite confusing.

Monica: So nine times out of ten I would choose to use a bone, the full skeleton, plastic models, things like that.

Three out of seven demonstrators (Max, Emily and Monica) talked particularly about the usefulness of a skeleton:

Max: When it comes to actually dissecting, I am a great believer in the fact that you must always have, if at all possible, a skeleton by the side of you while you're dissecting. Because it is not just what you see, it's what you palpate, okay. And you can only palpate in any meaningful way if you've got the skeleton there to show exactly what you're palpating. That's what I feel.

Emily: So I might have the skeleton, I might have a model or something to point at, but I am asking them the questions for them to feed me the answers and I'll point out important clinical things, if they don't seem to come up with them for themselves, but it's very much their responsibility from my point of view.

> Monica: And by using the skeleton I can demonstrate the difference between flexion and extension, and supination and pronation. Now you try and explain that. […] In a way, using the skeleton, it says a thousand words.

Another comment from Max shows that he places the use of the skeleton in the core of his approach to those introductions:

> What are we trying to achieve? Getting them to get actively involved. Or even if you're doing it… I mean doing it for them, you've got to get them started. Having these things to supplement it (*VRs*), but they should be not the core of it. The core of it should be, having read it up beforehand, using your visual and your tactile sense, get a sense of involvement and having a skeleton. That's my… and having these things to supplement it.

Two out of seven demonstrators (Emily and Monica) talked particularly about their use of bones as well, and Monica referred to the advantages of using a real bone instead a picture of it:

> Monica: So I try and get them to look at a bone, because a picture of a bone drawn in a text book is very different to a bone in your hand. And if you have a bone in a text book, you know the left and the right, you know the surface. Whereas if I give you a bone and say, right, which is the anterior surface, which is the inferior surface, is it a left bone or is it a right bone? Is it from your left arm is it from your right arm? And they can look at it and find it very difficult. Because unless you know the different grooves and the different nodules, and you know what to look for, it's quite confusing.

All the above show that demonstrators value a lot the usefulness of 3D visuals, like plastic models, bones and the skeleton to show mainly three-dimensional aspects of the things that they examine in the sessions. They argue that the 3D visuals give to the students an alternative, more realistic and tactile view of those topics than the one that the students experienced through their textbooks.

Disadvantages

However, 2 demonstrators talked also about drawbacks on the use of models specifically when teaching in anatomy. Max expressed the view that the number of students could cause limitations on the use of models:

> Oh, and models. Models too. They're useful. But again, the same thing restricts models, is that, you know, if you're sitting at the back and you've got that model at the front... They're great for small groups, but if you're teaching to 20 odd people, 20, 30, I don't… maybe I don't know, maybe they pick up more than I think they do. But to me, I would find that not satisfactory. So it's not the models that's wrong, it's the way and opportunities we have to use them.

Robert expressed concerns about the quality of the models:

> I don't use models. There are models provided as you know, in each of the tasking rooms. Some of them are quite good and others not so good.

Therefore, this small number of disadvantages that were mentioned by the demonstrators regarding the use of 3D visuals refer to the limited number of students that could interact and inspect models, and also to quality issues of the available plastic models in particular.

5.3.1.4. Text

Observations

Text was used by a very limited number of demonstrators. As illustrated in Table 11, only two out of seven demonstrators (Luke and Robert) were observed to use text in their introductions. Interestingly, the texts that one of these demonstrators (Luke) used have been created by another one (Robert) in the session of the previous day.

Table 11. Number of the DR sessions that the demonstrators were observed and times that they used text.

Demonstrator	Number of sessions observed	Frequency of text use
Luke	4	5
Robert	2	8

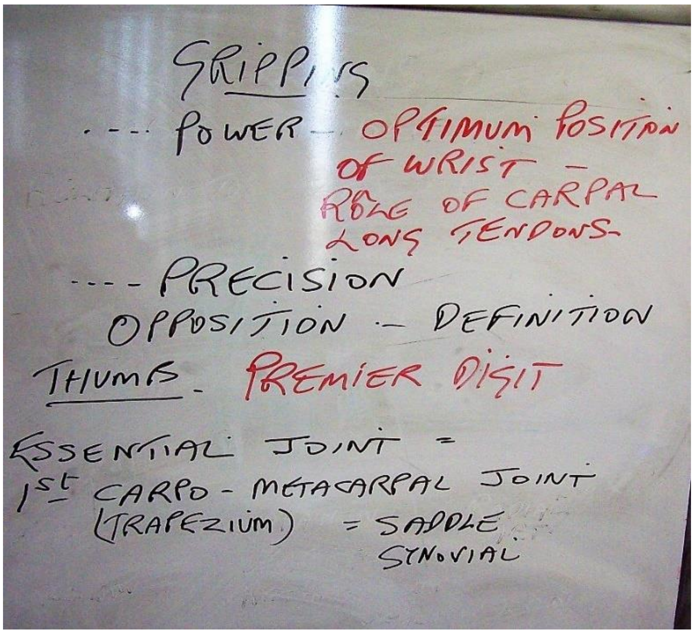


Figure 35. Text that was used by Luke in a session about the Anterior of Wrist and Hand.

Luke used text that was on the board from the previous days' sessions (e.g. Figure 35) and Robert used text that he had written on the board before the session. In terms of multi-representational usage, Robert was observed at least once to use text together with a 3D visual.

Interviews

Among the anatomy demonstrators, three out of seven referred to the written text (Monica, Emily and Robert). All the coded references reflect views on the use of text in those introductions. However, only the sub-code of the ***Disadvantages*** is reported, as there were no coded data extracts for the sub-code of ***Advantages***.

Disadvantages

Not useful for the sessions' learning objectives: Emily stated that she does not use text in her introductions and she gave a reason related to the way that she generally approaches them:

> Well, when I teach it I expect the students to come prepared, so I try and make it very interactive, so I tend to ask them for the answers not give them a lecture. So, I am one of the people who doesn't write anything on the board unless they have to.

Monica's comparison between text and drawings reflected her views concerning the contexts that are both effective or not:

> So, when you're trying to talk about the relationship of it, you've just got a paragraph of words versus a drawing, I'd rather have the drawing. The words can obviously be useful, when you're talking about function obviously. But if you're just trying to describe the position of something anatomically, a drawing is better than just text.

Interestingly, this small number of comments reveals that text is not considered useful by demonstrators for the particular learning objectives that those sessions aimed to achieve, such as an understanding of structural and spatial aspects.

5.3.2. External Representations in Learning

This theme included the coded references to the beliefs the demonstrators expressed concerning the use of external representations in learning. As in the previous theme, apart from visual representations, the external representations in this theme also include references to text. Among the demonstrators, six out of seven (Simon, Luke, Max, Dexter, Emily and Monica) discussed aspects of the external representations in learning anatomy. The same four types of external representations were identified as codes in this theme: ***drawings***, ***2D visuals***, ***3D visuals*** and ***text***.

5.3.2.1. Drawings

Six out of seven demonstrators (Simon, Luke, Max, Dexter, Emily and Monica) referred to drawing in learning and assessment in anatomy. However, most of the comments were focused in learning. Three sub-codes of this code are reported for this code about drawings. These sub-codes refer to the 1) ***Usefulness*** and 2) ***Disadvantages***.

Usefulness

Anatomy demonstrators commented on the usefulness of drawings in learning in anatomy. Firstly, two quite positive comments on drawing as an approach to learn were reported in the data by Simon and Dexter:

> Simon: I hope so, but I couldn't give you sort of objective data to prove that the drawings are really helping. Students seem to be interested in it, they copy the drawings, so it does seem to engage them. The whole process of actually drawing I think is part of a learning process, if you have drawn something you're more likely to memorise it, rather than just seeing something in a book or a picture.

> Dexter: I tell them one thing. That anatomy, you can learn anatomy all by "Ds", "D". Like drawing, dissection, discussion. […] So, when you are alone, you can just draw this topic and just, not a beautiful picture, something like a schematic diagram about this topic and what you have learned about this thing.

He reported also that he does not find any disadvantages in using drawing in teaching and learning:

> It is in my opinion. I don't, someone may differ about this, but diagrams and drawings at least. I find it so much easier way to learn still now. So, I don't think there is any disadvantages. Maybe someone can tell you differently but I don't think there are. It is my opinion, that there are always advantages for students.

In addition, demonstrators discussed potential uses of drawing to learn. For example, Emily believes that drawing can aid retention in such complex subject and support understanding:

> Emily: So if you just read something or just hear something it can sort of hit the brain and bounce back off again. Whereas, if you actually then do something with that information I think it aids retention. So in some cases if you are looking at a diagram, drawing your own diagram, makes you look at it more closely, makes you see the detail, makes you see the relationships […].
>
> Emily: And also making use of the information in some fashion certainly helps you understand it really and see what's important and what isn't, I think, yes.

Monica expressed the view that drawing supports understanding of positional relationships:

> Yes. I think a lot of the students do a lot of drawings. Not all of them, but some of them do. And I think it helps them understand the relationship of one structure to another structure.

Monica stated that drawing can help the students remember, but she stressed that this happens for the "visual learners":

> If they're good at drawing, it helps them remember, if they've drawn it out. As I said, not all of them do it, so I think it does depend. I mean, some people learn in different ways don't they, but of those that are visual learners, I think if they map it out, it will help them remember.

Consequently, from those comments that support the usefulness of drawings in learning, the interviews revealed that for demonstrators drawing to learn can aid retention and positional understanding. One demonstrator referred to "visual learners" as ones that could benefit most from drawings.

Disadvantages

Before the actual disadvantages of this type of representation are explored, one reason that a demonstrator believes that students might not use drawings is presented. Simon stated that a reason why some students might not choose to use drawing in learning might be their lack of drawing self-efficacy:

> I think a number of students, a proportion of the class, don't like drawing themselves, they will say to me I can't draw and I don't want to draw. And therefore, the whole idea of drawing is putting a block actually in the learning process, that they are switching off at that point, they think oh that's not for me, I'm not going to copy that diagram because I can't draw properly. So it may actually be counterproductive to some people.

Therefore, the students' drawing self-efficacy could become counterproductive in employing drawing to learn activities. Apart from this, demonstrators discussed other disadvantages related to the drawings themselves. Firstly, Emily expressed concerns on the lack of accuracy that the student may depict in their drawings:

> So I think it's important that they are factually correct even if they are not pretty. So, you know, they can very simple, they can just be little stick drawings or whatever, but they've got to be correct and you know a drawing is only as good as the information it can convey that is correct.

Max also stated that, from his personal experience, he was not convinced that drawing helps in learning (as employed in his case):

> We never had drawing sessions in anatomy, but we used to have histology sessions, where people would look through and draw. And I must say I was never convinced. There was a lot of just, you know, copy… it was just copying down without a lot of thought going into it. So I would not… So if you say to them, draw that as a way of… and

> you get these anatomy colouring books, don't you, you know. I don't use them I hasten to add, so maybe I'm being a bit harsh, but my experience of myself and my colleagues when I was a student doing the histology, was that I think that probably it was of little… it just ended up as a chatting session, you know. You were talking like this and at the same time you were just copying down, and it was… I didn't think much went in.

Although, he said that the context is important:

> Now you may be able to supplement that, you know. If you thought, that was because we were left freestyle to do it, you know. But if you say, right, at the end of that you'll be tested on it, okay, maybe we wouldn't have wasted our time so much. So it's a case of not what aids you have, but coming back to what I've been saying really all the way along, it's the context in which you're using them. And why you are using them in that particular context. Horses for courses.

Another drawback that Monica brought to the discussion is the dimensionality of the drawings:

> The only disadvantage I can think is it's 2D instead of 3D, but you've got no way of getting round that. I certainly think that for many, many, many students, at least some drawing is very helpful. And I think, when it comes to visual learning with regards looking at skeletons, it aids understanding massively if you've got a model, a 3D model, or a bone, a proper bone. I don't think anything could beat it. So if you've got a photograph of a bone versus a real bone, to me it's a no-brainer. Or a schematic of a bone, anything that's 2D versus the 3D, the 3D is, I think, far and away better. So in that respect I don't think drawings are the best. But I certainly think visually, looking at a proper bone, there's nothing that can beat that. And the same with prosections; visually looking at a prosection versus a 2D drawing. But then I think a 2D drawing is a lot more beneficial than a bunch of words.

Therefore, the depicted accuracy of the drawings, nature of the direction and the lack of the drawings' three-dimensionality were considered by the demonstrators as potential disadvantages in employing drawing as a learning method.

5.3.2.2. 2D Visuals

Four out of seven (Luke, Max, Dexter and Monica) mentioned 2D visuals in learning and assessment in anatomy. However, the demonstrators again put the emphasis in learning.

Usefulness

A limited number of data extracts referred to aspects related to the use of 2D visuals in learning. Two positive comments on the use of 2D visuals in the form of photos and diagrams were expressed.

Dexter stated that he considers to a great extend diagrams as well as drawings for learning in anatomy:

> It is in my opinion. I don't, someone may differ about this, but diagrams and drawings at least.

Also, Luke talked about the importance of a real photo:

> And that's why I think that very often the best mixture of illustrative material is to have a true photo of it. That's what it actually looks like.

From these two comments, it is worth highlighting here that the demonstrator's preference for a real photo the most appropriate 2D visual in this context.

Disadvantages

On the other hand, many disadvantages related to the use of 2D visuals in learning anatomy were expressed by the demonstrators. Firstly, some drawbacks of the use of illustrated diagrams were reported by two demonstrators. Simon and Luke expressed the view that illustrations could mislead:

> Luke: The other slight disadvantage is that it does make them think that some parts of anatomy are much easier than others. Because when they go into the dissecting room and they actually try to dissect something is actually much more difficult. And I can see students who obviously prefer book reading and who prefer looking at illustrations in the book, even though we go to the dissecting room, and actually let's try and find that nerve, a proportion of them will start looking for the nerve and say it's not quite as obvious as it looked on the diagram. […] That's the slight… the illustrations are so good now that they actually think "oh that's very easy, look at that. There will be no problem in finding that muscle and defying its attachment to there very easy". But hey forget you know there's other elements touching these relationships and is what structures feel like that's different of what it looks like on a superb illustration.

> Simon: Sometimes the diagrams, because they are just diagrams, can be misleading. They are not really showing the true structures and they are over simplified maybe or there are planes that you can't really see very easily. So students can learn the diagram but it doesn't relate to the real structure really, it's just a diagram that has labels on it and it doesn't closely enough translate to the actual material. So those would be the disadvantages, I think.

Related to that, Emily argued that students may struggle in transferring between what they have seen in 2D visuals to the actual 3D materials:

> I think probably, actually, finding their way round both the dissection and the pre-dissected parts, so that they are certain what things are. So I think probably the transfer of whatever picture they have seen in an atlas or a text book into the three dimensional, I think they find that difficult.

Emily's comment on the students' challenges with imaging methods that are used in medicine may reflect a problem that could relate also to other 2D visuals within the domain:

> And I also think they find some of the imaging difficult, particularly things like MRI and CT scans where you have got to orientate yourself into a slice rather than, as we dissect.

Finally, Max argued that that students should not see the pictures as words:

> Again, I try and stress that whilst diagrams are very, very useful, I tell them not to learn it just as words. Don't. Because you'll say to them, sometimes you'll give them a question, they'll come out with the right answer. But if you then give them a scope and say, well where is that, they just haven't got a clue. So I tell them not to learn it as words, not just as words, but to do as much as they can as to learn it both as a picture and a three-dimensional picture, if at all possible. Because I say to them, that's the only way it'll have any meaning to you. You have to learn it as words because words are the medium through which we fail or pass exams.

Therefore, a number of disadvantages around the use of 2D visuals in learning were expressed by demonstrators. They expressed views about whether 2D visuals can be misleading, as the students bring irrelevant expectations about how the anatomical features are in reality. That textbook illustrations were considered as "simplified" is what possibly confuses the students. Also, the students find difficult to transfer what they have seen in 2D to the real 3D material. Then they also struggle in reading 2D imaging methods, as opposed to the 3D materials that they interact with in dissection. In addition, it was stated that the students should be cautious in the way that they approach learning with 2D visuals. They should not approach them as learning with text but need to go beyond that.

5.3.2.3. 3D Visuals

Two out of seven (Dexter and Monica) talked about 3D visuals in learning and assessment in anatomy.

Usefulness

A limited number of comments related to the usefulness of 3D visuals in learning were identified in the data. Monica argued that 3D visuals are better from any other 2D Visuals and, of course, text:

> And I think, when it comes to visual learning with regards looking at skeletons, it aids understanding massively if you've got a model, a 3D model, or a bone, a proper bone. I don't think anything could beat it. So if you've got a photograph of a bone versus a real bone, to me it's a no-brainer. Or a schematic of a bone, anything that's 2D versus the 3D, the 3D is, I think, far and away better. So in that respect I don't think drawings are the best. […] And the same with prosections; visually looking at a prosection versus a 2D drawing. But then I think a 2D drawing is a lot more beneficial than a bunch of words.

And she described the difference that could make a bone compared to a 2D visualization of it.

> So I try and get them to look at a bone, because a picture of a bone drawn in a text book is very different to a bone in your hand. And if you have a bone in a text book, you know the left and the right, you know the surface. Whereas if I give you a bone and say, right, which is the anterior surface, which is the inferior surface, is it a left bone or is it

> a right bone? Is it from your left arm is it from your right arm? And they can look at it and find it very difficult. Because unless you know the different grooves and the different nodules, and you know what to look for, it's quite confusing. […] So it's quite difficult, but they need to know all that. It can easily be a question in an exam. Quite easily - because we put bones in.

Consequently, it becomes evident that the 3D visuals are considered superior to the 2D visuals in learning regarding the structural aspects of anatomy, although 2D visuals are considered superior to learning from text. In addition to these arguments related to the usefulness of 3D visuals in learning anatomy, a comment by Dexter stressed the availability of digital 3D visuals nowadays, as students could even have digital 3D anatomy for their learning:

> However, the things have been modernized now, I mean they have CDs now, they have three-dimensional anatomy by computer, by everything.

Thus, technological innovations make available more learning materials that involve three-dimensional characteristics, which are highly valued in the domain. It is worth noting that there were no coded extracts in the sub-code of ***Disadvantages***.

5.3.2.4. Text

Four out of seven (Luke, Max, Emily and Monica) referred also to text. A quite limited number of coded data extracts referred to aspects of the ***Usefulness*** and ***Disadvantages***.

Usefulness

The first comment that is reported here refers to the use of text when good 2D illustrations were not available in the past. Luke said that in the past they had to learn from the text, as illustrations were not available:

> Luke: In the past, we didn't have illustrations of that quality. We just had to read it from the text on the printed thing of it.

A positive opinion was reported concerning text in learning by Emily, who argued that writing, as drawing does, can aid retention when students read text:

> Yes, I think because if they… well I am a great believer in not just drawing but also writing when you are trying to learn anatomy because I think it is important that whatever you're trying to learn actually is processed. So if you just read something or just hear something it can sort of hit the brain and bounce back off again. Whereas, if you actually then do something with that information I think it aids retention. So in some cases if you are looking at a diagram, drawing your own diagram, makes you look at it more closely, makes you see the detail, makes you see the relationships and likewise if you are reading text, if you're writing notes as you go along at least it's going somewhere in your brain to control your hand.

Thus, the first comment implies that text was used more in the past within the domain, but that was due to the lack of high-quality illustrations. However, generally, it was argued that writing down text can aid retention, as the information is being processed in some way by the student.

Disadvantages

One disadvantage of the text in learning was identified in the data. In her comparisons of different external representations, Monica stressed that words are not as good as drawings in this domain:

> But then I think a 2D drawing is a lot more beneficial than a bunch of words.

As it was also reported above, text is considered as the least powerful representation to support learning of structural, spatially-intense aspects in anatomy.

5.3.3. External Representations in Assessment

5.3.3.1. Drawings

Demonstrators also commented on the use of drawings in assessment within their own training in anatomy. Luke and Max said that when they were medical students themselves, they were asked to create drawings in their assessments.

> Luke: You were told that in the examination, if you are asked a question about a particular structure, if you could actually do a brief outline/drawing of it that would give you marks.

Also, Luke justified why that was the case back then:

> What we used to do it, part of the skill, part of the thing that you taught the student at that stage was to do a drawing. You were told that in the examination, if you are asked a question about a particular structure, if you could actually do a brief outline/drawing of it, that would gave you marks. So, we actually learned, we were taught the important, how to do a brief line drawing of an important structure. That was because the illustrations in the textbooks were so bad. […] The original versions were just sort of paintings […]. But that's all gone now.

In addition to these, Max stressed that drawing skills are not required to use drawings in assessment:

> For simple drawings, I think that's not unreasonable to do. If I can do it with my complete lack of artistic talent, I'm sure that they can. So yes, it is.

However, he stressed the lack of time for the students to draw in the dissection sessions:

> Unfortunately, I mean when I was a lad, and I'm sure that Luke will tell you as well, you know, we used to have about 12-hour sessions a week on anatomy. Here they have, you know, just three hours. And half of that's stuck in a room. I don't say our 12 hours were always used as

> profitably as they might be, I hasten to add. But, you know, there is a lot to do.

Demonstrators referred to their personal experiences of being assessed with drawings when they were students and the high quality visual representations were not available. Moreover, they suggested that, in assessment, the drawing skills should not consider a barrier, although the limited time of the anatomy sessions considers an issue indeed.

5.3.3.2. 2D Visuals

The use of 2D visuals in assessment was discussed also by two demonstrators. Firstly, Max explained why assessment should incorporate both visual and verbal aspects:

> And there is a difference between verbal learning and visual learning. And I've said, it's a matter of combining the two. When I say, you know, you should learn it as pictures, I don't mean just as pictures, okay. I think that you need to learn it because you store it, some people have got better visual memory than others. So some people will store visual memories better than others. Some people will be able to express themselves quite well in words. But some people won't, but they will know the picture. So, I think that it is very useful to have things that they can be asked to point out, because if they do know it but can't put it into words, it's only fair that they should. […] And so, you know, you can say to somebody, ask them a question, and they'll get the answer right in verbal terms. Say now show me on a picture… […] So yes, I think it is important in terms of assessing them, to have visual aids, but because my whole thing is that visual and verbal should be brought together, because it makes it more interesting, and more tangible, and more real.

In the same vein, Monica's comment summarises briefly the use of 2D visuals that are being used in the assessment of the Year 1 Human Development: Structure and Function module:

> Well we do use a lot of diagrams in our assessment. So, for example, in the clinical problem assessment we have, we do have quite a number of schematics in there. So it's not like they're excluded from the exam, they're not. The spotter exam is pro-sections based, it's a prosection based exam. Then we have pretty much a true/false, where we don't have any diagrams. But in the clinical problem exam we have. Basically they have a clinical problem; they need to work it out. And they're taken through the problem and they need to give the answers. It's a linear exam, so they can't go back, so if they give a wrong answer that's it. And it's full of diagrams. Also X-rays, images, different images, MRI. Do we do any prosections in there, offhand? We have surface anatomy in there, so photographs with surface anatomy. I don't think we've got many prosections. So most of the ones that are internal, shall we say, instead of using prosections we use schematics, which are taken from their textbooks.

Finally, Max expressed the view that there are no disadvantages in using visual representations and drawing for learning and assessment, if students understand that it is essential to communicate in words what they see:

> Again, it's reaching the balance. I think that, you know, at the end of the day anatomy is a visual subject. It's a major visual subject. So I don't think there are any disadvantages, as long as they realise they have to be able to put what they see into words. It's important that what they say, they can put into pictures. But equally it's important for communication, to be able to put what you see into words as well. Because we don't, if we're talking to someone in a clinical setting, okay, you don't always have the visual aids there. We've always got our mouths, we've always got our words, we've always got our language, but we don't always have our visual aids. And at the end of the day they're learning this, not because they're going to go on and be anatomists, but because they're going to go on and be doctors.

Consequently, in terms of using 2D visuals in assessment, the interviews revealed that 2D visuals are valued to a limited extent in this context. This was not only supported by the demonstrator's belief that visuals, like pictures, should be mixed with verbal tasks in the assessment, but also by the description of the assessment approaches where 2D visuals are being used. However, four demonstrators did not reference them at all.

5.3.3.3. 3D Visuals and Text

It is worth noting that there were no coded extracts in the codes of 3***D visuals*** and ***Text*** in assessment.

5.4. Summary of Findings

- RQ1, Sub-question 1: "How do anatomy demonstrators use visual representations and drawings to introduce dissection sessions in anatomy?"

The findings from both the observations and the interviews show that, generally, anatomy demonstrators use the visual representations that they have available in the tasking rooms. Firstly, the results of the observations made apparent that drawing was used frequently in those brief introductions. Some demonstrators created drawings quite a few times. Two of them create their drawings before the sessions, due to the time limitations within those introductions. Moreover, those drawn representations could be reused by others, as observed in the case of one demonstrator in this study.

However, drawing is not the most important representation for demonstrators in these sessions, as it is apparent that 3D visuals are used frequently by all. A reason for this is their three-dimensional characteristics that are highly important in the anatomical domain.

Thirdly, the use of 2D visuals other than drawings had a relatively small role to play in teaching. However, an interesting issue was raised by one demonstrator, who talked about the need for students to be supported in their reading of the textbook illustrations, as they contain a lot of detail. And thus, again, the usefulness of schematic drawings was expressed by another demonstrator. Two demonstrators also talked about the use of images.

Finally, a very limited use of text was observed in these sessions. It seems that demonstrators much prefer 3D visuals that are available to them or drawings in cases where they are generally able to draw or get the chance to reuse one.

In addition, a very limited amount of multi-representational uses was observed. One demonstrator only seemed to employ such an approach. One demonstrator also referred in the interviews to the multi-representational use of a diagram and a 3D visual.

- RQ1, Sub-question 2: “What are their beliefs about using visual representations and drawing in teaching, in learning and in assessment in anatomy?”

Firstly, the demonstrators’ beliefs about the use of visual representations and drawing in teaching are discussed. After this, their beliefs regarding their use in learning and, finally, in assessment are presented.

Teaching

Some demonstrators highlighted the need for the drawn diagrams to be simple/schematic. The demonstrator who generally draws said that he does so in front of his students, as he believes that it is good for them to watch; moreover, they get time to copy down those representations. In addition, the anatomy demonstrators who generally draw reported that these drawings engage the students, as the students do not only copy/take notes from them, they also reproduce those representations. Their usefulness in the communication of structural aspects was stressed as well.

Regarding the disadvantages of the use of drawings in teaching, the lack of drawing skills that were reported by two demonstrators might be one reason for their decision to not generally draw. This also can be linked to the students’ lack of drawing self-efficacy, which claimed that could be counterproductive for students when they are drawing to learn (this will be discussed below in the section about learning). With respect to this type of representation itself, it was reported in the data that the disadvantages of the 2D nature of drawings and the complexity that can be represented in a simple pen and paper drawing were are unhelpful as well.

With respect to 2D visuals, the interview data showed that demonstrators find 2D visuals useful for pointing out things to students, especially when the demonstrators explain something and want to start with the real material of interest. Interestingly, a demonstrator also used a 2D visual in the form of an X-ray in his introduction, a visual that is particularly useful in the medical practice. Disadvantages were also reported regarding illustrated diagrams. The emphasis of those comments was regarding the number of students that could be involved and the lack of time for students to follow the presentation of illustrations. Drawing was considered better by a demonstrator than projecting illustrations, as the students could take more time to engage with the representation when the drawing is constructed in their presence.

It was revealed, quite evidently, that 3D visuals – which are used a lot by the demonstrators based on the observational data – are considered very useful due to the three-dimensionality they bring and for how valuable that this is considered when pointing out things to students, as they get a more realistic perspective compared to what they get from 2D visuals. The limited disadvantages around the use of 3D visuals focused either on the limited number of students that this method could accommodate or the potential quality issues of plastic models.

Finally, the usefulness of the external representation of text in teaching was not discussed by any demonstrator; this may relate to its very limited use, which was recorded in the observations. However – and this might be a reason for this lack of text use – two disadvantages of it were reported in the interviews. These disadvantages refer to the purpose of those sessions and the unhelpfulness of text when dealing with structural aspects. Nevertheless, text is useful when talking about function.

Learning

Most demonstrators commented on their beliefs concerning the use of drawing and visual representations with respect to learning. They were quite sceptical about the students' capability to transfer what they see in a 2D visual into real 3D cadaveric material. Both positive and negative views about the use of drawing in students' learning in anatomy were reported in the interviews.

Among the positive comments, it was said that drawing can help retention and support understanding of positional relationships. There was also an argument that "visual learners" could benefit from drawings in learning. Some drawbacks of the use of drawing in students' learning were expressed as the lack of drawing self-efficacy among students, the unstructured or no directed context employed, and the misconceptions that could be depicted in their constructions that would then be reused. In addition, the lack of three-dimensionality in drawings was argued to be a disadvantage as well.

Regarding the use of 2D visuals in learning, there was a very small number of coded extracts for this code. It is worth highlighting here a comment that referred to a real photo as the most appropriate representation for use within this context. However, many disadvantages were expressed concerning the use of 2D visuals in learning. Firstly, the comments referred to how they can be misleading to the students in relation to their expectations about the way in which anatomical features look in reality. They are often presented as "simplified", which might be confusing for the students. It was also argued that students struggle with transferring to the real 3D material what they have seen in 2D. This can be linked also to the claimed difficulties they face in reading 2D imaging methods, as opposed to what they experience 3D in dissection. Finally, it was argued that students need to move beyond approaching learning with 2D visuals as they do with learning from text.

As for the usefulness of 3D visuals in learning, it was said that 3D visuals are better than 2D visuals for the structural aspects of anatomy, and 2D visuals are better than learning from text. In addition, it was also noted that, nowadays, there is an increased availability of 3D visuals, as students could even have digital 3D anatomy for their learning. Demonstrators did not express any views on the potential disadvantages of 3D visuals' use in learning or on their use in assessment.

Finally, it was argued that the external representation of text was used more in the past within learning in anatomy, when high-quality visualisations were not available. As for the usefulness of this representation itself, it was argued that writing down text when learning supports retention because the information is being processed in a way. Nonetheless, regarding the learning of the structural and spatially intense aspects of anatomy, text is believed to be the least helpful.

Assessment

A limited number of comments were made concerning the use of visual representations and drawing in assessment. One reason for this might be the limitations of the current form of assessment within anatomy education generally, as well as in this course.

Finally, regarding the use of drawing in assessment, demonstrators reported personal experiences of being assessed with drawings as medical students, as high-quality visualisations were not available in their time. As for the use of drawing in assessment generally, it was stated that drawing skills should not be considered a barrier for "simple" drawings. However, the limited time within sessions in anatomy was considered an issue. It was revealed that 2D visuals are valued to an extent in the assessment. That was made evident not only by one demonstrator, who argued that the visuals should be mixed with verbal tasks in assessment, but most strongly by another, who described the current use of ready-made 2D visuals in the current assessments. As for the use of 3D visuals in assessment, there were no coded data extracts in this sub-code about assessment.

The discussion of these findings, their implications and links to the wider literature are presented in Chapter 9.

6. Study 2

6.1. Introduction

As discussed in the Chapter 2, anatomy education is claimed to play a fundamental role in the development of the medical practitioner. It is suggested by medical educators that dissection sessions are essential and vital for this knowledge development (Korf et al., 2008; Older, 2004) with visual aids additionally facilitating this (Sugand, Abrahams, & Khurana, 2010). It is argued by the people who support dissection that it helps students' understanding of the 3D organisation of the human body and they often consider the students first hands-on experience with the internal structures of the human body, amongst the other reasons considering dissection (Older, 2004). However, this is a contested area with others arguing that medical training can be sufficiently facilitated without dissecting cadavers to learn anatomy (McLachlan et al., 2004).

The main focus of this study is to explore a tool of assessment in medical education. As described in the literature review, there are multiple assessment tools that are currently being used in anatomy education. Medical educators argue that there is no single instrument that has the required quality to assess educational objectives from all the three different domains of educational objectives (cognitive, affective, psychomotor) (Brenner et al., 2015). Therefore, it is valuable to consider the learning objectives of courses and match them with the appropriate assessments. Although various assessment tools have been discussed so far in the research literature with much debate about their capability to assess medical understanding, it could be argued that drawing is neither thoroughly investigated nor firmly established as a tool to assess understanding in anatomy.

Pandey & Zimitat (2007) claimed that medical students seem to value the usefulness of visualisation in order to develop their anatomical knowledge. In this study, it is argued that external visualisations in the form of free hand drawing could be used to investigate changes that dissection makes on students' visualisations of the to-be-learned structures of the human body. This was based on arguments from science education supporting that drawing can aid assessment when students make their thinking visible (Ainsworth et al., 2011).

This study aimed to answer the RQ2: "Do student drawings reveal changes in understanding after dissection?" The purpose was to investigate if dissection sessions in anatomy change the representation of the structures that students are exploring. It was expected that data from this study would contribute both to discussions about whether cadaveric dissection has an irreplaceable role in medical education and whether drawing is a valid instrument to assess understanding of dissection activities. This investigation took the form of a real-world experiment. Data were collected in a real-world research setting from dissection sessions in anatomy at the University of Nottingham. Year 1 medical students were asked to draw the exterior of the heart and the superior mediastinum (SM) before and after their dissection activities. The main prediction tested was whether dissection would improve the informational content of their drawings and whether it would change the representational choices that the students made.

Therefore, this chapter reports on Study 2, which addresses these three aspects of RQ2:

- <u>RQ2, Sub-question 1</u>: "Does dissection change what Year 1 medical students draw in anatomy and do they show improved understanding of the spatial aspects after dissection?"

Specifically, the study explored whether dissection altered the informational content of the drawings in terms of the number of anatomical features that the students represented and their shape, location and labelling.

- RQ2, Sub-question 2: “Does dissection change the way that these students draw?”

This sub-question explored whether dissection influenced how the students drew their understanding of the anatomical features, not in terms of the content but with regard to representational features, such as their use of colour and the clarity and dimensionality of the drawings

- RQ2, Sub-question 3: “How do different anatomical structures affect student drawings?”

This last sub-question aimed to explore whether students’ drawings of the exterior of the heart or the superior mediastinum were different in content and representation.

6.2. Methods

6.2.1. Design

A two-factor [2-by-2] mixed design was used to answer these questions. Students were asked to draw a structure before and after its dissection. The first factor, experience, was within groups with two levels (draw pre dissection, draw post dissection). The second factor, the content drawn, was between groups with two levels (draw the exterior of heart before dissection and the SM after; draw the SM before dissection and the exterior of the heart after). Year 1 medical students were assigned to one of these two conditions by following the normal tasking-room groups that were already assigned in the DR sessions rota. From all the students who created drawings (see section 6.2.2), paired data were analysed from 44 students that were assigned to the first condition (draw the heart before dissection and the SM after) and from 54 assigned to the second condition (draw the SM before and the heart after dissection). Ideally, the same students would have drawn a structure both before and after dissection. However, this cross-design was employed due to the limited time each participant had available to them in the dissection session.

6.2.2. Participants

Out of the total number of drawings created in these two dissection sessions (218), drawings from 98 Year 1 medical students (61 female, 37 male), who attended both sessions and also provided consent for their drawings to be analysed formed the dataset for this analysis (i.e. 196 drawings). 44 participants were included in the analysis from the first condition and 54 from the second one.

6.2.3. Tasks and Procedure

In each of the sessions involved in the study, after a short briefing concerning the studied region, students split into two groups in each tasking room, as they normally do in the Year 1 DR sessions. Half of the students have stayed in their tasking room to learn with various study materials and the other half went to the main DR to undertake exploratory dissection activities, which involve dissecting in teams to discover sets of structures on a checklist. The provided workbook in the DR sessions by the Anatomy Teaching Group, a dissection guide and, where needed, demonstrators were available to assist these activities (Pratten & Loughna, 2013). The groups that remained in the tasking rooms were immediately directed to the drawing activity described below. After the end of this procedure students went back to their usual activities (10 minutes). When the groups swapped, the students returning from dissection activities immediately began the drawing activity. The study was conducted in the third and fourth teaching weeks of the semester, and so these students have attended two sessions in the DR prior to the study.

A4 sheets with the written instructions were given to the students and colour pencils were placed around the tasking rooms for students to use according to their preference. Students were given 10 minutes to complete the task. On the provided A4 paper, students were asked to report the time that they spent drawing and the time they already spent studying each structure. The drawing task for the second week had the same structure; the only difference was the anatomical structure that the students had to draw and dissect.

Students in Week 1 were asked to draw the exterior of the heart in order to show its anatomical features (see Appendix 3) and in Week 2 to draw the SM in order to show its anatomical features (see Appendix 4). These drawing tasks had been designed to address one of the fundamental learning outcomes of these two DR sessions, which is that the students should be able to demonstrate their knowledge of the heart and the SM. In the process of designing the drawing tasks, an expert anatomist/anatomy demonstrator had been consulted, and a pilot with second year medical students in the DR provided valuable feedback on the design. The pilot validated that the time was enough for the students to complete the drawing task (10 minutes) and that the drawing instructions were clear and appropriate. Moreover, the pilot generated feedback on practical issues and familiarisation with the environment/tasking room in which the study was planned to be conducted. Students were not assessed under formal assessment procedures, although a researcher was present to ensure they drew from memory and did not copy from textbooks, workbooks or each other.

6.2.4. Issues of Validity

Robson & McCartan (2016) suggest that when a relationship between the employed treatment and the outcome is likely to exist, with the former being responsible for the latter, then it can be claimed that internal validity can be achieved. The factors that could affect the internal validity (Cook & Campbell, 1979; cited in Robson & McCartan (2016) of this quasi-experiment are listed below and the extent that these were controlled is justified:

1) **History:** Major historical events that could have an effect on the way that the students responded in Study 2 were limited by selecting two contiguous sessions.

2) **Testing:** Due to the within subjects described above for the quasi-experiment in this study, the students had to draw a different structure pre/post dissection. Thus, the possibilities to become experienced through practice have been minimised.

3) **Instrumentation:** A great attempt was made to ensure the way that the participants were measured did not change between the conditions.

4) **Regression:** This effect has been controlled as the participants in the experiments of this projects were assigned in the conditions by following the pre-existing distribution into groups for the sessions involved, where the students were not chosen by measures of any skills or achievement.

5) **Experimental mortality:** For this quasi-experimental design, the data of the participants who did not complete both the drawing tasks (before and after dissection) were withdrawn and not analysed. There is no reason to assume that this differentially affected the two conditions.

6) **Maturation:** This effect was minimized as the data collection was conducted in two sessions (a week apart).

7) **Selection:** The groups of students which were pre-existing in the DR rota, were not chosen because of any special skills or achievements.

8) **Selection by maturation:** This could not cause any issues on the internal validity, as the quasi-experiments of this study completed in a very short period of time with adult participants.

9) **Ambiguity over casual direction:** It was expected that dissection would improve understanding of anatomical structures; making the opposite relationship not logical.

10) **Diffusion of treatments, equalisation of treatments and compensatory rivalry:** These factors were not considered issues for internal validity, because all the groups experienced very similar procedures, the received treatments (dissection sessions) were designed and directed by the Anatomy Teaching Group to be equally treating all the students who participate in the DR sessions and the studies did not involve a control group as each participant was their own control.

In addition, Robson & McCartan (2016) emphasized that in the natural settings, like the environments that the studies conducted, it is less likely to have the demand characteristics of experiments that are conducted in artificial environments.

6.2.5. Issues of Reliability

The reliability of this study was increased by the way that the collected drawings were analysed with the quantifiable coding scheme (described in Chapter 4) and with the inter-rater reliability tests that were conducted to establish the reliability of this instrument. All the drawings were coded by the first author. 10% were checked by a DR anatomy demonstrator for their informational content (present features, accuracy of shape and location, correct labels) and the use of colour. Clarity and dimensionality were checked by a postgraduate research student in the social sciences. All kappa values were above .7 and, thus, these results showed that inter-rater reliability was achieved for all the variables coded. The detailed report of the inter-rater reliability is available in Chapter 4.

6.3. Findings

It was expected that the representation of the heart and the SM will be more accurate after dissection while also moving away from the representation of a textbook. Furthermore, from this experimental design, it was expected that the participants would draw a higher number of anatomical features, while their shape and their location would be represented more accurately after dissection. Also, it was expected that students would use less labels in their drawings. Finally, it was hypothesised that their drawings would show higher clarity and dimensionality scores and that they would use less colour after dissection.

Multivariate Analysis of Variance (MANOVA) has been used for the informational content of the drawings: for the number of presented features in each drawing and the accuracy of their shape, location, and correct labelling. No effect of content drawn was expected, but an interaction between experience and content drawn and this would reveal a content drawn effect and a main effect of experience (pre and post) that would show an effect of dissection. Since the MANOVA showed a multivariate effect of experience, follow-up Analyses of Variance (ANOVAs) were performed. For the representational choices, two ANOVAs were used to analyse the clarity and dimensionality scores, along with two Chi-Squared and McNemar tests for the colour. The results are reported with figures and statistics.

6.3.1. Informational Features

A 2 (pre dissection, post dissection) by 2 (draw heart before, draw SM before) mixed MANOVA on the provided features, accuracy of form, accuracy of location and correct labels was conducted. Analysis revealed no effect of content drawn (F (4, 93= 0.587, p=.672, η_p^2 =.025) but a multivariate effect of experience (F (4, 93) = 2.922, p= .025, η_p^2 = .112) and an interaction between the experience and the content drawn (F (4, 93) = 40.769, p<.001, η_p^2 =.637). Consequently, follow up ANOVA tests were conducted.

6.3.1.1. Presented features

A two-way mixed [pre dissection - post dissection, draw heart before - draw SM before] factorial ANOVA on the percentage of the features that students include (from a total of 28) (Figure 36) found that the main effect of the experience was not significant, F (1, 96) =2.64, MSe=240.16, p=.107, η_p^2=0.027 nor was the main effect of the content drawn, F (1, 96) =1.52, MSe=415.16, p=.220, η_p^2=0.016, but there was a significant interaction between experience and the content drawn, F (1, 96) =4.88, p=.030, η_p^2=0.048. Bonferroni post hoc comparisons showed that before dissection there was no difference in the number of features included in the heart or the SM, (1.3, p=.740). However, when students drew after dissection, there were significantly more SM features included than there were heart features (8.5, p=.014). Moreover, students who drew the heart before and the SM after dissection did not differ in the number of features they included in either drawing (1.3, p=.695) but for students in the other condition, they did draw more SM features prior to dissection than heart features after dissection (8.5, p=.005). This means that students presented less features for the heart after dissection and the students of the second condition did better on presenting features on SM before dissection, than presenting features of the heart after dissection.

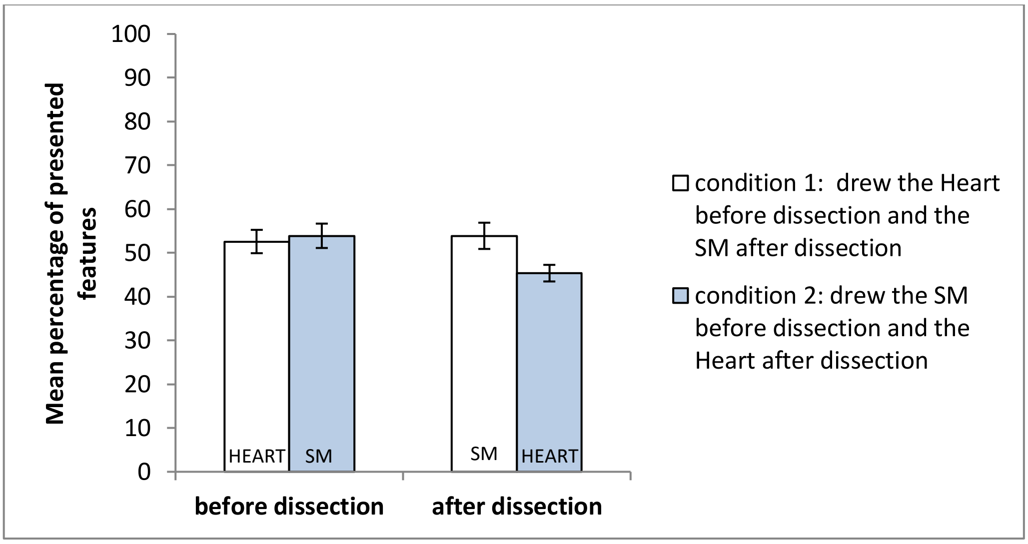


Figure 36. Mean percentage of the features that students included in their drawings for both structures in each condition

6.3.1.2. Feature Shape Accuracy

On the percentage of accurate shapes, ANOVA showed (Figure 37) that the effect of experience was not significant, $F(1,96)=1.38$, $MSe=188.24$, $p=.244$, $\eta_p^2= 0.014$ nor was the effect of content drawn was, $F(1,96)= 1.1$, $MSe=417.64$, $p=.297$, $\eta_p^2= 0.011$. However, the interaction between the experience and content drawn was significant, $F(1,96)= 46.47$, $p<.001$, $\eta_p^2=0.326$. There is a difference in the amount of accurate shapes between the heart and the SM that the students created when they drew before dissection as there were more accurate shapes for the SM than the heart (10.35, $p=.006$) and after dissection students created more accurate shapes for the SM than the heart too, (16.5, $p<.001$). Furthermore, students who drew the heart before dissection and the SM after dissection created a higher number of accurate shapes for the SM than the heart (11.1, $p<.001$) and when students drew the SM before and the heart after as they included a higher number of accurate shapes for the SM (15.7, $p<.001$). This means that, both before and after dissection, the students generally created less accurate shapes for the heart than the SM and, no matter what condition they were assigned to, the shape of the heart's features was less accurate compared to the SM's features.

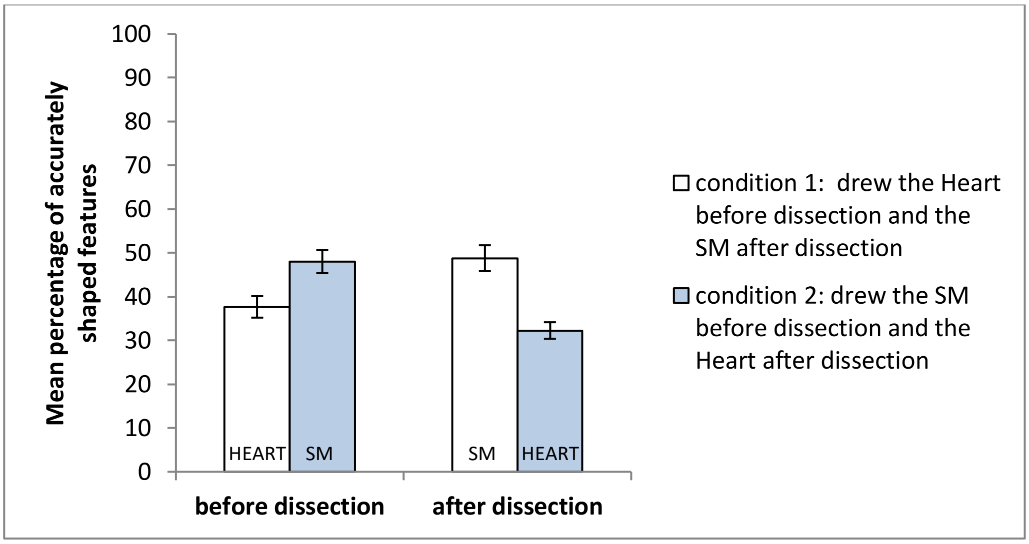


Figure 37. Mean percentage of the accurately shaped features for each structure in each condition, out of the total number of the required features

6.3.1.3. Feature Location accuracy

On the percentage of accurately located features, the ANOVA showed (Figure 38) that the main effect of the experience was not significant, $F(1,96)=0.908$, $MSe= 212.12$, $p=.343$, $\eta_p^2=0.009$ nor was the main effect of the content drawn, $F(1,96)=1.11$, $MSe=350.35$, $p=.294$, $\eta_p^2=0.011$. However, the experience and the content drawn interaction was significant, $F(1,96)=5.16$, $p=.025$, $\eta_p^2=0.051$. Before dissection there was no difference in the amount of accurately located features for the heart and the SM (1.9, $p=.596$). However, when students drew after dissection, there were more accurately located SM features included than there were heart features (7.6, $p=.020$). Moreover, students who drew the heart before and the SM after dissection did not differ in the number of accurately located features they included in their drawings (2.8, $p=.376$) but for students in the other condition, they drew more accurately located SM features prior to dissection than heart features after dissection (6.7, $p=.018$). This means that the students drew less accurately located individual features of the heart in comparison to the SM after dissection. In addition, the students in the second condition presented the location of the heart individual features less accurately after dissection in comparison to their drawings of the SM before dissection.

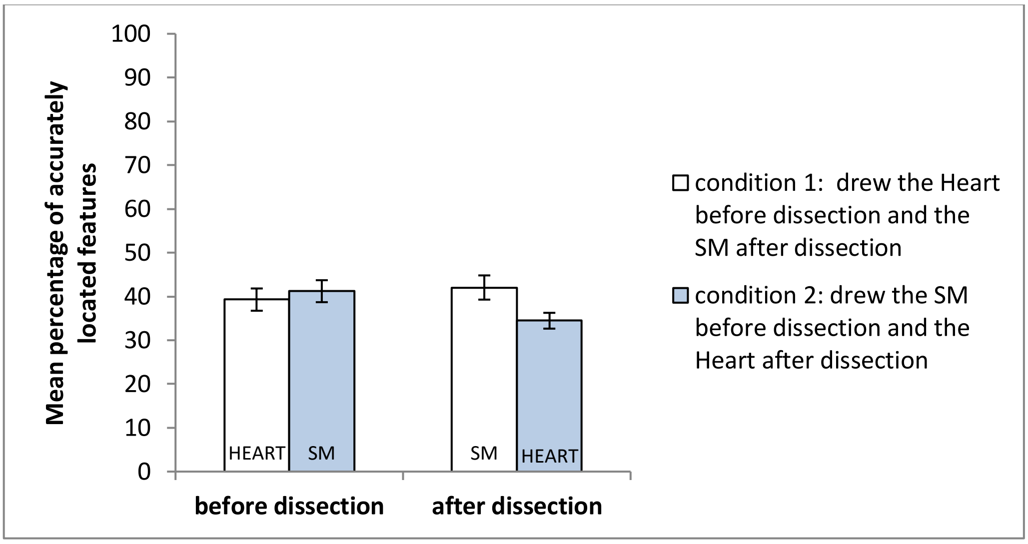


Figure 38. Mean percentage of the accurately located features for each structure in each condition

6.3.1.4. Feature Labels

On the percentage of correct labels, the ANOVA showed (Figure 39) that the main effect of the experience was significant, $F(1,96)=9.73$, $MSe=224.81$, $p=.002$, $\eta_p^2=0.092$, but not the effect of the content drawn, $F(1,96)=2.17$, $MSe=499.30$, $p=.144$, $\eta_p^2= 0.022$. There was a significant experience and content drawn interaction, $F(1,96)= 16.80$, $p<.001$, $\eta_p^2=0.149$. Before dissection there was no difference in the number of correct labels provided for the heart or the SM (4.1, $p=.330$). However, when students drew after dissection, there were more correct labels for the SM than there were for the heart (13.6, $p<.001$). Moreover, students who drew the heart before dissection and SM after dissection did not differ in the number of correct labels they provided in their drawing (2.1, $p=.511$), but for students in the other condition, they did provide a higher number of correct labels for the SM prior to dissection than for the heart features after dissection (15.5, $p<.001$). Thus, it can be concluded that, after dissection, there were less accurate labels for the heart compared to the SM. The students of the second condition also gave less accurate labels to the individual features of the heart in their drawings after dissection compared to their drawings of the SM before dissection.

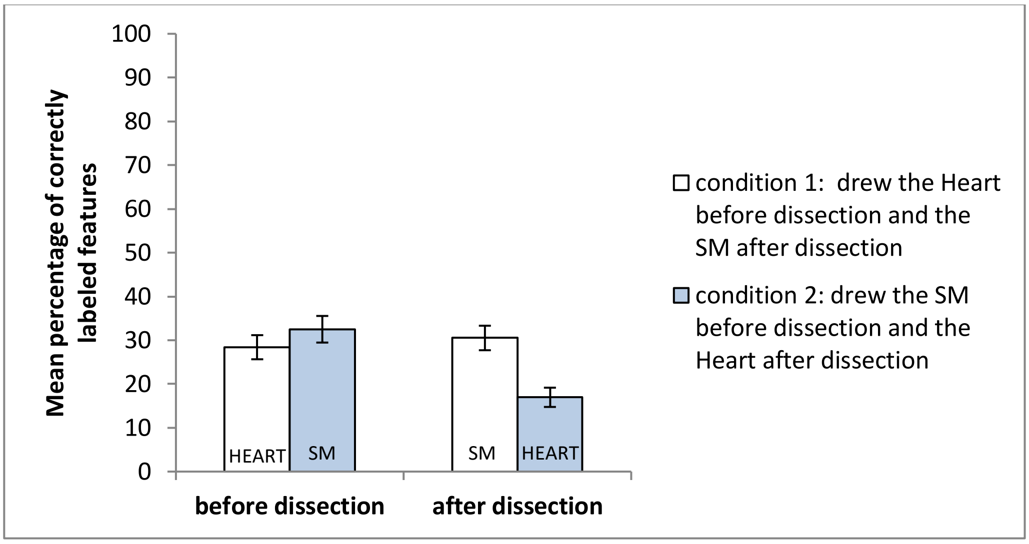


Figure 39. Mean percentage of the correctly labeled features for each structure in each condition

6.3.2. Representational choices

To examine if the structure drawn influenced students' decisions to use colour, two chi squared tests were performed: the first on drawings prior to dissection and the second on post dissection drawings. The tests revealed that structure did not affect the use of colour either before $C^2(1, N=98)= 0.738, p=.390$) nor after dissection $C^2(1, N=98)= 2.478, p= .115.$). The number of drawings which used colour or not for each structure before dissection are illustrated in Figure 40 and Figure 41 below:

Figure 40. Use of colour between the structures before dissection

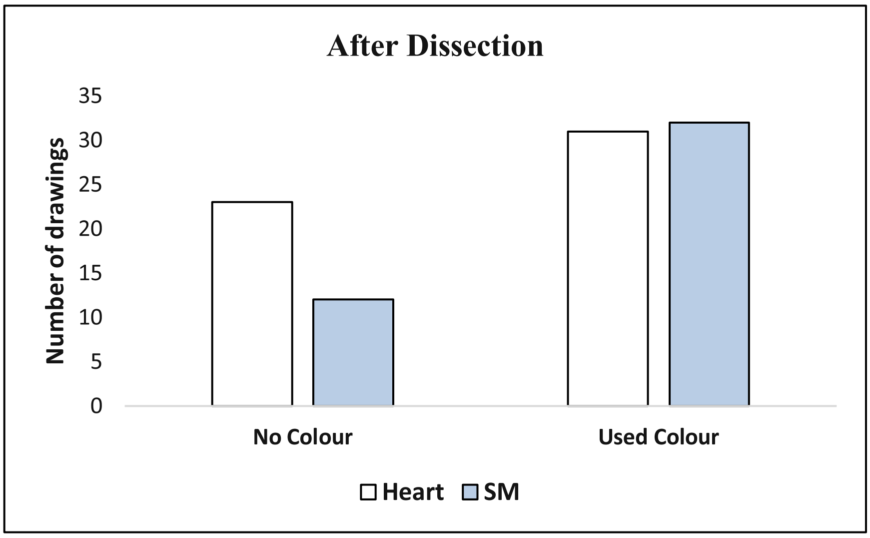


Figure 41. Use of colour between the structures after dissection

A McNemar's test determined that there was no change in the proportion of drawings with colour before and after dissection, p=.664. The illustrated results in Table 12 clearly show that dissection did not change the preference of students to use colour both before and after dissection.

Table 12. Use of colour before and after dissection

	Before Dissection		
After Dissection	No Colour	Used Colour	Total
No Colour	26	9	35
Used Colour	12	51	63
Total	38	60	98

A two-way mixed factorial ANOVA on the clarity scores showed (Figure 42) that the main effect of experience was not significant, $F(1,96)= 0.00$, MSe= 0.229, p=.995 , $\eta p2=0.00$, nor was the effect of the content drawn, $F(1,96)= 0.072$, MSe= 0.569, p= .789, $\eta p2= 0.001$. However, the interaction between the experience and the content drawn was significant, $F(1,96)= 8.83$, p= .004, $\eta p2= 0.084$. Bonferroni post hoc comparisons showed that before dissection there was no difference in the scores of clarity between the heart and the SM, (.175, p=.171), nor for the clarity scores after dissection between the heart and the SM, (.233, p=.075). However, drawings of the SM after dissection showed higher clarity scores from the heart drawings before dissection, (0.205, p=.048) and drawings of the SM before dissection showed higher clarity scores from the heart drawings after dissection as well, (0.204, p= .029).

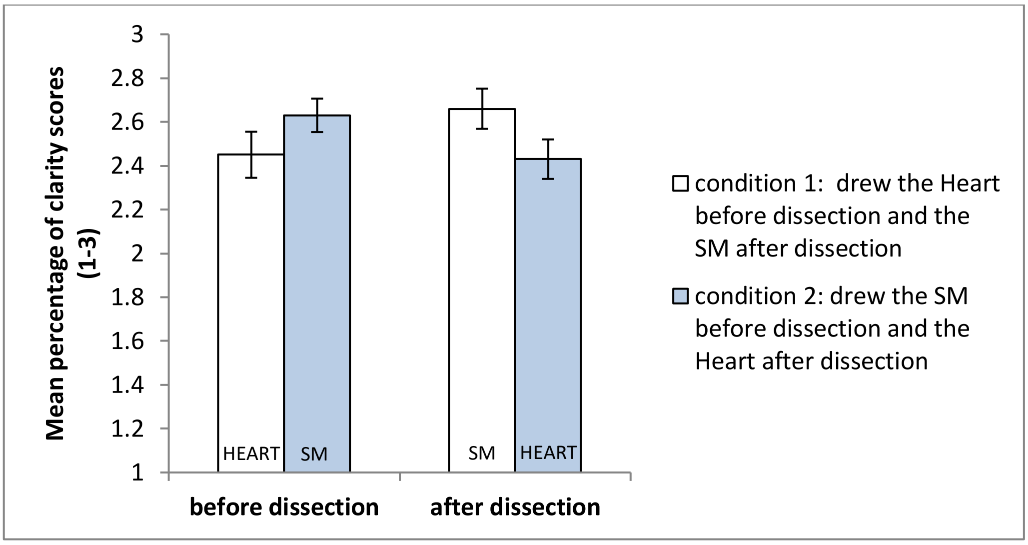


Figure 42. Mean score of clarity on drawings for each structure in each condition

Lastly, another two-way mixed factorial ANOVA on the dimensionality scores showed (Figure 43) that the main effect of experience was not significant, F(1.96)= 0.24, MSe= 0.425, p=.628, η_p^2= 0.002, nor the main effect of the content drawn was, F(1,96)= 0.017, MSe= 0.709, p=.895, η_p^2= 0.000. The interaction between the experience and the content drawn was not significant as well, F(1,96)= 0.23, p= .628, η_p^2= 0.002.

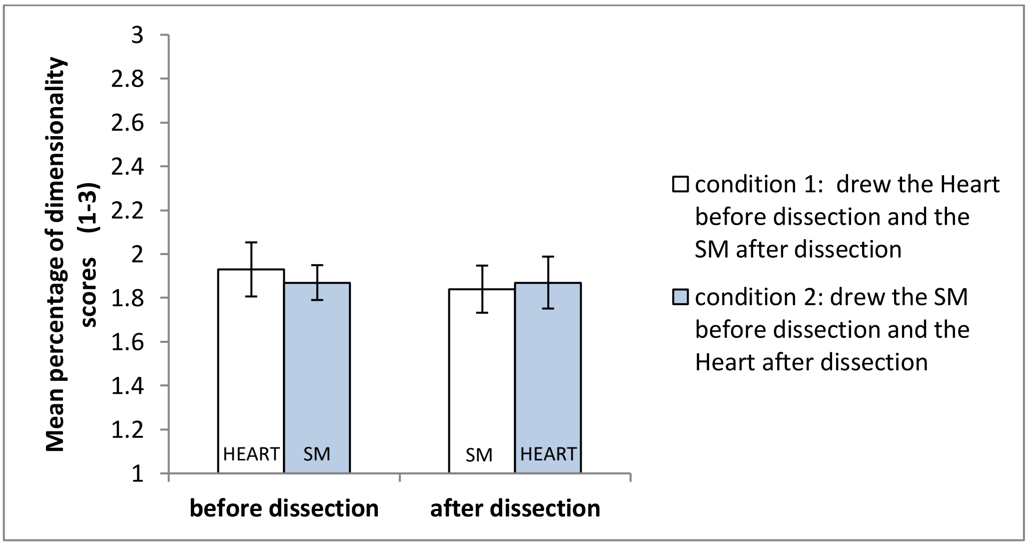


Figure 43. Mean score of dimensionality on drawings for each structure in each condition

6.5. Summary of Findings

The objectives of this study were to identify whether dissection changes what Year 1 medical students draw in anatomy, to discuss the way in which different anatomical structures are represented after dissection in students' drawings, and to consider if the students show improved understanding of spatial aspects after dissection. These have been examined under the umbrella of exploring if Year 1 medical students' drawings in anatomy reveal changes in their understanding after dissection activities.

- <u>RQ2, Sub-question 1</u>: "Does dissection change what Year 1 medical students draw in anatomy and do they show improved understanding of the spatial aspects after dissection?"

It was hypothesised that drawings after dissection would include more anatomical features, and these would include a higher number of accurately shaped and located features but less labels.

These results suggest that dissection seems to have changed the number of features students drew for the heart, but it had no impact on the SM. When students drew after dissection, there was a decrease in the percentage of features included for the heart. With respect to the differences before and after dissection within the two conditions, when students drew the SM before and the heart after (condition 2), they included more features for the SM prior to dissection than heart features after dissection. Thus, the first part of the hypothesis is not supported, since the students included less anatomical features for one of the two structures instead of more, as expected after dissection. Moreover, the number of features that the students drew for the SM did not change after dissection. It seems that dissection had a negative effect on the number of the anatomical features students included in their drawings of the heart, as these decreased after dissection. This result will be discussed further, along with the accuracy of the features' shape and location results.

The hypothesis concerning the improvement of the features' shape accuracy was not supported. In terms of the accuracy of the features' shapes, dissection did not change the number of accurate shapes featured. Both before and after dissection, there was a lower percentage of accurate shapes for the heart in relation to the SM. Moreover, out of the total number of features, students in both conditions constructed more accurate shapes for the SM either before or after dissection in relation to the heart. Thus, dissection did not change how the anatomical features' shapes were represented. Results of the overall shape of the heart will be discussed in Study 3, where drawings of the heart from Year 3 students are compared with those from Year 1 in this study.

The hypothesis concerning the improvement of the location accuracy was also not supported. However, in terms of the accuracy of location, dissection possibly changed the number of accurately located features, but not for the better. The results revealed that, after dissection, there was a decrease in the percentage of features that students accurately located for the heart and, lastly, they drew more accurately located SM features prior to dissection than heart features after dissection (condition 2).

In terms of labelling, which was the last of the informational content coded, the results indicate that dissection changed the number of accurate labels for the heart and the SM. Consequently, the hypothesis regarding students providing less labels after dissection was partially supported. The data showed that, after dissection, there was a decrease in the percentage of accurate labels of the heart. Moreover, the students constructed more correct labels for the SM prior to dissection than for the heart features after dissection (condition 2).

- <u>RQ2, Sub-question 2</u>: "Does dissection change the way that these students draw?"

It was expected that drawings after dissection would show higher clarity and dimensionality scores and that students would use less colour after dissection. However, dissection does not seem to have changed either the clarity or the dimensionality scores of the drawings. It was hypothesised that drawings after dissection would be clearer than before and students would give more 3D characteristics to their drawings after dissection. In both cases, in terms of dimensionality, there was no significant difference between the SM and the heart in the drawings before dissection, nor in the drawings after the dissection activities. However, only for the clarity scores, drawings of the SM after dissection were clearer from the heart drawings before dissection (condition 1) and drawings of the SM before dissection were clearer than the heart drawings after dissection (condition 2) as well. Finally, the hypothesis that students would use less colour after dissection was not supported either. The results showed that most of the students did not change their use of colour between pre and post dissection drawings.

Overall, based on the answers to the sub-questions 1 and 2, it cannot be argued that dissection improves student drawings for the better. In fact, it may have unexpectedly altered students' representation of the heart, but not for the better.

- RQ2, Sub-question 3: "How do different anatomical structures affect student drawings?"

The answer to this sub-question has already been addressed in the answers of RQ2, Sub-question 1 and RQ2, Sub-question 2.

6.6. Conclusion

Due to the wide range of the advantages claimed for dissection on the development of a medical practitioner, one of the objectives of this study was to shed light particularly on whether dissection promoted the acquisition of one of the main learning outcomes of these sessions; the students to be able to demonstrate increased accuracy in their understanding of the contents of the heart and the SM, especially with respect with their shape and location.

Unfortunately, the results of this study did not show any improvements on students' understanding of the regions under investigation, based on their constructed external representations - drawings. In the next chapter, an investigation was conducted to examine whether free-hand drawing can reveal changes in the understanding of anatomy as the medical degree progresses. Thus, drawings of the heart from this study were used to conduct a comparison between the Year 3 medical students (with the same drawing instructions given for the Year 1 students) and the Year 1 medical students (drawings of the heart pre- and post dissection). Moreover, for the last study of this thesis (Chapter 8), an investigation was conducted on the way in which anatomy demonstrators in the DR sessions approach the assessment of students' drawings from this study; this is explored through the demonstrators' responses to the various questions on the criteria they use to assess these drawings.

The discussion of these findings, their implications and links to the wider literature are presented in Chapter 9.

7. Study 3

7.1. Introduction

In the previous chapter, Study 2 explored how dissection changed what Year 1 medical students drew in anatomy using a within-subject quasi-experimental design in a natural setting. In this chapter, a between-subject quasi-experiment was carried out to continue the discussion on the use of drawing to assess understanding in medical education and investigate the RQ3: "Do student drawings reveal changes in understanding of anatomy as the medical degree progresses?" In this study, the question addressed longer term changes after students receive years of training in medicine. This further investigation, although not originally planned offered a fruitful opportunity to explore the issue of the use of drawing for assessment, especially given unexpected results in Study 2. Hence this study addresses:

- RQ3, Sub-question: "Do the Year 3 students show improved spatial aspects of the anatomical structures or different visual characteristic in their drawings of the heart to the Year 1 students?"

To answer this question, the informational content of the drawings and the shape of the heart along with the use of colour, the clarity and the dimensionality in the drawings were assessed and compared across the two year groups.

Overall, this thesis can explore how the representation of the heart changes not only before and after dissection activities in the very early beginning of the degree, but also whether the training in medicine as the degree progresses is transforming this representation in students' drawings. In order to do that, Year 3 medical students were asked to respond to the same drawing task about the exterior of the heart as the Year 1 students did in Study 2 (Chapter 6) by following the same instructions.

7.2. Methods

A between-subjects quasi-experimental design was employed for this study. Data from Year 3 medical students was compared with data that was reused from Study 2.

7.2.1. Design

The Year 3 drawings of the exterior of the heart were compared with drawings created by Year 1 medical students. The participants of this experiment divided in three conditions: Year 1 (before dissection), Year 1 (after dissection) and Year 3.

7.2.2. Participants

Year 3 medical students in clinical placement were informed about the study and (n=46, 22 female, 24 male) agreed that their drawings to be digitalised and analysed for this research. These were compared with drawings from Year 1 (n=98, 61 female, 37 male) students attending the dissections sessions of Year 1 modules (described in Chapter 3). Those students participated in the drawing activity for the second study of this thesis (Chapter 6) as their data reused for this comparison.

7.2.3. Task and Procedure

Year 1 medical students were asked in Study 2 to draw the exterior of the heart, either before or after dissection. Year 3 medical students in a clinical placement session created heart drawings by following the same instructions and time limit for this study. Thus, Year 3 students in clinical phase were asked to draw the exterior of the heart in order to show its anatomical features, exactly as the Year 1 students did for Study 2 (see Appendix 3). Students had 10 minutes to complete the drawing task and they were provided with paper and coloured pencils that they could use according to their preference. All students were asked to report the time they started/finished drawing and the time they spent studying the particular structure. They were directed to draw from memory and to not copy from textbooks or workbooks. The session was run in the environment of the Clinical Skills Centre of the Medical School at the

University of Nottingham, where all the students who participated were located in the same room. This room was simply a standard classroom with tables arranged in small groups and no specific anatomical features were present.

7.2.4. Drawing Analysis

The same coding scheme as for Study 2 used to analyse the drawings created by the Year 3 students too. This coding scheme for both studies was presented and explained in the Chapter 4.

7.2.5. Issues of Validity

Internal validity

The factors that could affect the internal validity (Cook & Campbell, 1979; cited in Robson & McCartan, 2016) of this study for the data collection from the Year 3 students are listed and the extent that these were controlled is justified below. As Study 3 compared data from Year 3 students with data that was reused from Study 2 (issues of validity for this data are discussed in Chapter 6), only the considerations for the Year 3 data are discussed here:

1) **History**: No major historical events that could have an effect on the way that the students responded in Study 3 were observed at the time that the data collection was conducted.

2) **Testing**: The students could not become experienced through practice as they participated in only one session.

3) **Instrumentation**: Although an effort was made to treat these participants in a similar way with the students from the other two conditions from Study 2, the context that this study conducted was different from the one in Study 2. This different context, which also involved life drawing tasks, could have influenced the results of this study.

4) **Regression**: This was controlled as the participants assigned in the conditions by following the pre-existing groups for the session that involved and the students were not chosen by measures of any skills or achievement.

5) **Experimental mortality**: This was not a problem as the Year 3 students participated in a single session.

6) **Maturation**: This effect was eliminated for Year 3 students as data were obtained from a single session and they were all adults.

7) **Selection**: The groups of Year 3 students were pre-existing and not chosen because of any special skills or achievements.

8) **Selection by maturation**: This study completed in a very short period of time, thus this effect could not have caused any issues.

9) **Ambiguity over casual direction**: It was expected that dissection and further training in medicine would improve understanding of anatomical structures, as the opposite relationship is not logical.

10) **Diffusion of treatments, equalisation of treatments and compensatory rivalry**: These factors did not consider as issues for internal validity, because Year 3 students experienced very similar task procedures with the Year 1. The Year 3 session was designed to administer equal training to all students and did not involve a control group.

Generalisability

Robson (2011) suggests that experiments in natural settings are associated with less worries about the generalisation of the results. The fact that this study involved the real-world environment of the third-year session at the clinical placement stage was a factor that increased the generalisability of the outcomes. LeCompte and Goetz, 1982 (Robson, 2011) have given the threats to generalizability that are listed and the extent to which they were controlled in this study is described:

1) **Selection**: The population of the students in Study 3 was pre-existed, as the Year 3 students who participated were year medical students in clinical phase at the University of Nottingham. This population was not selected based on any

particular skills or achievements but constituted the normal third year cohort of a medical school in the UK.

2) **Setting**: Data for this study was collected in a real-world setting of a Year 3 session for clinical placement students.

3) **History**: No historical experiences observed that could have influenced the results of this study.

4) **Construct effects**: The task involved in the study represents a basic drawing task about a popular human organ that is considered fundamental to the medical training.

7.2.6. Issues of Reliability

The reliability of the coding scheme which used in the analysis of the drawings was established by inter-rater reliability tests. All kappa values were above .7 and, thus, these results showed that inter-rater reliability was achieved for all the variables coded. The detailed report of the inter-rater reliability is available in Chapter 4.

7.3. Findings

The hypothesis of this study was that Year 3 students would show higher scores and drawings fromthe Year 1 (after dissection) students would show improvements compared with those from Year 1 (before dissection). No expectations about the representational choices between Year 3 and Year 1 drawings were made, although it was expected in Study 2 that the representational choices of the students to differ before and after dissection.

7.3.1. Informational Features and Overall Shape

A multivariate effect of condition shown by analysing the first [3 by 1] MANOVA on the content ($F (8,278) = 6.77$ $p<.001$, $\eta_p^2=0.163$). Consequently, follow up ANOVAs conducted for all four variables: features presented accuracy of shape, accuracy of location and correct labels.

A three-way between subjects [experience] ANOVA (Figure 44) on the percentage of the features that students presented found that the main effect of the condition was significant, $F(2,141) = 9.11$, $MSe=270.22$, $p<.001$, $\eta_p^2=0.114$. Bonferroni post hoc comparisons showed that the Year 1 (before dissection) students included significantly more features for the heart than the Year 3 students (14.8, $p<.001$). However, although the Year 1 (after dissection) drew more, this did not significantly differ from the Year 3 students in the percentage of features that included for the heart (7.6, $p=.070$).

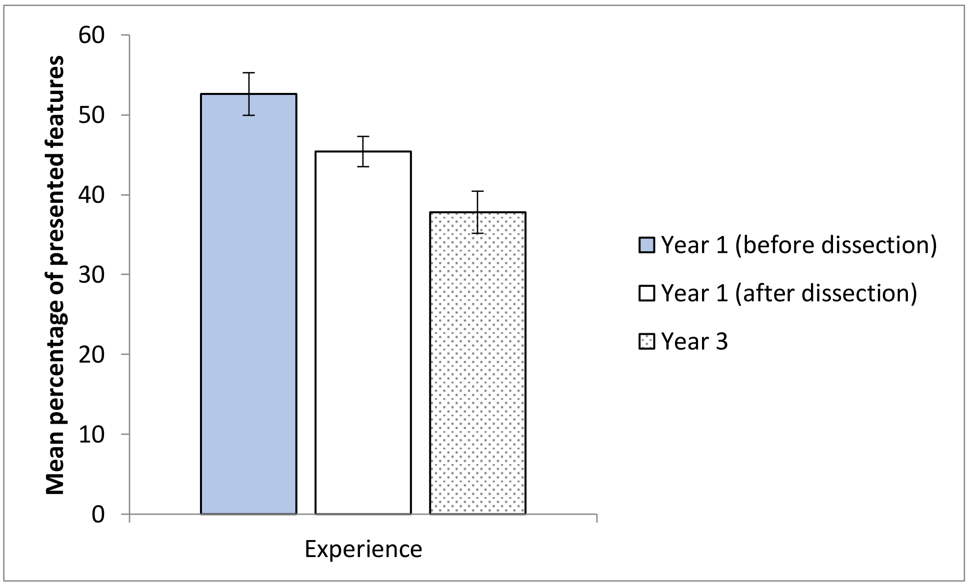


Figure 44. Mean percentage of the features that students included in their drawings for the heart in each condition

The second three-way between subjects [experience] ANOVA (Figure 45) conducted on the percentage of the features that students accurately shaped found that the main effect of the condition was significant, $F(2,141) = 7.42$, $MSe = 215.18$, $p = .001$, $\eta_p^2 = 0.095$. The Year 1 (before dissection) students included significantly more accurately shaped features for the heart than the Year 3 students (11.9, $p = .001$). However, the Year 1 (after dissection) students did not significantly differ from the Year 3 students in the percentage of features that were accurately shaped for the heart (6.5, $p = .087$).

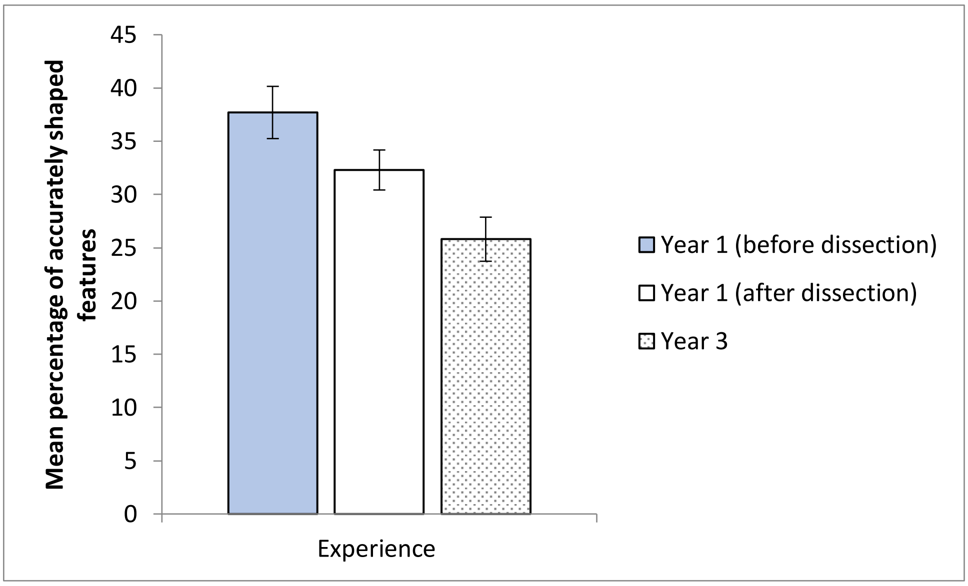


Figure 45. Mean percentage of the accurately shaped features for the heart in each condition

The third three-way between subjects [experience] ANOVA (Figure 46) on the percentage of the features that students accurately located found that the main effect of the condition was significant, $F(2,141) = 6.99$, $MSe = 227.43$, $p = .001$, $\eta_p^2 = 0.090$. The Year 1 (before dissection) students included significantly more accurately located features for the heart than the Year 3 students (11.8, $p = .001$). However, the Year 1 (after dissection) students did not significantly differ from the Year 3 students in the percentage of accurately located features that were included for the heart (7, $p = .068$).

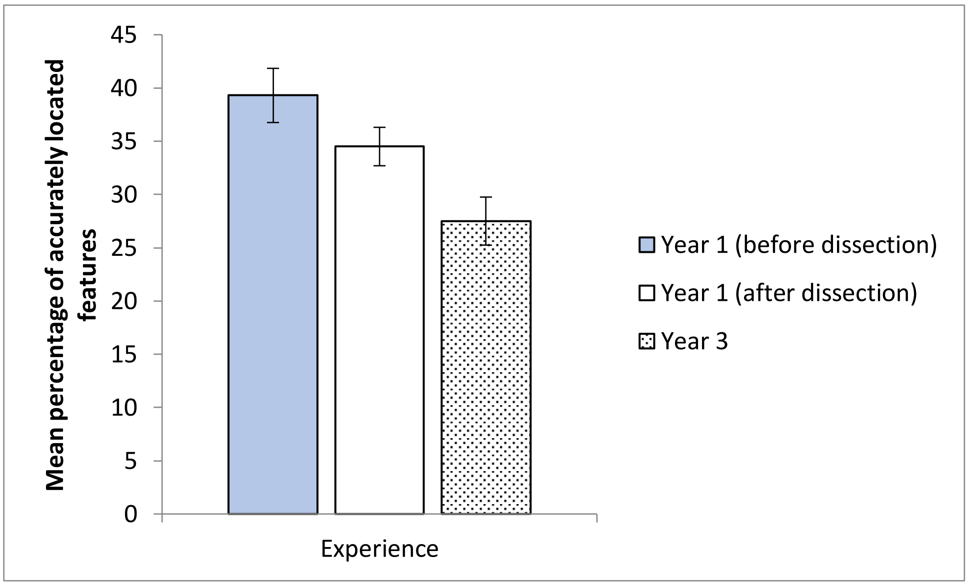


Figure 46. Mean percentage of the accurately located features for the heart in each condition

The last three-way between subjects [experience] ANOVA (Figure 47) on the percentage of the features that students correctly labeled found that the main effect of the condition was significant, $F(2,141) = 31.70$, $MSe = 228.28$, $p < .001$, $\eta_p^2 = 0.310$. The Year 1 (before dissection) students included significantly more correct labels for the heart than the Year 3 students (25.3, $p < .001$). Finally, the Year 1 (after dissection) students also included significantly more correct labels for the heart (13.9, $p < .001$).

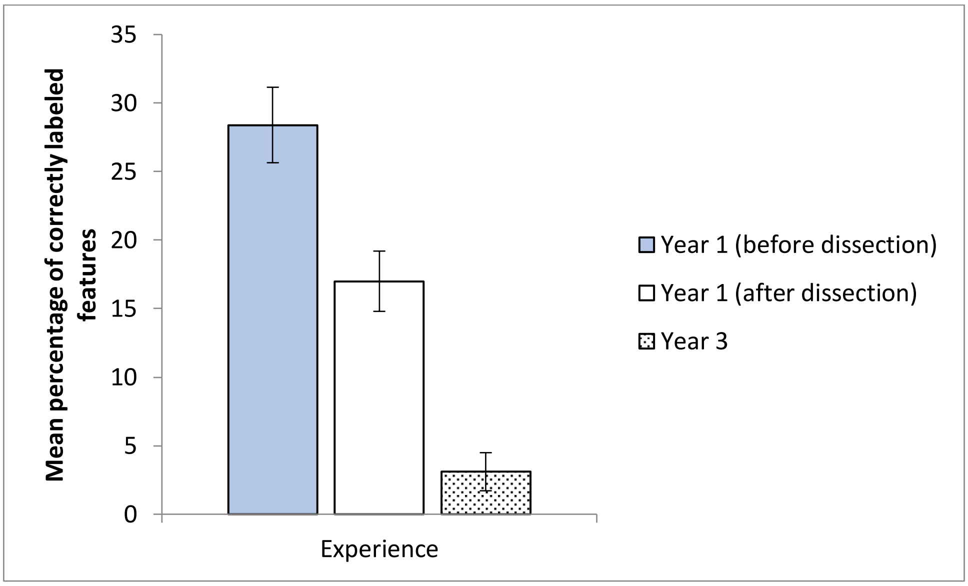


Figure 47. Mean percentage of the correctly labeled features for the heart in each condition

The second [3 by 1] MANOVA shown a multivariate effect of condition by analysing heart's overall shape ($F(6,280) = 3.86$ $p = .001$, $\eta_p^2 = 0.076$). Thus, all individual ANOVAs have been conducted for the three variables associated with the overall shape (width/height, the point of maximum width and the point of maximum height).

The three-way between subjects [experience] ANOVA (Figure 48) on width/height percentage shown that the main effect of the condition was not significant, F (2, 141) =1.83, MSe=362.85, p=.164.

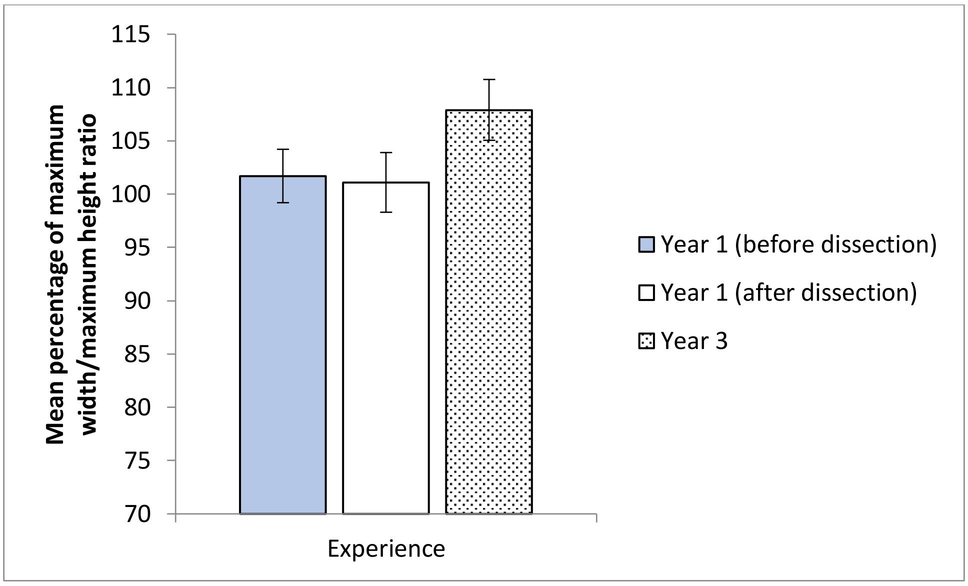


Figure 48. Mean percentage of the maximum width/maximum height ratio

The three-way between subjects [experience] ANOVA (Figure 49) on the point of maximum width percentage found a significant main effect of condition, $F(2,141) = 10$, $MSe = 273.14$, $p < .001$. Year 3 students put the point of maximum width significantly further down compared with the Year 1 (after dissection) students, which is more accurate as well, (14.8, $p < 0.001$). However, the comparison between the Year 1 (before dissection) and the Year 3 shown that Year 3 students put slightly further down the point of maximum width, which is more accurate, (7.8, $p = .082$). In addition, there was no significant difference on where the Year 1 students placed the point of maximum width (7, $p = .113$).

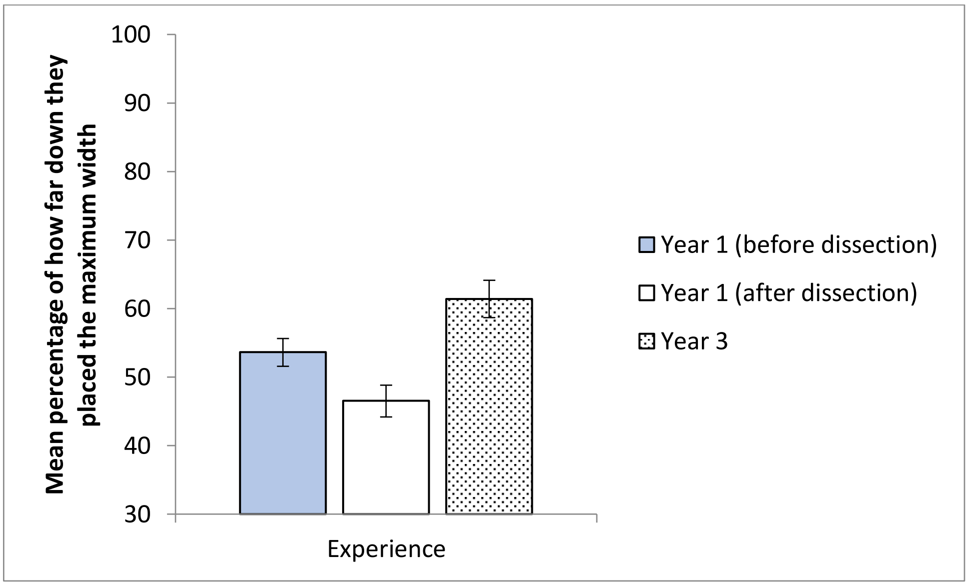


Figure 49. Mean percentage of how far down they placed the maximum width

Lastly, the three-way between subjects [experience] ANOVA (Figure 50) on the point of maximum height percentage shown a significant main effect of the condition, $F(2,141) = 6.65$, $MSe = 230.58$, $p = .002$. Year 1 (before dissection) students did not differ from Year 1 after dissection on how left they placed the point of maximum height (-1.1, p=1). It seems that Year 3 students slightly differ from Year 1 (before dissection) students in where they put the point of maximum height, as it was slightly further to the right compared to the Year 1 before dissection students, which is more accurate (-9.3, p=.013). However, when Year 3 students compared with Year 1 (after dissection) students, the post-hoc tests shown that Year 3 students put the point of maximum height more accurately, as it was significantly further to the right (-10.3, p=.003).

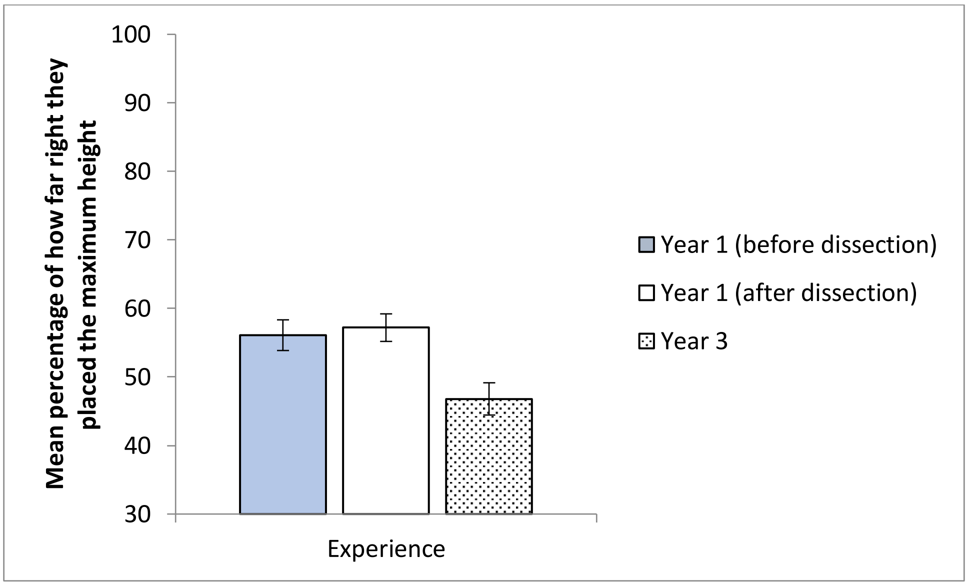


Figure 50. Mean percentage of how far right they placed the maximum height

7.3.2. Representational Choices

The students' representational choices were analysed by three chi-squared analyses. The first chi-squared (Figure 51) did not reveal any differences in the way that the students used colour between the three conditions as the $C^2(2, N=144) = 0.74$, p=ns.

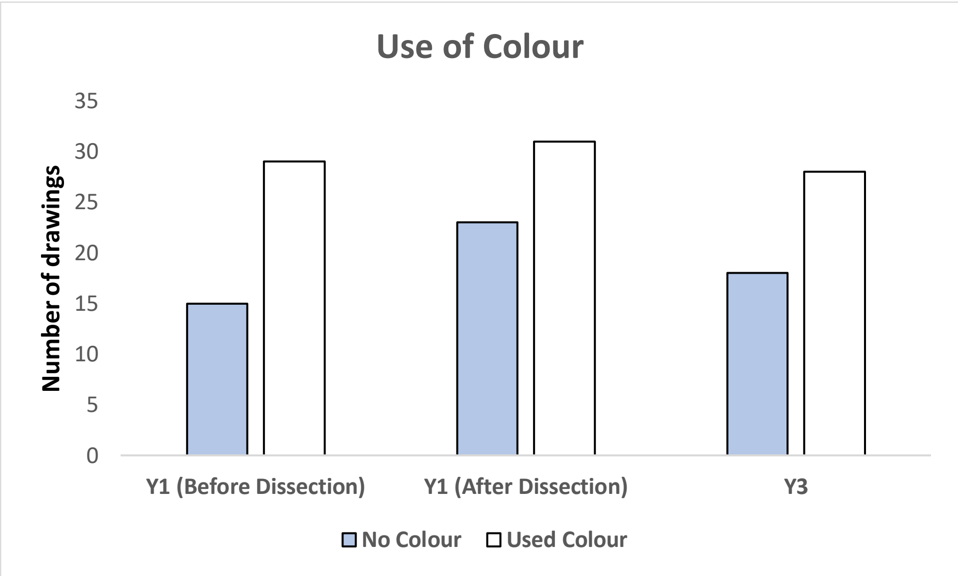


Figure 51. Use of colour in the drawings between the three conditions

No difference shown in the way they drew 3D representations as well, $C^2(4, N= 144) = 1.74$, p = ns (Figure 52).

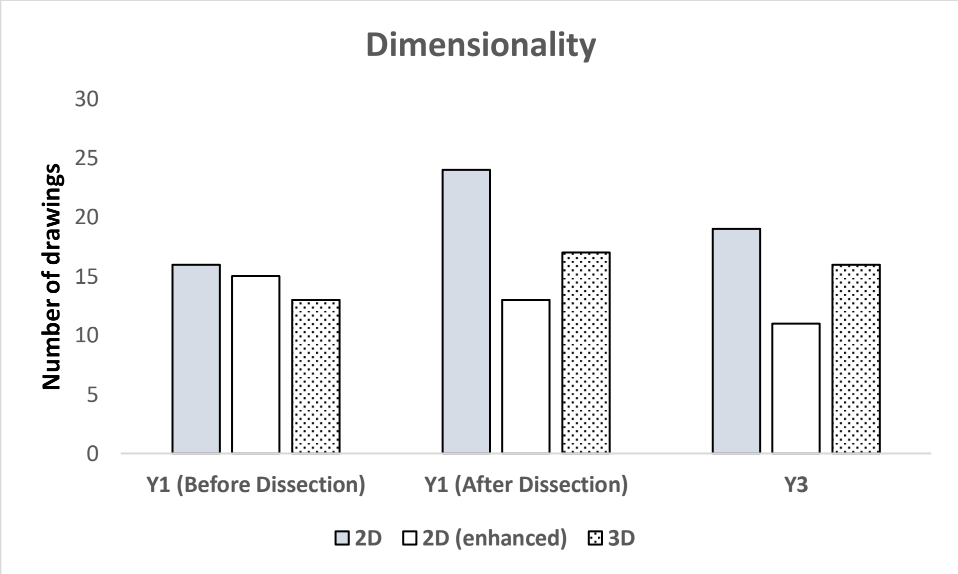


Figure 52. Dimensionality of the drawings between the three conditions

Nonetheless, drawings from the third year were judged as less clear $C^2(4, N=144) =11.03$, p=.026, being on average more “sketchy”. The last chi-squared test shown that 25/44 drawings from Y1 (before dissection) and 28/54 from Y1 (after dissection) were judged as clear, but only 13/46 from Year 3 drawings (Figure 53).

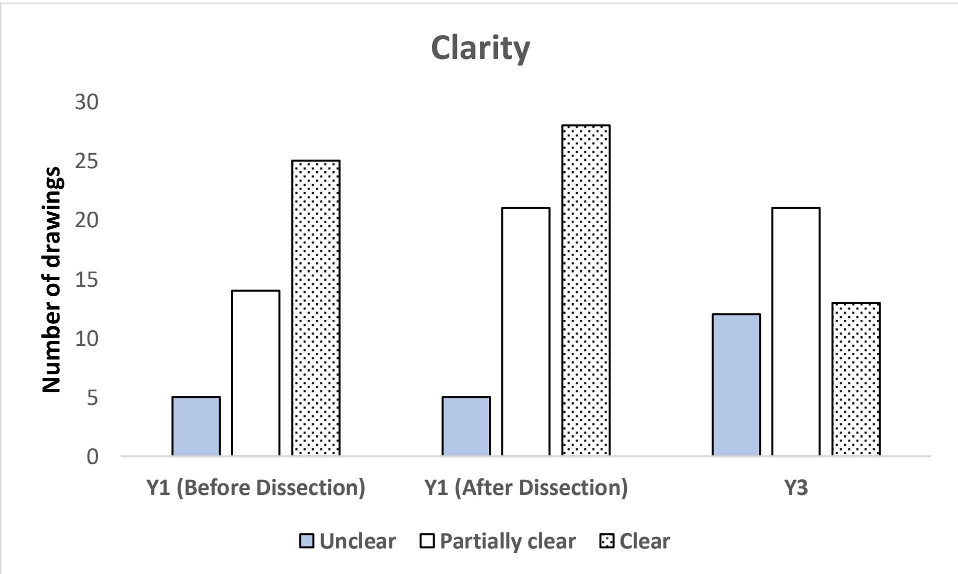


Figure 53. Clarity of the drawings between the three conditions

7.4. Summary of Findings

In summary, these results show that in comparison to the students in the third year, drawings from the Year 1 (before dissection) students included more accurately shaped, located and labeled anatomical features. Drawings from the Year 1 (after dissection) were somewhere in the middle, although they do not significantly differ from the Year 3 students in the percentages of features they included, accurately shaped and located. Only the variable of the features that the students correctly labelled was significantly different, as the Year 3 students correctly labelled less features from both conditions of the Year 1. The comparison of the heart drawings before and after dissection revealed that the only reported difference was on the percentage of the correct labels that the students provided for the heart. Moreover, Year 3 students placed the points of maximum width further down as well as the point of maximum height further to the right (left in anatomy), which both are more accurate. Lastly, the Year 3 drawings were classified as “messier” and being on average more “sketchy”.

Informational Content

Although it was expected that the Year 3 students would depict on their drawings a better understanding of the heart compared to the Year 1 students, the results show that this was not the case here also. The Year 3 students drew representations with less anatomical features in them, which were less accurately shaped and located from the drawings created in the Year 1 (before dissection). The drawings from the Year (after dissection) seem to differ less with Year 3 drawings than the drawings created from the Year 1 (before dissection). Their only significant difference was on the percentage of correct labels that provided for the heart, with Year 3 labelling their drawings far too less than students in both Year 1 conditions.

The measurements of the overall shape of the heart reveal that the shape of the heart is more accurately depicted by Year 3 students (as illustrated in Figure 54, Figure 55 and Figure 56). By experiencing the heart in situ, lecturers expected that students in Year 1 would perceive that it rests upon the diaphragm. However, this was not the case for the drawings from Year 1 (after dissection). Even though the overall shape did not significantly differ between the three conditions, the specifics of this shape were improved for Year 3 students. These students created a more accurate shape of the heart, although specific features were constructed less properly. The Year 3 students placed the points of maximum width further down on their drawings and the point of maximum height further to the right, both of which are more accurate. This result implies that dissection itself is not changing the understanding of the heart's shape based on the Year 1(after dissection). However, subsequent medical training (although it is not known what) seems to improve their understanding of the overall shape.

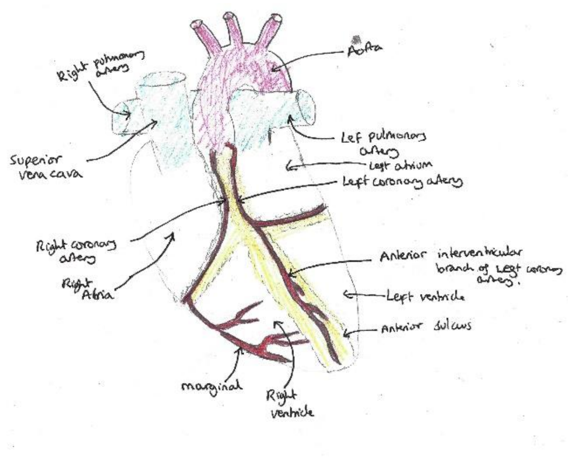


Figure 54. Example Year 1 (before dissection) drawing

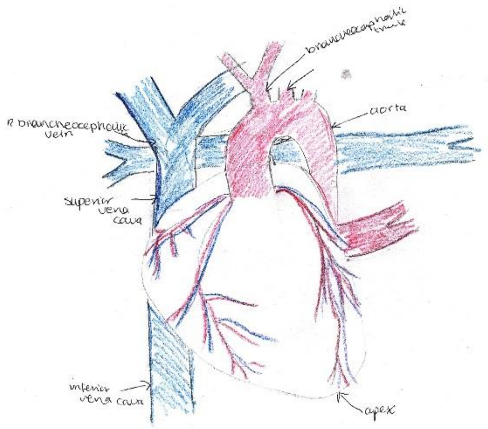


Figure 55. Example Year 1 (after dissection) drawing

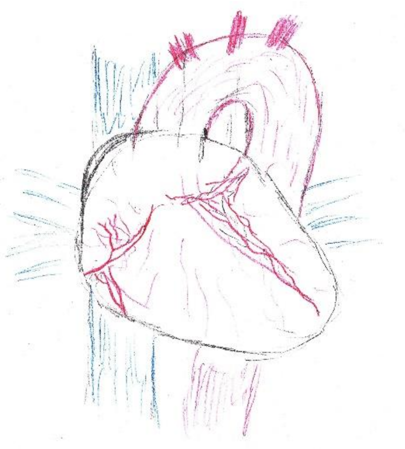


Figure 56. Example Year 3 drawing

Representational Choices

There were no expectations for the representational choices of the Year 1 and Year 3 drawings. The comparison of the three conditions revealed that the representational choices the students made between the three conditions did not differ in the use of colour or in terms of the dimensionality given to their drawings. However, the clarity scores changed for the drawings created by the Year 3 students, as their drawings were less clear compared to the Year 1 students' (Figure 57). Their drawings could be described as being more "sketchy" compared to the neat constructions of the Year 1 students. This result was not predicted in advance and it might imply that Year 3 students rely less on reproducing the textbook representation than the Year 1 students did.

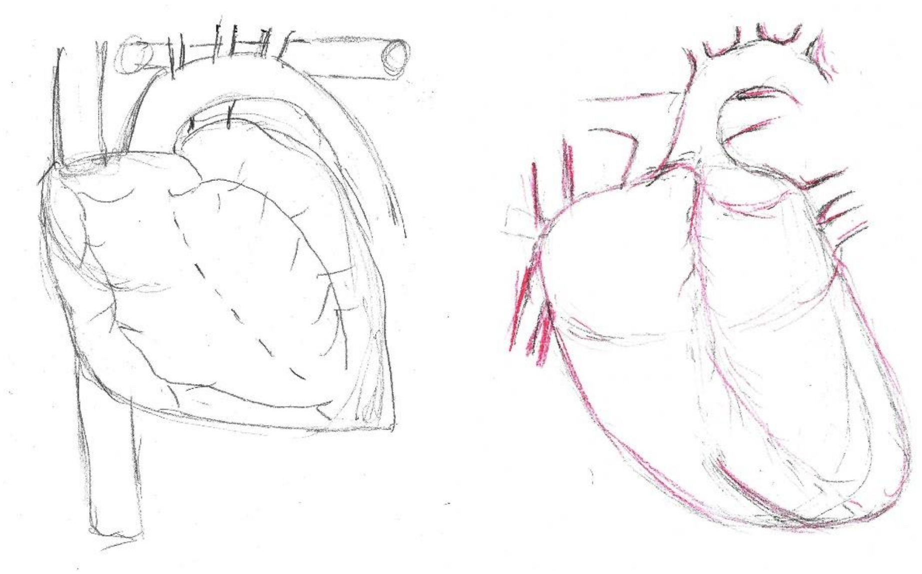


Figure 57. Examples of Year 3 drawings judged as "Unclear"

7.5. Conclusion

In this study, the way that the representation of the heart in medical students' drawings change as the degree progresses was revealed by comparing Year 3 medical students' drawings of the exterior of the heart with the same drawings that Year 1 medical students constructed in Study 2. These results suggest that the shape of the heart becomes more accurate with the years of training, although that comes at the cost of less informational content presented in Year 3 drawings. The discussion of these findings is presented in Chapter 9.

8. Study 4

8.1. Introduction

This final study attempted to investigate the way in which anatomy demonstrators approach the assessment of the students' drawings from Study 2. An extensive coding rubric was developed for Study 2 to examine whether dissection changed Year 1 medical students' drawings. The same coding rubric was used for Study 3, which compared Year 3 to Year 1 medical students' drawings to uncover the way in which further medical training changed drawings of a "popular" anatomical structure. This researchers' assessment rubric is very detailed and takes a significant amount of time to apply. It would not be possible to use such an approach in day-to-day teaching practice. Therefore, this thesis also needed to explore practitioners' perspectives on drawing as an assessment strategy for anatomical knowledge, both in general and specifically for these drawings. Therefore, interviews were conducted with expert anatomy demonstrators working at the DR sessions of Year 1 and utilised specific students' drawings from Study 2. These interviews focused on the demonstrators' understanding of drawings of the exterior of the heart and the SM and address RQ4: "How do the anatomy demonstrators understand the use of drawing in the assessment of anatomical knowledge" by answering three sub-questions:

- RQ4, Sub-question 1: "How do practitioners approach assessment of the students' drawings?"

The purpose of this sub-question was to uncover the way that they look at the students' drawings (what they do), which aspects of the informational content they consider and which they do not and whether the students' representational choices affect the decisions practitioners make about them.

- RQ4, Sub-question 2: "What do practitioners believe about the use of drawing in the assessment of anatomical knowledge?"

This sub-question set out to examine the anatomy demonstrators' beliefs (what they say) about drawing as a strategy to assess the anatomical understanding of medical students, as it explored their views on its perceived advantages and disadvantages in this context.

- RQ4, Sub-question 3: "Does the practitioners' approach of assessing students' drawings show similarities to that of the researchers'?"

This sub-question is addressed by comparing the answers practitioners give to RQ4.1 to the coding rubric in Study 2.

8.2. Methods

8.2.1. Design

Semi-structured interviews were conducted with anatomy demonstrators in the DR at the Medical School of the University of Nottingham. The interview was divided into five parts. The first part of the interview involved questions related to the informational content of the drawings. The second part was a sorting task, with a prompt to discuss the overall shape of the heart. The third and the fourth part examined whether the colour or the dimensionality in the drawings make a difference to their assessment. The last part involved questions about the demonstrators' beliefs about using drawing for assessment in anatomy. Examples of the students' drawings were included in the majority of the interview tasks in order to further direct and ground the interviewees to the issues of the discussion: the drawings that were created by the medical students in Study 2. For that study, drawings of the exterior of the heart and the superior mediastinum (SM) were collected from Year 1 dissection sessions either before or after dissection. Students had 10 minutes to draw, they could optionally use colour or labels, and they were directed to draw from memory. All interviews were audio recorded and conducted in the School of Life Sciences. One pilot of the interview questions and materials was conducted with an anatomy demonstrator before the actual interviews.

8.2.2. Participants

Anatomy demonstrators were chosen to participate in this study as they were familiar with both the curriculum of the DR Year 1 sessions and the environment in which Study 2 was conducted. Eight anatomy demonstrators at the DR participated. Participants' real names were replaced with pseudonyms in order to protect their identities. Three out of eight (Emily, Monica and Dexter) also participated in Study 1 and they are referred to with the same pseudonyms. These participants were approached and then informed about the interview and their involvement via email. The majority of them were academics at the School of Life Sciences, members of the Anatomy Teaching Group at the University of Nottingham. Four out of eight of the participants were female.

8.2.3. Interview Tasks

This interview was utilised to explore how expert anatomy demonstrators approach the assessment of students' drawings in anatomy, and to investigate the extent to which the researchers' approaches on coding those creations overlap with the teaching staff's. The context – i.e. that the drawings were collected for Study 2 – was described many times during the interview. The reason for this was to keep the interviewees grounded regarding the knowledge level of the students and the real-world environment in which the students created their drawings. In addition, example students' drawings were used for the majority of the questions, and they facilitated the discussion around the interview themes.

The first part of the interview involved questions related to the informational content of the drawings. The demonstrators were asked to assess drawings and provide their criteria of the decisions that they made, firstly about three drawings of the exterior the heart and then about three drawings of the SM. In the second part, interviewees were asked to sort three drawings of the heart from worst to best, provide the criteria of the decisions they made and comment on the overall shape/outline of the heart. In the third part, they were given one non-coloured and one coloured drawing of the SM, approximately at the same level of achievement, and they were asked if the colour makes a difference to their assessment of those two drawings. In the fourth part, they were given one drawing of the SM in 2D and one drawing that was presented with a 3D pattern; they were asked if the three-dimensional characteristics of the structure make any difference to their assessment of those drawings. For the last part of the interview, the participants were asked two questions about their beliefs on the advantages and disadvantages of using drawings for assessment in anatomy.

The examples included in the interview tasks were chosen after consulting a learning scientist and an expert anatomist (the research supervisors of this PhD). The decisions about the included drawings were made following the idea of representing various levels of informational content accuracy or various representational choices that were made by the students. The interview script and the drawings are available in Appendix 5.

8.2.4. Thematic Analysis

The data in this study were analysed by following thematic analysis principles by Braun & Clarke (2006) and described in Chapter 4. The analysis produced the themes, codes and sub-codes that are presented in Table 4 in 4.5.1.2. Some chunks of the data considered in more than one codes or sub codes. NVivo 11 was used for the coding and visualisation of the data.

8.3. Findings

In this section, the results of the thematic analysis are presented and complimented by quotes of the participants' interview data. The patterns that were identified in most or all of the participants are summarised together.

8.3.1. Anatomical Knowledge

The first and most frequent theme that was identified in the data was anatomical knowledge. This theme was captured using two codes: the anatomical content and accuracy.

8.3.1.1. Anatomical content

One pattern that was readily apparent in the data was demonstrators' consideration of the anatomical content in the drawings. This code included demonstrators' consideration of the features that the students presented in their drawings or features that students should have included but they left them out.

All anatomy demonstrators (8) considered in their assessment anatomical features that they had expectations that the students would depict and they did. For example:

> Grace: This one has an extreme amount of detail, it's actually quite impressive. You can see also they have the coronary arteries as well. Are they the coronary arteries, right marginal, yeah.

> Ivy: So I guess I'm assessing it by looking at what structures there, one of them is just very basis with a couple of structures which I thought they would have known prior to starting degree. So it's kind of like an A level type thing. Then there's an intermediate where they've got a bit more of an understanding. But then this one is pretty detailed and shows the nerve supply, and we focus on that. That's quite important, the vagus and the phrenic in the dissection, which is what this one doesn't appreciate. So this is good, okay for the vessels, but this just shows more of the structures that we'd be looking for.

All anatomy demonstrators but Brian (7/8) mentioned the missing anatomical features that they expected to see in students' drawings but were not depicted in specific instances. For example:

> Colin: I think this is poor. And it's only poor, there is no external aspects of the heart, none of the aspects of the heart are shown here, not one of them. Here, you kind of get the impression they might have run out of time, they haven't shown the left coronary system… they've taken a strange view as well, unless that is supposed to be a coronal view.

> Monica: However, the absence of information is worrying. I don't really know what these vessels are, supposed to be here. But they are obviously then completely failed to do anything else, associated with the vasculature coming off the heart. So that one is a little bit concerning.

8.3.1.2. Accuracy

The anatomy demonstrators talked on many occasions about the accuracy of the features that the students included in their drawings. This second code of anatomical knowledge theme included three sub-codes. These were coded references that captured demonstrators' consideration of aspects related to the accuracy of the shape, location and labelling of the anatomical features that the students provided. The aspects of the shape accuracy deal with the individual features as well as the overall shape. The aspects of location deal the individual features as well as the positional relationships of them. Lastly, the aspects of labelling deal only with the individual features.

8.3.1.3. Shape

Four out of eight anatomy demonstrators (Emily, Ivy, Colin and Monica) considered shapes of the individual anatomical features.

> Emily: This one has less information but is more correct in terms of its, its position of things and the shape of things.

> Monica: The drawing of the right coronary sinus is strange. It's not a box, it's actually a vessel.

Three out of eight demonstrators (James, Brian, Dexter) did not talk about the shape of individual features and for one (Grace) shape was not considered, as she believes that it is associated with drawing skills:

> Grace: Mostly I was just looking for accuracy. So the shape is not so important to me because perhaps drawing is not their skill set. I mean, obviously this one has some artistic merit. It’s very beautifully drawn, but the anatomical details are missing. And I guess, from my perspective, because probably they will be assessed on their knowledge of anatomy, it’s probably more important to have information like this presented to me in a way that at least I can recognise. I can recognise, even though this doesn’t look very well, I can recognise what every structure is.

Six out of eight demonstrators (Emily, James, Ivy, Colin, Monica and Dexter) considered the overall shape of the heart. Their comments show that they have expectations about the way that the overall shape should be presented in the drawings and they considered the extent to which drawings conformed to those expectations.

Emily, Ivy, Monica and Dexter’s comments clearly show their expectations about the heart being “twisted” or “tilted” or “at an angle” in students’ drawings:

> Monica: That one is more like a box. Neither of them have entirely got the shape right, I mean they are doing it like an egg shape here and here. And it is more twisted around the apex. It is a bit further over here, particularly on this one.

> Dexter: This is, again, this is better in that way because it is showing that the heart is tilted towards the left. It’s not exactly like this. I mean,

> this is expected. More or less. This is the one I would give the maximum weightage.

Emily clearly expressed her expectations also about the way that the bottom of the heart is represented in the drawings:

> They don't seem to get the idea that it is quite flat at the bottom. But that one isn't bad. This one does have a flat bottom, but doesn't have any of the rest of it correct. So, and that one's somewhere between the two in terms of shape. But what I wouldn't expect is for the arch of the aorta to have sharp angles in it. I'd expect it to be more like that.

James in his evaluation shows his preference for a heart's shape that was as the heart would look in the body cavity:

> James: The one which impressed me most tries to draw the heart as it would lie in situ when you open the chest and look at the heart, so you would have opened up the pericardium and look at the heart with the blood vessels. Also with the coronary arteries outside and the bigger vessels connected to the heart.

Colin's comment about the shape shows his dissatisfaction about some other aspects of the overall shape:

> Colin: I think that… this is very strange isn't it, this is from somebody who has a rigid kind of quadrangular view of the world, you imagine that everything has to be exactly right. I don't know. You kind of imagine that that one might have turned out quite nicely if they'd put the decorations on it, but either they ran out of time or something else. This is just slightly odd, the fact that the artery comes much too far downward here, and the fact that the anterior interventricular artery isn't only bowed over like that.

Two out of eight (Grace and Brian) did not consider the overall shape of the heart in their evaluations. Grace did comment briefly on the overall shape of the heart but her evaluation shows that she did not put that much emphasis on searching for details that make different the three shapes of the heart that were presented to her:

> Grace: I think all are virtually the same. I mean, it's close enough, it's accurate enough.

For Brian, however the overall shape is not important:

> I don't really, given the heart is a dynamic structure, and changes shape, I don't really put much emphasis on the shape.

8.3.1.4. Location

This code described reference to individual anatomical features location accuracy and the positional relationships between features. Location accuracy seems that it was something that appeared to a great degree in demonstrators' evaluations of accuracy.

All anatomy demonstrators except James (7/8) considered the accuracy of location of individual anatomical features. They considered aspects of the positional accuracy or inaccuracy that depicted in students' drawings as illustrated in two examples:

> Emily: It's partly the amount of information and partly anatomical correctness. So, I judge that one the worst because it doesn't really resemble the structures. Although there is information on it. This one has less information but is more correct in terms of its, its position of things and the shape of things.

> Grace: I would take off marks because of the incorrect position of the subclavian vein here. But otherwise everything is correct.

To a greater extent, all demonstrators (8/8) considered the accuracy of location by looking at the positional/relative relationships of the anatomical features. For example:

Ivy: I think I was looking at the kind of overall shape of the heart, looking at where the great vessels are coming out from. Looking if there's any information about the chambers, seeing if they're in their relative positions because this is something that they, from A level coming into their degree they tend not to understand. They see it as a kind of like a 2D, chambers at the top, ventricles at the bottom, and how it's kind of… the anatomic position is slightly different. But yeah, thinking about what the great vessels coming out, their position, the chambers.

Colin: And so it isn't clear for example, what happens to the aorta and the pulmonary artery here, but you can see there the person has actually thought and managed to remember that they go round one another. They've put the superior vena cava behind the pulmonary artery which is a problem, but there we are.

8.3.1.5. Labelling

Although the labelling of the anatomical features had not been required by the students and this was clearly stated in the interview brief, six out of eight considered labelling in their assessment of the students' drawings. It seems that only two out of eight demonstrators, James and Brian, did not consider labelling at all in their evaluations, as there were no references to aspects of labelling in their interview.

For six out of eight demonstrators (Emily, Grace, Ivy, Colin, Monica and Dexter), their considerations of labelling were related to the quantity or quality aspects of the labels that the students provided, as illustrated in two examples:

Colin: They are correctly labelled. They are all the correct labels.

Monica: A quite long shot, it's reasonably accurate, it's not got all of the labels I certainly would like to see.

Monica also identified incorrect labels in her evaluation of the drawings:

> They haven't labelled it but this is clearly the vagus…They've done…. They've messed the left and right though. So this is, I've just realised, this is right vagus, it is supposed to be left vagus. This right phrenic, it is supposed to be left phrenic.

Monica and Dexter considered labelling to be a practice that helps the identification of anatomical features that the students included in the drawings:

> Dexter: This is ugly. I don't like it very much because I can't read also, whatever they have written. That's why it should… the naming should be legible. For example, because the examiner will have to search for what are they firstly. Secondly is that the… no, I'm not impressed with that.
>
> Monica: These two…that must be the trachea there…I wish they labelled this a bit more, because I'm presuming this is the trachea and this is supposed to be vagus nerve? They haven't fully labelled this one, which is not very helpful. Presumably these lines going across, that's how we depict the trachea, so I presume that's the trachea. And I presume that's the vagus? If so, it's not very accurate the position of the vagus but they haven't labelled it, so I can't be sure…

8.3.2. Representational Choices

This theme deals with the representational choices that the students' employed in their drawings. Two codes were emerged in the data. These codes referred to the three-dimensional nature of the anatomical features and the use of colour in the drawings.

8.3.2.1. Three-dimensions

Three-dimensional (3D) characteristics in the drawings were considered by all anatomy demonstrators. Based on their responses, for all eight demonstrators the dimensionality of the drawings does make a difference to their assessment of the drawings.

For six out of eight of them (Emily, Brian, Grace, Ivy, Colin and Monica) the drawings with 3D characteristics were clearer and it was easier for the demonstrators to read them.

> Monica: It makes easier to interpret. I would spend, have to spend a lot less time looking at this to understand it than this one. This one would require more time and a bit more effort to interpret it and I'd be concerned. With this one it's quite clear that the student understood what's in front of what. And in this one, how would I know? How would I know that the student doesn't think that that the right bronchus sits on top of the arch of the aorta from that picture? From that picture, I know that the student knows the positional relationship of these two structures.

Brian stressed the importance of letting the students know that the depiction of the 3D relationships is one of the criteria that they are assessed on.

> It does, yes. It's much, much clearer. But again, it depends on what you want to assess. If you want to assess the students' detailed knowledge, this is probably alright. At the moment, I cannot see a clear mistake. If there was, if the emphasis is here on showing the 3D relationships then that's a different story. Even… to… basically with assessments you have to stick to the criteria you gave to the students, unless you tell them you judge also by impression. (and continues a bit later) But I wouldn't, the temptation of course as a teacher to judge, because it's much easier to grasp, to judge this much as better is higher, but I think you'd have to be clear and fair to the students to do that.

However, Emily's response was considered more neutral than the others.

> I think the three-dimensional aspect of that does give you a perception of depth, of what structures are in front of what. Whereas, this one is not terribly clear, if you didn't know, you could imagine that the trachea is in front of all of these. Whereas it is clear from this drawing

> that it's behind it, if you see what I mean. Yeah, but rather than that, I don't think this one adds any information, it's just, this one I think is easier to understand instantly, whereas that one you have to study it a bit to work it out.

Additionally, five out of the eight anatomy demonstrators (James, Brian, Grace, Ivy and Monica) put an additional value on the students' understanding in drawings that demonstrated 3D characteristics.

> Brian: And it's telling that this one and this one are thinking of providing some of the 3D effect, because the biggest problem that, or one of the big problems that I see with the students learning anatomy is that they learn from a 2D textbook and they try to translate it into a 3D environment. And you can see, you can see here that the one that has the least precision, also has the least 3D information, the 3D attempt of it. So, this is probably an earlier stage or not quite as developed stage of 3D understanding compared probably to this one.

> Ivy: It makes you realise whether they truly appreciate how the structures are related to one another. And again, indicates an appreciation that perhaps they've got after dissection, more than before dissection. So they appreciate what goes behind where, and where things cross each other, and those kinds of things. So yeah, I think an attempt to do this shows a greater level of understanding than perhaps the previous ones that you've shown me, of the superior mediastinum.

For three out of eight demonstrators (Grace, Colin and Monica) the three-dimensional characteristics were associated also with strong drawing skills.

> Grace: And many students like to draw, but many students aren't very skilled at it. So it could very well be, like that last one you showed me, where I was saying shading adds this dimensionality and it allows me to tell where things are in order. And by not shading, that student didn't

give me that information, but it could very well be that they know that information, it's just they're crap at drawing.

8.3.2.2. Colour

All demonstrators considered aspects of the use of colour in the drawings. For all eight demonstrators, the use of colour seems that makes a difference on the way that they looked at them.

For seven out of eight of them (Emily, James, Brian, Grace, Colin, Monica and Dexter) the colour made easier the reading of the drawings and some of them highlighted how that relates to the textbook conventions/anatomy conventions in colouring their drawings.

> Grace: But I would probably give this one a slightly higher mark just because it is really quick and easy to see everything. This one is correct also, but I have to struggle to figure out.

> James: Well the colour makes it much easier of course, of course. It is the usual colour scheme of the blue for veins, red for arteries and yellow for nerves. It is much more, more difficult on the black and white drawings because you have to read the labels and see what they relate to. So the use of colour is much easier.

However, Brian stressed that the drawing materials should be available to all students in order to consider the use of colour to be considered fair in the assessment of them.

> If this student would have used colour, it certainly would have gained. But again, what do you want to do with the judgement? Insofar as that, in an exam situation, I would only be fair judging the use of colours, if the students would have been pride accordingly. So, if this one by chance had a few colour pencils in his kit and he didn't, he would be outjudged [Unknown].

Although Dexter did not imply that the colours made the drawings easier to read, Dexter comments about the colour showed that he's passionate about drawings which considers "properly" coloured, the drawings which were coloured by following conventions in anatomy

> Definitely. Definitely, definitely. See, though this is almost… both of them are of the same standard. Standard means I'm talking about the standard, the information they have given, okay. The level of information they have given, they are the same. But this stands out because this one is coloured. And it's properly coloured, not that the arteries are level or drawn in blue or the veins are in red, something like that. Proper colours and properly coloured. So that's what makes it stand out.

Two out of eight demonstrators (Brian and Ivy) commented that the use of colour revealed an additional dimension of the students' understanding in their drawings by showing whether the blood was oxygenated vs deoxygenated blood.

> Brian: It does make a difference, absolutely. With the blood flow, of course. It shows a functional understanding.

Three out of eight of them (Emily, Grace and Ivy) talked also about issues around the aesthetic quality of the drawings.

> Grace: But when I'm assessing, I mean, obviously then the use of colour… well also this one is a little more aesthetically pleasing too, to be honest. But that shouldn't really be taken into account in our assessment. But I would probably give this one a slightly higher mark just because it is really quick and easy to see everything. This one is correct also, but I have to struggle to figure out.

8.3.3. Functional Aspects of the Drawings

This theme captured the aspects related to various functions that drawing serve in teaching, learning and assessment. Two codes were identified in the data to bring together references to the use of drawings in formal assessments (two sub-codes: advantages, disadvantages) and references about the use of drawings in teaching and learning.

8.3.4. Drawing in Formal Assessments

This code gathers together the two sub-codes with the references from the interviews where they talked about the advantages and disadvantages of using drawing in the formal assessments.

8.3.4.1. Advantages

Five out of eight of the demonstrators (Emily, James, Brian, Ivy and Monica) expressed views about the advantages of using drawing in formal assessments, either in the DR assessments at the end of the sessions or the assessment at the end of the semester. Some of them (Emily, Ivy, Monica) stressed that uncover positional understanding in particular.

> James: But as I said I think that it's a brilliant. Very easy, very quick to see how much and how deep somebody understood a certain topic.

> Ivy: I think you can really get if they understand it. Whereas a multiple-choice question will take a bit of knowledge, but trying to understand how things relate to each other, I think you can get that kind of level of understanding if you ask.

Three out of eight of them (Emily, Brian and Ivy) commented on the advantages of drawing against to the mode of answering questions:

> Emily: Because I think the recall of relationship is demonstrated better by them drawing it in some ways than just answering questions about it. Obviously, we 've got the option of them looking at the real specimens and identifying things, but there is a limit of how much of that you could do. Whereas, if they have to draw them, it does have to come out of their head, rather more if you are asking them a set of questions, that sort of thing.

> Brian: And it tests something very different than just a bunch of questions, where the guess factor always comes in.

8.3.4.2. Disadvantages

Demonstrators also talked about the disadvantages of the use of drawing in assessment. The most common concern – reported by six out of eight demonstrators (Emily, James, Brian, Grace, Ivy and Monica) – was whether a lack of drawing skills was a disadvantage for the use of drawing in assessment.

> Emily: The only thing about is that obviously some students are much more talented in drawing than others. And when you ask students to draw something and you see what they produce, some of them are almost like a work of art and others are not very helpful at all. They are like spiders gone mad. So, I wouldn't like the assessment to penalise people who haven't got a natural talent for drawing.

> Grace: So I would say that it is useful, but probably more useful would be to provide them with a very nice drawing that’s clear, and have them label the structures. That would be my preference. Just because then you take out the subjective component, the artistic talent of people.

James suggested an approach to assessment as a response to the students’ arguments regarding their drawing skills.

> In theory, as students could argue that some are better in drawings than others. But during assessment we would just ask for a quick sketch and wouldn’t, wouldn’t, how to say, assess it in artistic way but just for the content.

Four out of eight demonstrators (Emily, Brian, Ivy and Monica) talked about the time constraints of using drawing in assessment.

> Emily: (DR assessments): I think probably time would be the issue there. If they had the time to do the drawing, it would take us a lot of time to assess it. Because you'd have to look at them all. And within the

> in-course assessment at the end, time is very tight and if you ask them to draw something, it would be a very sort of sketchy on the hoof type of drawing. Because there isn't the time for them to do it properly. So I don't think it would work in these contexts without a lot more staff time being allocated to it.

> Monica: The other thing is that...time I think. A lot of the assessments we do, certainly in the first year, they wouldn't have time. I mean a lot of it is computer based and in the second year we are trying to get them to write more. But certainly, in the first year we do. It's a lot computer based. So timewise...

Two out of eight of them (Ivy and Colin) talked about students who learn with visuals and those who do not, as illustrated in Ivy's comment:

> So yeah, I guess it would disadvantage people who… and people who don't learn in a visual kind of way. For me that makes sense, and I think anatomy is quite a visual kind of discipline. But some people just don't find that, and can picture it in their mind but could never reproduce it.

Lastly, two out of eight demonstrators (Emily and James) talked about the form of current assessments in which drawing does not easily fit.

> Emily: Since we switched to electronic media, drawing is not easy electronically. If it was possible to for the university to invest in better tools to draw, where you can use styluses to draw quite accurately. I've got a stylus that works quite well on a screen, where just moving a mouse around is horrible for drawing.

> James (on DR assessments): So we have quite a large number of staff and the students always complaint that somebody assessed harsher than another member. So the solution we came up with is to make a question bank and then have each assessor ask same question. And this makes it really impossible to assess students on an individual basis.

8.3.4.3. Drawing in Teaching and Learning

Five out of eight demonstrators spontaneously referred to the application of drawing in teaching or learning, even though they were not prompted to talk about this.

Four out of eight demonstrators (Emily, Grace, Ivy, Dexter) seemed to value drawing as a learning tool. For example:

> Emily: I do think if students could be encouraged to draw more, they would appreciate spatial relationships better. Because if you draw it, you've got to look at it properly. Whereas if you just look at other people's pictures or trying hold it in your head it’s not, only when you draw it you look at it in a more critical way I think.

Two out of eight demonstrators (Grace and Ivy) reported that they used drawing to learn themselves.

> Ivy: So I kind of experienced drawing it, and actually that, for me, it was one of the ways where I could learn anatomy when I wasn’t in the dissection room. So even now when I teach stuff, I have to draw it if I’m trying to refresh my memory. I have to draw things out because I can’t appreciate it in written word. So, for me, drawing is fundamental for me knowing and testing myself.

Lastly, two out of eight demonstrators (Monica and Dexter) talked about the employment of diagrams and drawings in their teaching, with Dexter being very passionate about drawing for teaching.

> Dexter: I believe in 3D’s, drawing, discussion and dissection. So these are things. So, drawing is definitely an essential and important tool in the hands of the anatomist. Because I also teach with drawings, on the board or on the smartboard. So, drawing definitely plays an important part in my teaching, that is for sure.

8.4. Summary of Findings

The objective of this study was to identify the way in which anatomy demonstrators approach the assessment of learner-generated drawings, their views about drawing as an approach for assessment in anatomy and, lastly, whether how they look at drawings is consistent with the quantitative approach undertaken by the researchers to analyse the drawings for Study 2 and Study 3 in this thesis.

- RQ4, Sub-question 1: "How do practitioners approach assessment of the students' drawings?"

The results showed that the informational content that the students included in their drawings was of predominant importance to practitioners. Whether students included (8/8) or excluded (7/8) anatomical features was mentioned by the vast majority of demonstrators. This finding is not unexpected, as the target of those students' drawings was to assess students' understanding of anatomy, and the grasp of anatomical content is a fundamental objective of their training in anatomy.

Beyond their simple presence, demonstrators also commented on the accuracy of those anatomical features in terms of their shape, location and labelling. The shape of the individual anatomical features was not considered by half of the demonstrators. One demonstrator stated that she does not consider shape that much, as she relates shape with drawing skills and she only wants them to be at least recognisable. However, more demonstrators (6/8) talked about the overall shape of the heart, but we should consider that this, in part, may be because they were prompted to do so. Their evaluations revealed that they expected to see some characteristics of the heart's shape as it is inside the body with specific characteristics being illustrated (e.g. the heart to be twisted around the apex), but some aspects were considered very problematic.

Their discussions around location accuracy were not only focused on the correct or incorrect location of the anatomical features (7/8), but were also extended (to a greater extent) to positional relationships (8/8). The results show that demonstrators not only value the accuracy with which the students place anatomical features in their drawings, but they also value how those anatomical features are drawn with respect to their related features. This emphasises the importance of understanding the location of the anatomical features when students receive training in anatomy.

In addition, even though the labelling in the students' drawings was optional and the demonstrators were informed of this, it seems that most of them (6/8) considered the quality or quantity of the labels that the students provided. One demonstrator also identified incorrect labels when she was assessing the drawings. Moreover, a small minority (2/8) of the demonstrators highlighted in their responses that a label is a mode in drawings that helps them identify the illustrated anatomical features. It can thus be suggested that labelling is considered an aspect of the students' understanding that the demonstrators value and expect to see in their drawings. In addition to the informational quality, labelling was considered as something that assists demonstrators' assessment of the drawings, as it makes their reading easier. It can be argued that this quality of labelling is key for identifying features when the person who looks at them is unsure about their nature, especially in a context like this where the students were not available to provide clarifications.

To sum up, the interview data clearly showed that the informational content of the drawings was considered of great importance when demonstrators looked at the drawings. The demonstrators looked beyond the presence of the anatomical content, as they considered aspects of the individual features' location, positional relationships, the overall shape of the heart, the individual features' labelling and, to some extent, the individual features' shape.

Demonstrators also discussed the representational choices made by drawers but only in terms of the dimensionality of the drawings and the use of colour. Dimensionality seems to make a difference to all demonstrators' assessments. For most of them (6/8), drawings that presented 3D characteristics were clearer and easier for them to read. However, one demonstrator stressed the importance of making sure that the students knew that they should depict three dimensions in drawings if they were to be assessed in these terms. In addition, many of them (5/8) believed that understanding was shown through 3D characteristics. These results support the argument that dimensionality should be considered not only as a representational choice that makes the drawings more readable, but also as a choice that the demonstrators associate with understanding. However, a minority (3) of the demonstrators associated dimensionality of the drawings with strong drawing skills.

The second sub-code concerned the representational choices regarding the use of colour. The responses of almost all of the demonstrators (7/8) highlighted that colour makes drawings more readable; in particular, some of them referred to the textbook/anatomy conventions. In addition, a small minority (2/8) of demonstrators talked about an additional, functional understanding that could be shown in the coloured drawings concerning the blood flow. Finally, a minority (3/8) associated colour with aesthetic quality, although they implied that the aesthetic result is not considered in their judgements. These patterns strongly support that colour is not only associated with aesthetic qualities, but, to a great extent, is also considered a key aspect of the drawings in such "crowded" representations depicting anatomical content and can provide access to additional understandings of the students' knowledge. Without a doubt, the dimensionality of the drawings and the use of colour can be argued as representational choices that do make some difference to the way in which demonstrators look at the students' drawings.

In general, anatomy demonstrators could also express any additional expectations for the drawings that they looked into, but they did not. For example, they could have expectations for more than one view of the structure with regard to the informational content, comment extensively enough on the clarity of the drawings for it to be considered a code in the analysis or mention other aesthetic elements in the representational choices. However, it seems that they were not considered relevant to the context or important in their assessments.

- <u>RQ4, Sub-question 2</u>: "What do practitioners believe about the use of drawing in the assessment of anatomical knowledge?"

Demonstrators identified both advantages and disadvantages in the use of drawing as an assessment tool. Most participants (5/8) identified advantages for drawing as an assessment tool and stressed that they see it as a valuable assessment tool in anatomy. Specifically, 3/8 demonstrators compared drawing with answering questions, and saw drawing as having the potential to cover aspects that the questions could not.

However, they identified a number of disadvantages of using drawing as an assessment tool. It seems that the majority of them (6/8) consider the need for drawing skills as a drawback of employing drawing to assess students. Interestingly, one demonstrator stated that drawing skills are something that the students would argue is influential in their assessment; instead, he suggested that a "quick sketch" could be assessed regardless of its artistic quality. In addition, a small minority (2/8) talked about students who learn with visuals and those who do not. Another disadvantage that was expressed by half of the demonstrators (4/8) was the time pressure of the DR and final assessments. Lastly, a small minority (2/8) brought up the issue of drawing not fitting into the way in which the current DR and final assessments are conducted (electronic assessments, question banks for fairness). It can thus be suggested from the demonstrators' beliefs that, although many of them consider drawing a valuable assessment tool that can provide advantages that answering textual questions cannot capture, they see many disadvantages that cause them concern regarding the use of drawing to assess their students' understanding.

Finally, even though the demonstrators were not prompted to talk about it, a code emerged concerning drawing in teaching and learning. A small minority (2/8) suggested that they use diagrams and drawings in their teaching. In terms of drawing to learn, half of the demonstrators (4/8) seemed to value drawing as a learning tool, with two of them using drawings to learn themselves. Thus, it seems that a section of the demonstrators saw the potential in drawing beyond assessment, with some of them also employing drawing in their practice or for personal goals.

- RQ4, Sub-question 3: "Does the practitioners' approach of assessing students' drawings show similarities to that of the researchers'?"

The last issue that this study attempted to explore was whether the two approaches undertaken in this thesis (the researchers' and the teaching staff's) were similar in the way they approached drawing for assessing understanding in anatomy.

To analyse students' drawings in anatomy for Study 2 and Study 3, an extensive coding rubric was developed by the researchers of this project. At a fundamental level, this approach was echoed by the practitioners. The informational content of the drawings dominated both approaches. Researchers' consideration of anatomical features and the accuracy of features' location, labelling and the heart's overall shape were considered by most of the demonstrators. However, the shape of the anatomical features was only considered by 4/8 demonstrators. One reason for this could be that it was considered a time-consuming feature to be excessively assessed. This argument is further supported by the time required from the researcher to evaluate individual features' shapes compared to the evaluation of location and labelling accuracy. In addition, it seems that the demonstrators value the representational choices of dimensionality and colour to a similar extent as the researchers, who considered them in their coding rubric. However, the clarity of the drawings, a code that was included in the coding scheme for the data from Study 2 and Study 3, it rarely explicitly referenced enough in demonstrators' interviews. It can thus be concluded that the fundamentals of the two approaches of assessing students' drawings in anatomy overlap to a great extent.

- RQ4: "How do the anatomy demonstrators understand the use of drawing in the assessment of anatomical knowledge?"

The answers of the three sub-questions examined in this study synthesise in the answer to the research question set in this chapter. Undoubtedly, the findings revealed areas of the informational content that the demonstrators consider highly important when they assess drawings in anatomy, and the way in which representational choices could make a difference in how they examine them. Beyond that, it becomes apparent that the fundamentals of the two different approaches – the researchers' versus the teaching staff's – overlap in the criteria that were used to look into students' drawings in anatomy. Moreover, these findings also revealed the demonstrators' views on the advantages and disadvantages of drawing as an approach for assessing understanding in anatomy. Although a number of them considered it a valuable assessment tool in anatomy, the majority discussed the drawbacks of employing such a tool in their practice.

The discussion of these findings, their implications and links to the wider literature are presented in Chapter 9.

9. Discussion

The outcomes of the four research studies in this thesis are discussed here and organised into four sections, one for each study. Then, the limitations of the undertaken research approaches in this thesis and the implications are described, before the concluding remarks.

9.1. Research Question 1 (Study 1)

RQ1: "How do the anatomy demonstrators understand the use of visual representations in anatomical dissection: in teaching, in learning and in assessment?"

Study 1 explored the use of visual representations and drawings when anatomy demonstrators introduce dissection sessions to the Year 1 medical students. This study also revealed these demonstrators' beliefs about visual representations and drawing in teaching, learning and assessment. This exploration took the form of observations of seven anatomy demonstrators during their introductions and interviews with the same seven demonstrators.

The results showed that drawings are used by some demonstrators. There are some people who draw a lot and some people who are not big fans of drawing, as they consider themselves not great drawers. One demonstrator stated that he draws in front of his students and not prior to the session, as he expressed the belief that students can benefit from watching and that they also get the time they need to copy down the demonstrator's constructions. There is evidence by Fiorella & Mayer (2016) that shows that observing the instructor creating drawings enhanced the learning of university students with low prior knowledge of the depicted content. In addition, anatomy demonstrators who generally draw in our study reported that these drawings engage the students, as the students do not only copy them or take notes from them, but also reproduce those representations. A reported aspect of drawing is its usefulness in the communication of structural aspects, which it was also argued by

Tversky (2011) to be something that visual communications can project immediately to an extent contrary to words.

The view was also expressed that the drawn diagrams need to be simple/schematic. It could be argued that this demonstrator decision is wise for the students, as Winn & Snyder (1996) argue that it is the schemas' abstraction (the memory's organised structures) that makes them useful, as the important parts are emphasised effortlessly. Tversky (2011) also claimed that the speed and accuracy of information processing is boosted when schematisation of diagrams is employed.

Another type of visual representation used quite a lot by all of the anatomy demonstrators who participated in this study is 3D visuals. The advantage of the three-dimensionality of those visuals was claimed to be what makes them very powerful tools for the demonstrators in the spatially intense anatomical domain. Drawings was thus not the most used type of visual representation by the anatomy demonstrators, as 3D visuals were used to a great extent by all the demonstrators and also reported a lot in the interviews. As argued by Azkue (2013, p. 146), who characterises learning in this domain as an "essentially a three-dimensional endeavour", demonstrators usually preferred to be assisted by physical models, among other 3D visuals, when the focus is on small and complex anatomical structures.

The use of images was also reported in the interviews by a small minority of demonstrators. This pattern was also reported in the study by Cook (2011a), where a high school teacher stated that, in biology, photographs of tissue cross-sections were used when teaching anatomy and physiology, and diagrams were only employed for content that was impossible to depict in real pictures.

Only a very minimal use of text was reported in the observations. It could be suggested that demonstrators prefer to use 3D visuals (which are available in their task room in the Dissection Room) or drawings (if they draw or have the chance to reuse a drawing from another demonstrator). This choice seems strategic and relates to the structural nature of the content, which they argued can be communicated easier through visual means, as structural aspects are projected immediately in visual communications, contrary to what words could convey (Tversky, 2011).

Finally, it is worth discussing here that a limited use of multiple visual representations at once was observed, as only a single demonstrator seemed to use more than one representations together. Another demonstrator also commented on the multi-representational use of a diagram and a 3D visual in the interviews. It seems that this is contradictory to the results by Ainsworth & Newton (2014) in science, where teachers' multi-representational use of visual representations was quite evident.

9.2. Research Question 2 (Study 2)

RQ2: "Do student drawings reveal changes in understanding after dissection?"

This investigation took the form of real-world experiments, where drawings of the exterior of the heart and the SM by 98 Year 1 medical students were collected. A crossover design was employed with two conditions, where students in condition 1 drew the exterior of the heart before dissection in Week 1 and drew the SM after dissection in Week 2. This was reversed for condition 2. An extensive coding scheme was developed to analyse these drawings for the purpose of this research study.

The results did not show a strong effect of dissection on the drawings that the students created either immediately before or after dissection. For those specific learning outcomes under investigation, dissection seemed to not immediately change students' understanding – and, when it does, it is not for the better. It could be valuable to determine for which of these improvements dissection is proven to be responsible to the greatest extent or whether these improvements can be developed by other forms of training. It could also be, as has been argued in the field, that dissection puts the students' focus on the process – such as taking decisions about the process of dissection itself – and not so much on the content related to what they are learning (Ross, 2015). It might also be that dissection, as part of medical training, does not radically transform students' understanding for the better, but gradually adds to the medical practitioners' development alongside other anatomical training and learning materials. This improvement might need time, and possibly does not show the characteristics of a rapid transformation.

If anything, it could be argued that dissection might have destabilised prior understandings of a popular structure, as some aspects of the representation of the heart showed differences after dissection. It could possibly be that, for structures such as the heart where students have prior expectations formed by prior knowledge or popular culture, dissection possibly destabilises this. Tunnicliffe & Reiss (2001, p. 93) highlight "…the public awareness and usage of terms related to the internal organisation of bodies, particularly blood, brains and bones and the heart", which is consistent with the results of their study. Moreover, they reported that even five-year-old children at the very beginning of their education show some extent of understanding regarding animals' internal anatomy in their drawings. Visual representations seen by students in their prior education or in popular culture could have significantly influenced the knowledge that they bring to their anatomical training for specific regions of the human body. However, this is not immediately replaced with a more expert and nuanced understanding. Pawlina & Lachman (2004, p. 10), argue in support of the teaching method of dissection in learning anatomy that the students, "…before they can understand the true anatomy of these structures, they must unlearn information that they have already been taught". Thus, it might be that, for the heart, dissection possibly destabilised students' reliance on "textbook" knowledge and popular culture but did not immediately replace it with a more nuanced understanding.

On the other hand, for the SM, students did not appear to have strong expectations or knowledge prior to studying dissection. This collection of structures of the human body is not usually presented to the students widely before the start of their degree, as the representation of the heart is. Thus, it can be suggested that students possibly do not bring to the DR extensive prior knowledge or expectations formed by popular culture for the SM and, consequently, their representations of it did not show great differences after dissection.

This argument is additionally supported by the expected decrease in the labelling on the heart drawings. There is evidence suggesting that medical students do value textbooks as a useful method of teaching in anatomy (Snelling, Sahai & Ellis, 2003). Therefore, it could be argued that dissection might be a reason for their reduced attachment to the textbooks' fully labelled representations of heart drawings. It would be more encouraging if the students had increased their scores for the rest of the informational content. However, the results of this study show that the heart drawings were not altered for the better after dissection.

The results of this study need to be interpreted with caution. The extent to which dissection might have helped students destabilise their prior understanding and replace it with something better is not known. It is also not known whether the destabilised content was replaced with something more accurate as the medical degree progressed.

Another possible explanation for these results might be that drawing is not the right medium to reveal any fast improvement in the students' understanding after dissection tasks. It might be that small-scale changes might need more sensitive or targeted instruments to be measured. By all means, there is a variety of methodologies that could give different views on students' understanding such as spotter tests, multiple choice questions etc. (as described by Brenner et al., 2015 in Chapter 2) and they might demonstrate a better understanding of this content. Moreover, it was not possible to interview a representative sample of students about their drawings and achieve a wider perspective on their understanding. Thus, the provided conclusions are limited to their constructed representations.

However, it should not be easily assumed that drawing is not helpful as an assessment tool for some areas or that dissection does not much change students' understanding. Empirical evidence from the literature on drawing for learning by Van Meter (2001) suggests that, when students received instructional support, their drawings showed increased accuracy as compared to students who drew unsupported when reading a science text. Therefore, it might be that the lack of instructional support when the students constructed their drawings was responsible for not allowing them to adequately depict their understanding in their drawings.

9.3. Research Question 3 (Study 3)

RQ3: “Do student drawings reveal changes in understanding of anatomy as the medical degree progresses?”

This investigation emerged after an invitation to participate in another project and it was not initially planned. It took the form of a real-world experiment, where Year 3 medical students drew the exterior of the heart by following the same instructions as the Year 1 medical students from Study 2. Eventually, the drawings from the Year 3 medical students were compared with the data of the Year 1 drawings from Study 2, which was reused to answer this research question. The same coding scheme developed for Study 2 was used to analyse the Year 3 drawings in this study.

Although it was expected that the Year 3 students would depict, in their drawings, a better understanding of the heart as compared to Year 1 students, the results show that this was not the case. The hypothesis of this study is only somewhat supported. Firstly, heart drawings from the Year 3 students were more accurately shaped (the heart’s overall shape) but this came at the cost of the accuracy of specific anatomical features. The Year 3 students drew representations with less anatomical features in them, which were less accurately shaped and located than the drawings created by the Year 1 students before dissection. The drawings from the Year 3 students seem to differ less with Year 1 drawings after dissection. Their only significant difference was on the percentage of correct labels provided for the heart, with Year 3 labelling their drawings far less than students in both Year 1 conditions.

One explanation for limited informational content and its less accurate depiction in Year 3 drawings might be the limited training in anatomy after the beginning of the medical degrees. On one hand, this supports the arguments of those who criticise the reduction of anatomy training in the medical degrees as they proceed (e.g. Older, 2004; Turney, 2007). For example, Turney (2007) when discussing the course of anatomy in the modern curriculum, expresses the opinion that further improvements in modernization can be made if the required essential knowledge of anatomy is agreed and assessed also throughout the clinical years and beyond. As much of informational content is related (to a certain degree) with memorisation (the number of anatomical features on the exterior of the heart and labelling especially), the little exposure to anatomy education as highlighted by Turney (2007) might be responsible for this limited informational content in the Year 3 drawings. By any means, this does not imply that a short refresher of the content could not reactivate this knowledge. However, the fact that the drawings have become more abstract and less detailed does not necessarily mean that students did not have this detailed understanding, instead it could be argued that perhaps they simply choose to privilege other aspects of the heart when drawing it.

We know as well that medical students value textbooks as a useful teaching method in anatomy (Snelling, Sahai, & Ellis, 2003); therefore, the results of this study might suggest that the detail of the informational content in Year 1 (before dissection) drawings suggests that the students relied a lot on textbook representations. Moreover, Year 1 (after dissection) drawings relied less on the textbook representation as they included less labels. The Year 3 students undoubtedly showed the minimum association with what is presented in textbook drawings of the heart.

It was expected that the students in Year 3 would hold a more established and accurate idea about the representation of the human heart overall, formed by the training received during that time. However, the results revealed the development of a more precise understanding of the heart's overall shape as the degree progressed, but this came at the cost of the number and accuracy of the anatomical features. This finding resonates with the studies which have found that compared to novices, experts tend to have developed more abstract representations. For example, Adelson (1984) studying computer programmers found that undergraduates focussed on concrete details (how it functions) whereas teaching fellows focussed on its abstract form (what it's for). This finding has now been replicated in Hay et al. (2013) for example, where neuroscience novices (undergraduates) constructed textbook-ish drawings of neurons, whereas trainee scientists (PhD and postdoctoral researchers) relied more on mechanical observation and experts in the domain (laboratory leaders) created more schematic constructions.

It seems that drawing is helpful for assessing an understanding of the spatial aspects of internal anatomy, especially shape. The results of this study justified that drawing as an assessment tool can reveal the wrong expectations that Year 1 students bring regarding the shape of the heart, as claimed also by other studies where drawing uncovered students' misconceptions (Dikmenli, 2010; Köse, 2008). Based on the results, the use of drawing in the assessment of anatomical understanding can reveal changes in spatial characteristics as the degree progresses, such as the overall shape of the heart. The results from Cooper et al (2015) also recommend that students' drawings make evident to a greater extend the students' understanding, especially of spatial characteristics compared to writing. However, the results may suggest that drawing can be time-consuming as a tool to assess specific anatomical context, and possibly adds little beyond written responses. As Reiss & Tunnicliffe (2001, p. 384) stated in a study that investigated the understanding of human organs and organ systems in students' drawings, "…it may be that different methodologies reveal different things about the multi-dimensional complexity usually labelled understanding but better recognised as understandings".

9.4. Research Question 4 (Study 4)

RQ4*:* “How do the anatomy demonstrators understand the use of drawing in the assessment of anatomical knowledge?”

Artefact-based interview data were collected from eight anatomy demonstrators in the Year 1 dissection sessions to answer this research question. Those demonstrators were asked to assess some drawings of the exterior of the heart and the SM that were created by Year 1 medical students in Study 1. Those artefact-based interviews were based around questions regarding the informational content and the representation features of those drawings. This study predominantly investigated the way in which anatomy demonstrators approached the assessment of students’ drawings. However, in addition, this investigation also showed that the areas of interest in the evaluation of students’ drawings for research purposes (Study 2 and Study 3) are very highly related to the ones that the anatomy demonstrators focused on during their assessments.

Firstly, the anatomy demonstrators focused their assessments predominately on informational content – i.e. the anatomical accuracy of the drawings. The number of anatomical features in the students’ drawings was something that they all examined. Adding to the presence of the anatomical features, they also examined, to a great extent, the location and positional relationships of those features, as well as their labelling. The shape of the individual anatomical features was also considered by some demonstrators, with several discussing the overall shape of the hearts that they were shown; they were able to identify problems in the ways in which students depicted the heart’s overall shape. Scoring based on the accuracy of students’ drawings is evident; accuracy is also evident in the coding schemes within the *drawing to learn* and *drawing in assessment* literature of various domains, including neuroanatomy (e.g. Cooper et al., 2015; Dove et al., 1999; Schwamborn, Mayer, Thillmann, Leopold, & Leutner, 2010; Slominski, Momsen, & Montplaisir, 2017; Van Meter, 2001; Van Meter, Aleksic, Schwartz, & Garner, 2006).

Regarding the students' representational choices, most of the anatomy demonstrators believe that the drawings' dimensionality makes a difference to their assessments, as it makes the drawings more clear and readable. This was also reported for the use of colour, with some demonstrators referring to textbook/anatomy conventions. It is worth emphasising that dimensionality was also associated with understanding. This was not unexpected at all, as an understanding of three-dimensional anatomy is included in the arguments of medical educators on teaching methods in anatomy (Estai & Bunt, 2016; Korf et al., 2008; Older, 2004).

Regarding the demonstrators' beliefs about the use of drawing as an approach to assess understanding, many of them considered drawing as having advantages for the assessment of anatomical understanding. Some of them reported that drawing could provide information for some aspects that the questions could not. This pattern was reported in the results of the study by Cooper et al. (2015), where it is suggested that drawings could give a better view of students' understanding compared to their written responses, especially for spatial aspects. However, anatomy demonstrators reported a number of disadvantages related to the implementation of drawing to assess understanding in anatomy. The majority of them consider drawing skills a drawback for using drawing in assessment. Another disadvantage that was expressed by some of them concerned the time pressure within the dissection sessions and the final assessments. The time pressure within the anatomy curriculum nowadays is something that medical educators stress quite a lot, and they express worries regarding the consequences on the development of medical practitioners (e.g. Estai & Bunt, 2016; Korf et al., 2008; Turney, 2007).

In addition, it was also evident that some of the demonstrators consider drawing a valuable strategy in learning, something that is increasingly being investigated in the reviews by Van Meter & Garner (2005), Quillin & Thomas (2015) and Tippett (2016). A small minority also report that they use drawings in their teaching.

Finally, it is worth mentioning that the fundamentals of the practitioners' approach to assess students' drawings in anatomy and the one undertaken by the researchers in this thesis overlap to a great extent. Both the researcher, deriving his approach for previous studies which have identified features of drawings that predict understanding, and the practioners, based upon the teaching experiences, emphasised content and dimensionality. Neither approach was particularly focused upon aesthetics choice except to the extent they impacted upon the clarity of information content information. However, there were significant differences in how the approaches were enacted. The practioners were drawn immediately to salient errors in content, allowing quick perceptual marking of the drawings. The researcher conducted a painstaking and detailed systematic coding approach which left no aspect of the content unmarked. Whilst the researcher's approach might therefore be needed for statistical analysis it would not be practical to implement in in the classroom. It could however form the basis of computer marking of drawings, as seen recently in approaches such as CogSketch (Forbus et al., 2011) which required a detailed model to be created in advance.

9.5. Limitations

This section aims to describe the limitations of the research studies in this thesis and highlight what could improve the design and implementation of those studies. Some of these limitations have already been mentioned at some point earlier; however, this section aims to sum them up and dig deeper into what could have been better.

The first limitation relates to the observational data that was collected for Study 1. It would have been better if all the demonstrators could have been observed an equal number of times. This was not possible, as some demonstrators taught less than others and four of them taught at the same time in all sessions. Efforts were also taken not to cause any inconvenience within the busy lab environment of the DR; thus, the decision about the sessions involved were based on matters of convenience.

A second limitation concerns the design of Study 2. This study had very limited time available within the ongoing curriculum and, thus, the pre-existing distribution of students (random assignment) had to be followed, as well as the different anatomy demonstrators within the four task rooms in the DR and sessions, which also repeated biweekly (task room variation). It would have been better if we could get the same participants to complete the same drawing task before and after dissection.

Another limitation in Study 2 concerned the topics that were involved in the design. The topics of the heart and the SM were being taught at the beginning of the Year 1 dissection sessions. Consequently, if the time had allowed, more topics would have been included from different times of the Year 1 dissection sessions.

A limitation in both Study 2 and Study 3 concerns an issue related to the content the students depicted in their drawings. It could have helped if the students were interviewed after the drawing tasks or if they were asked to provide written descriptions with their drawings. However, due to the limited time that was available within the ongoing curriculum where Study 2 and Study 3 were conducted, those additional approaches were not possible.

Another limitation that concerned both Study 2 and Study 3 has to do with the environment that “informal” assessment procedures were conducted. A significant effort was made in to proctor the environments to limit any copying from one another or materials, although the tasking rooms of the DR cannot be considered as a strictly “formal” assessment environment and the way that the sitting areas in the task rooms in Study 2 or the room that Study 3 was conducted, certainly they cannot relate with environments that fully supervised, strictly proctored assessments are being conducted.

Finally, Study 3 was not planed and it emerged after an invitation to participate in another project. This project involved life drawing tasks and this might have had an influence on how the students approached my drawing task. Although, an effort was put to stress to the students that my drawing task was part of a research study with specific issues under investigation.

9.6. Implications

This section deals with the implications for further research, as derived from the results of the four studies in this thesis and their discussion. The section is not subdivided according to the research studies, as some of the implications are based on more than one of them.

Firstly, it could be suggested that drawing skills should be better mastered within the domain, and, eventually, the self-efficacy of both students and staff should be boosted. Potentially, this could remove some barriers of employing drawing for teaching and assessment.

Secondly, a further investigation on the distinct levels of medical training is needed, where the gap in the level of training between the starting and the senior medical students would be more apparent. This could help to uncover if there are any areas in which drawings could show an advantage compared to the forms of assessment currently being used. One additional future area of research is the investigation of the extent to which cadaveric dissection is destabilising students' prior expectations about the structures for which they bring prior knowledge to the DR. Therefore, future studies on these topics are recommended.

Lastly, further research is needed to establish the areas where drawing could benefit assessment in anatomy compared to other methodologies. Based on the results of Study 3, it seems that drawing could be used successfully to assess students' understanding of an organ's shape, which would be difficult for other assessment instruments to do. Further longitudinal studies should be undertaken regarding the use of drawing in assessment, especially for revealing misconceptions and quickly assessing the overall shape accuracy. In addition, further research is needed to explore what current assessments are missing out on this and whether computer marking could support the use of drawing in assessment within this context.

9.7. Concluding Remarks

The first contribution of this thesis is made to the research area of the use of visual representations and drawings in teaching. It has increased our current understanding about the way in which these tools are being used in teaching within anatomy education. In addition, this study reveals more about the anatomy demonstrators' perspectives regarding the use of drawing in teaching, learning and assessment.

The second contribution is made to the area of using drawing as an approach to assess students' understanding. The results of this thesis have enhanced our current knowledge on the use of drawing as an approach to assess students' understanding in the spatially intensive domain of anatomy – specifically, regarding the way in which drawing can be used as a tool to assess any immediate changes in students' understanding and changes as the degree progresses. Moreover, our understanding of the way in which anatomy demonstrators approach students' drawings in anatomy has been significantly enhanced.

A third minor contribution is made to the discussion around the use of dissection as a teaching method within anatomy education. However, those implications from Study 2 regarding the use of dissection to destabilise students' prior knowledge should be interpreted with caution.

A methodological contribution is made by developing, evaluating and employing a coding scheme to analyse university students' drawings in the context of anatomy education. An extensive coding scheme to analyse drawings in this field of expertise, created by students at that level, was not found in the literature. Moreover, the already available approaches in the literature on *drawing to learn* and *drawing in assessment* were judged as insufficient to capture the detail expected when assessing medical students' understanding with the use of drawing. A characteristic of this coding scheme is that it considers not only the informational content of the drawings, but also the representational choices that their creators made.

Therefore, it could be concluded that a step forward has been made towards knowing more about drawing in teaching and assessment within anatomy education, a practice evident in the domain since the ages of Leonardo da Vinci. Hopefully, further research will cover more aspects and further develop our knowledge on the use of such a low-cost tool in the field, thus providing more recommendations on how its full potential can be achieved.

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Appendices

Appendix 1: Observational Schedule (Study 1)

Demonstrator:

Date: Time:

Location:

Duration	*Activity*	*Type of representation*	*Comments*
	C **I**	**Photograph** **Diagram** **Picture** **X-ray** **Physical models** **Text** **Video**	

Appendix 2: Interview Questions (Study 1)

General

1. What factors / points are important for you when you teach the dissecting room sessions?
2. What aspects / topics do the students find most difficult?
3. Can you describe the methods you prefer to use to teach these classes?

Representation

4. Could you list the types of representations that you use?
5. Do you prefer to create them yourself or you prefer to use existing material?
6. If you create new material; do you do so during the sessions or before the session starts?

Drawing

7. Do you think that using visual representations and drawing in particular can improve student learning and assessment in anatomy? If so, why?
8. Do you think that there are disadvantages in using visual representations and drawing in particular for learning and assessment in anatomy? If so, why?

Appendix 3: Drawing Task for the Exterior of the Heart (Study 2 & Study 3)

Name: Start time:______

End time:______

Please estimate the amount of time you have already spent studying the structure ______

Instruction: Make a drawing of the **external aspects of the heart to show its anatomical features**. Please draw the structure from memory (do not look at books or notes). If you wish you can use the colour pencils provided. At the end, if you consent please leave your drawing for me and sign a consent form.

Please make your drawing in the space below

Appendix 4: Drawing Task for the Superior Mediastinum (Study 2)

Name: Start time:______

End time:______

Please estimate the amount of time you have already spent studying the structure ______

Instruction: Make a drawing of the **superior mediastinum to show its anatomical features.** Please draw the structure from memory (do not look at books or notes). If you wish you can use the colour pencils provided. At the end, if you consent please leave your drawing for me and sign a consent form.

Please make your drawing in the space below

Appendix 5: Artefact-Based Interview Questions (Study 4)

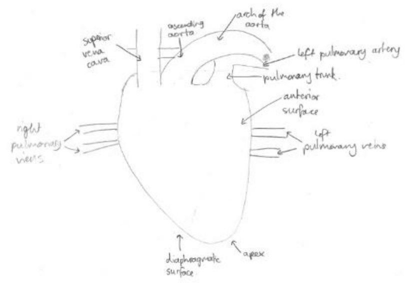
Introduction: Thanks for your time today. Earlier in my PhD I've collected from the first-year practical dissection sessions a large number of student drawings of the heart and the superior mediastinum and I've analysed those drawings for their content and form.

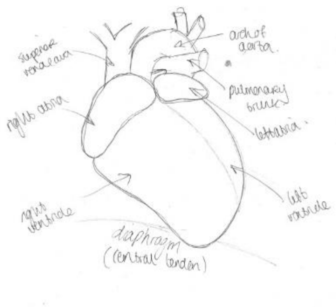
At this stage, I would like to see what you as a member of the teaching staff think about these drawings. Today I will show to you some of the students' constructions and I would like to have a conversation with you about some of their features.

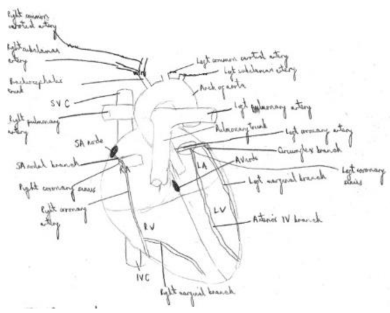
A. CONTENT

Introduction: Let's start with these first drawings. I'm going to show you 3 drawings of the exterior of the heart and 3 drawings of the superior mediastinum and I'll ask you some questions related to their content.

Here are the three drawings of the exterior of the heart created by first year medical students either before or after dissection. Students had 10 minutes to draw, they could optionally provide labels or use colour and they were directed to draw from memory.







<u>Questions</u>

a. How would you assess these drawings of the heart?

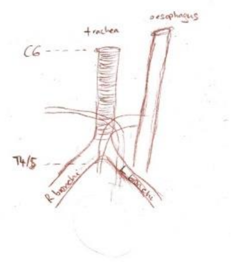
(Do you think they are any good?)

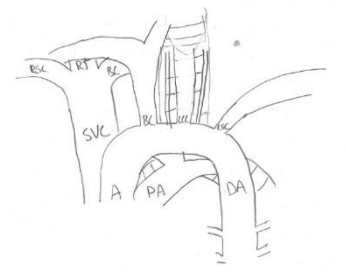
b. Now that you have looked at these three drawings, could you tell me the criteria you used for the decisions you've made about how good they are?

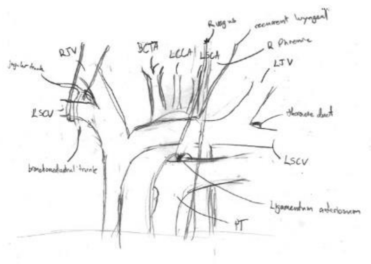
(Which of their features are important to you when you assess these drawings?)

After I finish with the questions about the heart:

Now I'm going to show you 3 drawings of the superior mediastinum created in the same context.







a. How would you assess these drawings of the superior mediastinum?

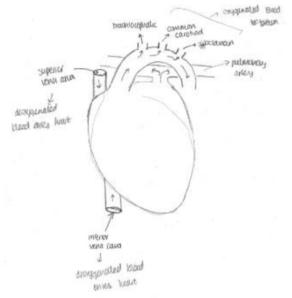
(Do you think they are any good?)

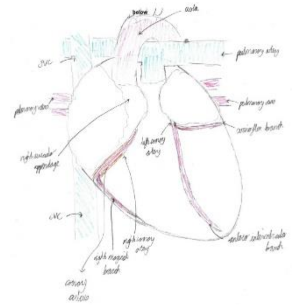
b. Now that you have looked at these three drawings, could you tell me the criteria you used for the decisions you've made about how good they are?

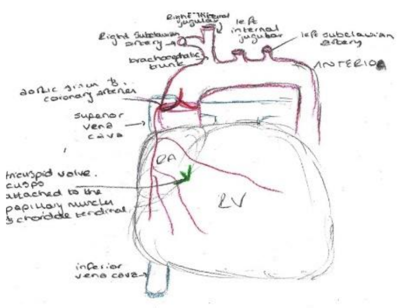
(Which of their features are important to you when you assess these drawings?)

Exit to task B: Thanks for your useful comments. Now I'll show you another 3 heart drawings and I'd like to ask you a couple of different questions.

B. OUTLINE OF THE HEART SHAPE







These drawings created in the same context, either before or after dissection, where students had 10 minutes to draw, they could optionally provide labels or use colour and they were directed to draw from memory as I mentioned to you earlier.

<u>Questions</u>

a. Can you sort these drawings from worst to best for me?

(Do you think they are any good?)

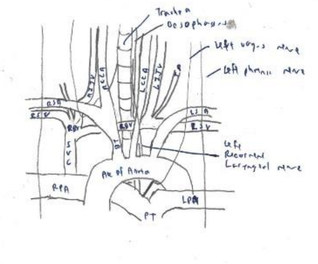
b. Now that you have looked at these three drawings, could you tell me the criteria you used for the decisions you've made about how good they are?

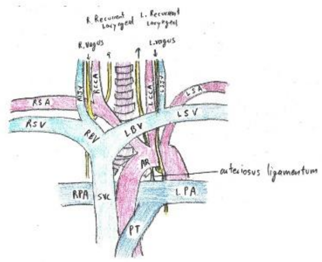
(Which of their features are important for you when you assess these drawings?)

-*If they don't mention the outline then I will after expectedly draw their attention to it:* What do you think about the overall shape/the outline of the heart in these drawings? Is it what you expected to see?

Exit to task C: Let's change the focus now. I'm going to show you two drawings of the superior mediastinum that first year medical students created in the dissection practical sessions in the same context as the heart drawings I've shown you before and I'd like to ask you a question about a specific characteristic of them: the colour.

C. USE OF COLOUR





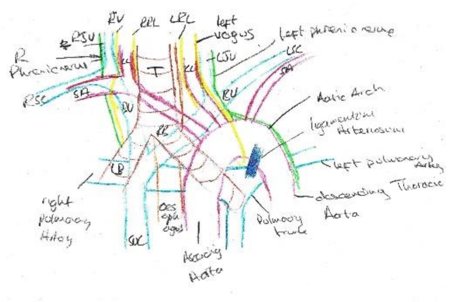
Questions

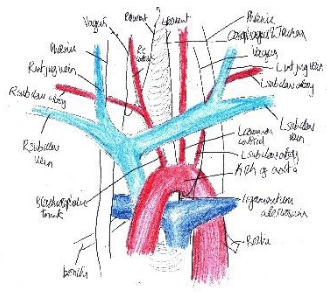
a. Does the use of colour make any difference to your assessment of these two drawings?

(Does the colour here add anything to your opinion about these drawings?)

Exit to task D: Now let's move to another visual feature of two superior mediastinum drawings I'll show you now.

D. DIMENSIONALITY





Questions

Again, these drawings created in the same context as before.

a. Does the attempt to represent the three-dimensional nature of the structures in the drawing make any difference to your assessment of these two drawings?

(Do the 3D characteristics and the clear spatial relations here add anything to your opinion about these drawings?)

Exit to task E: Thank you for all your useful answers to my questions. Now that you've seen a number of students' drawing in anatomy, I'd like to ask you a few questions about the use of drawing as an approach of assessment in anatomy.

E. ASSESSMENT

Questions

a. Do you think that there are advantages in using drawing for assessment in anatomy, at any place that assessment can be conducted?

b. Do you think that there are disadvantages in using drawing for assessment in anatomy, at any place that assessment can be conducted?