Duncan of Jordanstone
College of Art & Design
University of Dundee

ZOË JARVIS

Art Observation and Visualisation Advances Medical Learning and Clinical Proficiency

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Zoe Jarvis

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Abstract

In the field of medicine, art and visualisation has influenced the progression of medical education, practice and research from the early renaissance to now. This interdisciplinary dissertation aims to explore these contributions to medicine and suggest appropriate inclusions of art visualisation within medical practice and research. These contributions additionally suggest innovations in pedagogy for medical education that is partly interdisciplinary through an inclusion of valuable artistic methods and visualisation practice.

The practice of visualising can make information easier to understand (Agosti *et al.*, 2013) and improve observational skills (Dolev, Friedlaender and Braverman, 2001). Therefore, historically and up to the present day, the use of visuals has aided medical understanding and the formation of improved clinical proficiency. The information in this dissertation demonstrates firstly how art observation and in more recent years, artistic methods in medical curricula, have directly increased anatomical learning. Then there will be a demonstration of how artistic study can improve observational skills that are essential for effective clinical practice. Finally, discussions will explore how both technological visualisation and science art have progressed many aspects of medical learning including wider public engagement. Consequently, this dissertation argues that art and visualisation techniques have considerable potential and value within modern medical pedagogy.

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Glossary of Scientific Terms

Clinician:	A highly proficient healthcare worker with relevant qualifications, such as a doctor (*Clinician*, 2025).
Physician:	A doctor, someone who has general medical skills and does not perform surgery in their medical practice (*Physician*, 2025).
Biomedical image analyst:	An expert in technological analysis tools who then offers these skills to Life Sciences research that requires imaging experts ('Career - NEUBIAS: Network of BioImage Analysts', no date).
Applied sciences:	Applied Science courses offer learning about the practical application of scientific research instead of theoretical learning.(*Why Study Applied Sciences? | Guides | Northumbria University*, no date)

<u>Introduction</u>

Throughout history, art and visualisation has been known to progress medical learning from the first anatomical illustrations to technological visualisation used currently. An involvement of artistic study and teaching methods in education can have direct benefits to clinical proficiency. Through an exploration of various sources relevant to the research topic, this dissertation will argue for art observation to be utilised throughout medical practice and research, as well as providing an advised medical pedagogy that values a frequent involvement of art observation and practice of visualisation. This aim of suggesting a partially interdisciplinary medical pedagogy is to provide medical students with the best ability to retain and easily understand information which would then develop improved clinical proficiency.

Chapter 1 will discuss how the implementation of illustrations vastly advanced the knowledge of anatomy and hence clinical treatment historically. By exploring the discoveries of new anatomical findings in the 1500s made by Andreus Vesalius (Vesalius, 1543) and Leonardo Da Vinci (Jones, 2012), the involvement of visualisation and artistic approaches towards these discoveries will become clear. An acknowledgment of the first influential anatomical illustrations will emphasise the revolutionary effect on learning in the field of medicine. In more recent medical curricula, there will be a discussion on the occasional employment of artistic methods in addition to dissection which can engage medical students and allow information to be more easily understood (Agosti *et al.*, 2013).

Chapter 2 will discuss how artistic study within medical pedagogy improves clinical proficiency. There will be an exploration of various studies that determine how the deep looking and discussion of paintings can develop enhanced observational skills which then directly enhance diagnostic skills (Bardes, Gillers and Herman, 2001; Dolev, Friedlaender and Braverman, 2001). Both skills being imperative for clinical practice when interacting with and accurately diagnosing patients shall be addressed. The essential role of empathy within clinician proficiency will be discussed, using evidence that it contributes to improvement in patient conditions. Finally, the value of patient observations within medical practice will be explored, describing the developments throughout time from physical drawings to technological visualisation.

Chapter 3 will discuss how the growing use of technological visualisation in the medical world assists learning within all aspects of medicine: research, practice and education. However, there will be a deliberation of the challenges of using technology such as its correlation to a reduction of observational training in education (Boudreau, Cassell and Fuks, 2008) and training of clinical skills in medical practice (Thacharodi *et al.*, 2024). Therefore, there shall be a conversation about managing and utilizing technology to act as a tool to aid clinicians and a call for more worth to be placed on observational skills training in medical pedagogy. Finally, there will be an examination of both technological visualisation and science art in their ability to grow public engagement which encourages funding opportunities and increased knowledge in scientific research.

Chapter 1: How Art Develops Understanding of Anatomy and Clinical Treatment

Anatomy is a key component in the knowledge required for clinical practice. Without a basic knowledge of the structures of the body and how it works, it would be inconceivable for a clinician to provide proficient clinical care to patients (Turney, 2007). To analyse the full scope of artistic methods used in anatomical learning within medicine, it is critical to view the development from early examples to more current applications. This analysis will demonstrate how artistic visualisation has been implemented in anatomical learning over time and how the outcomes have affected the overall progression of medical knowledge and medical education specifically.

One of the earliest involvements of art that directly advanced medical learning was work by Andreus Vesalius (1514-1564). His book titled *De Humani Corporis Fabrica Libri Septem* (Vesalius, 1543) made a significant impact to medicine as one of the original anatomical books published that contained illustrations. Over 200 woodcut prints in the book successfully illustrate and visualise the supplementary descriptive typography (Figure 1.1). The prints were developed at the Art School of Titian and although the artists responsible have not been identified, there is an assumption that Jan Steven Van Calcar (1499-1546) was involved (Saunders and O'Malley, 1973; *De humani corporis fabrica (Of the Structure of the Human Body)*, no date).

Figure 1.1: *De Humani Corporis Fabrica Libri Septem* by Andreus Vesalius (1555): woodcut print.

In 1533, Vesalius travelled to study Anatomy at the medical school of Paris and it was during his studies there that the inspiration arose to create *De Humani Corporis Fabrica Libri Septem* (Vesalius, 1543). Prior to Vesalius's arrival at the medical school, the faculty had made an appeal to the Paris Parliament in 1926 to allow more dissections to take place in anatomic learning (Saunders and O'Malley, 1973). This demonstrates that even in the 1500s, visualization in medical learning was beginning to be considered valuable. However, it was Vesalius that was key to the appreciation of medical learning displayed through visual images.

Regardless of the fact that this appeal was a success, Vesalius still only witnessed 3 or 4 dissections during his time there. For a young and determined anatomist, this was not enough (Saunders and O'Malley, 1973). Therefore, in order to progress his skill and knowledge he accessed bodies through whatever means necessary, including journeying to Gibbet of Montfaucon where criminals would hang and the cemetery of the Innocents where bodies of Plague victims lay. (Fulton, 1949). Through his visual examinations of cadavers, he began to discover errors in the anatomical knowledge of early physicians such as Hippocrates (460-375BC) and specifically Galen (129-216AD) (Saunders and O'Malley, 1973). These prolific academics were consistently viewed as supreme in the medical world and within medical education even a thousand years after they were alive. This proposes that it was necessary at this time for their theories to be questioned in order for new perspectives and knowledge to be gained in Anatomy. However, it was vastly unpopular to publicly disagree with distinguished figures of Anatomy or any field for that matter. This needs to be understood within the broader historical context of the renaissance in Europe, where across a number of fields, ancient knowledge was beginning to be challenged (King, 2003). Vesalius's observational skills played a crucial role in providing evidence of errors in the well-known anatomists' theories and through his detailed and accurate visual illustrations he had the confidence to reveal them no matter the scrutiny.

Another perspective that may have affected Vesalius's decision to provide illustrations is the concept that visualisation can make information easier to communicate and learn. There is a theory that observing or interacting with the subject one is learning can create a mental image that is effectively retained (Goetz, 1991). In the textbook of published lectures titled 'Information Retrieval Meets Information Visualization,' Alan Dix states that 'visualisation makes data easier to understand through direct sensory experience (usually visual)' (Agosti *et al.*, 2013, p.1). With this idea in mind, it seems logical to assume that Vesalius included illustrations with the intention of proving that his anatomical findings were accurate, but also of generating mental images that would be effectively retained. By creating multiple images, some of the whole body and some of smaller sections (Vesalius, 1543), he was able to produce a complete visual context of the human body which allowed his ideas to be more easily translated and understood. The ability to capture knowledge using illustrations in such a descriptive and detailed way was extremely uncommon at this time and Veslius's work has been valued by medical students for over four hundred years (Fulton, 1949). It is clear that these illustrations progressed the field of medicine, both by providing a more accurate knowledge of anatomy and by shaping an effective new method of medical learning. This growth in the knowledge of anatomy then directly benefitted clinical proficiency as clinicians could understand the human body with further certainty.

Although Vesalius took credit for these significant anatomical findings, it was in fact Leonardo Da Vinci (1452-1519) who discovered them originally (Jones, 2012). Da Vinci is renowned for both his artistic and scientific achievements in the renaissance (West, 2017). Yet, Da Vinci never published his accurate anatomical discoveries (Jones, 2012), and it was only following his death that his extensive but disorganised notes and drawings spanning numerous scientific fields were compiled and published. Da Vinci's collection of notes was known to be extremely messy due to his choice to prioritise observation and investigation (Benesch, 1943). This immediately demonstrates the worth Da Vinci placed on observational practice within his work. Over the course of his life, Da Vinci was documented to have performed many dissections and although for a long time he would follow the structure of work by anatomists such as Galen, there is reason to believe that his observational ability as an artist and a skilled dissector caused him to spot mistakes in their ways. Perhaps the most significant use of visualisation in Da Vinci's anatomical investigations was his choice to construct multiple visual experiments such as a glass model of the aorta located in the heart (Jones, 2012). This process of study included pouring water with grass seeds through the model to consider how blood might move through the aortic valve. This is one example of how Da Vinci's investigations include practical experiments but also an artistic and visual approach. This approach aided his learning enabling him to find errors in previous anatomical knowledge, similarly to Vesalius.

His passion for the subject was a major reason for Da Vinci's anatomic success yet it was also down to the connection between art and science known to be prominent in the period of the early renaissance (Benesch, 1943). At this period of time in Italy, artists were considered valuable to mathematics and the life sciences through their use of drawings which subsequently furthered the knowledge of scientists and the skill of artists. Da Vinci described painting as a science itself in his piece of literature published after his death, *Treatise of Painting*. (Da Vinci, Rigaud and Brown, 1835). Da Vinci evidently believed that artistic methods aided understanding of anatomy which can be seen in his own work. However, this opinion was likely common at the time due to the interdisciplinary learning method between art and science in the renaissance. Additionally, this prevalent learning method required representative art to accurately represent scientific information (Benesch, 1943). This suggests that there may have been an alternative incentive for Da Vinci to complete his work if it would lead to a flourishing career, though this is not a strong argument as Da Vinci never published his work (Jones, 2012). It is unclear as to why, but one theory indicates that dissection of criminals at the time was disapproved of; therefore, he may have felt discouraged to publish for the fear of backlash. Although his reasoning for not publishing is not known for certain, what can be agreed upon is that Da Vinci's priority and focus was the process of anatomical observation which then led to his discovery of new knowledge.

The anatomical information discovered by Da Vinci and Vesalius had significant effects on learning that transcended through generations and can be seen in the book *Anatomy: descriptive and surgical* by John Henry Gray (1825-1861) often referred to as *Gray's Anatomy* (Gray, 1858). Gray's book was frequently compared to *De Humani Corporis Fabrica Libri Septem* (Pearce, 2009) based on the similar and advanced illustrations displayed created by the artist Dr Henry Vandyke Carter (1831-1897). In Borland's paper, he describes that 'The year 1885 was too late for one to make any great discoveries in anatomy' (Borland, 1908, p.430) and that Gray's success came not from new anatomical discoveries but 'the clearer and more systematic presentation of old ones, backed strongly by unparalleled drawings' (Borland, 1908, p.432). This proves not only that anatomical drawings held great significance in medical learning from the 1500s onwards but also that the quality of drawings created would set certain anatomical work apart. When the knowledge of human anatomy was considered to be complete in the 1800s, aided by illustrations throughout history, illustrations once again remained an essential tool in medical learning. The success of *Gray's Anatomy* is well known and appreciated in medical education with thirty nine editions of the book published in the 150 years since the original's release demonstrating the importance of clear, descriptive illustrations (Pearce, 2009).

In current medical education, Universities and Colleges are involving artistic methods in their anatomical teaching through engaging and interactive techniques. There have been various investigations that support the inclusion of art within a medical curriculum for the purpose of improving students anatomical learning. At Dickenson's College in Carlisle, Pennsylvania, a new cadaver room was opened in 2025 and students from the course entitled Creativity, Innovation, Discovery: Art and Science from the Enlightenment to AI were invited to view it within their learning (Jackson, 2025). The influence for incorporating cadavers within this method of teaching was inspired by Da Vinci. As discussed previously (Benesch, 1943) during the early renaissance artists were able to advance their skill through anatomical study and artists including Da Vinci then helped widen the knowledge of anatomy with produced drawings. These in turn create a cycle where both subjects of art and medicine aid each other. The students taking the course felt that Da Vinci's methods had been successful with the author describing his anatomical work as spot on. (Jackson, 2025). Vanover, the professor of this course, believes that being involved with learning in a hands-on format can create the best possible engagement from students thus be the best learning tool. Vanover's discussion connects with the theory mentioned previously, that the process of visualising makes subjects easier to learn but especially with the involvement of a sensory experience (Agosti *et al.*, 2013). Vanover evidently saw the worth in Da Vinci's use of visualisation and felt that exploring his artistic methods would be beneficial to students.

A similar study that explores visualisation in teaching but in an extremely interactive way is *Body Painting as a Tool in Clinical Anatomy Teaching* (McMenamin, 2008). The aim was to allow students in the medical program at the University of Western Australia to practice their anatomical knowledge through painting. They were tasked to paint accurate anatomy onto one another in its correct location on the body (figure 1.2). This activity aimed to improve learning through the creation of visuals and active involvement from students. This theory that art can increase engagement is not held solely by McMenamin. The process of active learning which involves perceiving, engaging and reflecting on information has been found to be extremely effective at increasing understanding and memory of knowledge (Graffam, 2007). Additionally, artistic methods in medical learning can create an affordable, simple way to generate higher levels of engagement (Rea, 2020). This forms an argument for the involvement of artistic methods within medical education which aligns perfectly to the results of McMenamin's paper demonstrating that the medical students found the body painting helpful as a tool towards learning.

Figure 1.2: 'Body painting as a tool in clinical anatomy teaching' in Paul G. McMenamin (2008): body painting.

Another interesting aspect of the paper is McMenamin's call for educational reform describing his disapproval of the belief that anatomical teaching should be returned to a traditional standard leaving no room for development of artistic teaching. (Hanna and Tang, 2005; McMenamin, 2008) It is probable that because anatomy is considered a prestigious and intellectual subject of study, there is often a push for it to remain the way it is, not involving new artistic methods. (McMenamin, 2008). However, based on the information presented here it can be suggested that visual and artistic methods can create deeper anatomical knowledge through the practice of observing and active learning (Graffam, 2007).

It is clear that the use of observational skills and documented illustrations produced historically were momentous in the progression of medical knowledge and education (Vesalius, 1555; Gray, 1858; Jones, 2012). Clinical treatment has also directly benefitted due to this expansion of anatomical knowledge. In current medical pedagogy the use of artistic methods in education effectively advance engagement and learning. Therefore, it would be useful to medical learning if more schools followed the example of Dickenson's College (Jackson, 2025) and The University of Western Australia (McMenamin, 2008) in using innovative interdisciplinary methods.

Chapter 2: How Art and Observation Improve Clinical Proficiency

Observational skills heavily support the development of clinical proficiency through the ability to accurately diagnose and treat patients. Consequently, observational skills must be trained at an educational level and researchers have found the study of paintings to be an effective technique for training observational skills. Both qualitative and quantitative studies provide evidence that an implementation of artistic study into medical curricula would be beneficial.

The study, 'Use of Fine Art to Enhance Visual Diagnostic Skills' (Dolev, Friedlaender and Braverman, 2001) explored visual training in medical students and successfully proved that examining paintings contributes to improvement of clinical observational skills. Students in their first year of medical school were divided randomly into either a control group or an art observation group. The control group was taught by a physician who educated them verbally on the significance of patient history and examination techniques. The art observation group was taught by the Yale Centre for British Art Project (YCBA) and the students were tasked to look at representational paintings, such as figurative or portraiture. These paintings are relevant to clinical practice as, similarly to their typical teaching methods, students maintained the ability to train in examinations of people. They were given a short period of time to observe the paintings, followed by discussions of their findings to a group. Any points that had possibly been missed were actively brought up by the curator of education who would encourage continued discussions. This displays an integration of active learning, which can be argued was significant to the results of the study. As discussed previously, (Graffam, 2007) engagement and active learning can effectively increase understanding and memory, demonstrating why these continued discussions were beneficial in the art observation group. To relate the study to diagnostic skills, both groups were required to describe a set of 10 medical images of patients before, and a different set of images after the teaching interventions. This ensured that any observational improvement assessed could only have resulted from teaching in the study, not from practice or memory of the images. Each of the photos had roughly 10 visual indicators suggesting a medical diagnosis, yet students were asked only to describe the aspects they had seen and not to provide their opinion of a diagnosis. The purpose of this was to measure observational skills without students thinking too far ahead to a diagnosis, which would have resulted in a risk of bias.

The results showed that both group's answers barely differed when asked to describe the images at the beginning. However, after the teaching interventions had been implemented, the art observation group had become the most effective at spotting accurate indicators in the medical images. The improvements the groups made at identifying indicators in the medical images were measured over two years, and in the first year, the art observation group improved by 56% and the control group improved by 44%. Similarly in the next year, the art observation group improved by 57% and the control group by 47%. These quantitative results highlight the art observation group's success in effective visual training through improved accuracy at finding diagnostic indicators. Another significant part of the study was the absence of background information provided for each painting. This was imperative as it removed any biased observation and all perceived details were discussed. Although looking specifically for diagnostic indicators is the most conventional way of learning as a medical student, these results conclusively suggests that this style of artistic and unbiased teaching is more effective. The outcome of this paper suggests that the involvement of art observation within medical curricula encourages a deeper consideration of all visual indicators which improves observation skills and evidently diagnostic skills as well.

However contradictory results were found in the paper 'Training the clinical eye and mind: using the arts to develop medical students' observational and pattern recognition skills' (Shapiro, Rucker and Beck, 2006). This study instead found that both traditional clinical teaching and art-based teaching had benefits for diagnostic skills. However, in this study, it was the traditional clinical teaching that resulted in better pattern recognition, while the art-based teaching resulted in stronger focus on empathy and the importance of understanding a patient's wellbeing as well as their illness. Similarly to the method of the previous paper, students were split into two groups, one that involved traditional clinical teaching and the other involved art-based teaching. The structure of the traditional teaching included: observing clinical photos and creating a pattern, thinking of symptoms holistically, reducing the number of important factors by deliberating their significance, and finally, explaining the patient's story again to question what could have been done differently. The art-based teaching involved the majority of this structure except paintings were studied instead of clinical photos.

Qualitative trained observers dissected data gained from interviews and written feedback during the study, and categorised the results to compare both forms of teaching. In contradiction to the previous paper (Dolev, Friedlaender and Braverman, 2001), the traditional clinical teaching method was more successful in demonstrating deeper pattern recognition by the students. However, the consideration and empathy towards the patient was far more central to the art-based teaching. *Studies of Six figures* was looked at specifically for the purpose of increasing empathetic consideration (Figure 2.1). The creation of a story towards diagnosis was also more significant and students felt that their observational skills had improved as a result of the training.

Figure 2.1: *Studies of Six Figures* by Leonardo Da Vinci (1480-1): Pen and brown ink on paper.

There is an effective argument that clinical skills would be improved by the combination of these teachings. Even the students collectively said that 'we need imaginative flexibility to rethink what we've decided is important based on additional information,' (Shapiro, Rucker and Beck, 2006, p.267) after observing *Harvest a la Crau (The Blue Cart)* (Figure 2.2). They clearly saw the value in the art's-based teaching to improve their way of thinking and help them question initial observations. The increased consideration of empathy is an alternative and positive outcome of art-based teaching for proficient patient treatment in medical practice.

Figure 2.2: *Harvest a la Crau (The Blue Cart)* by Vincent Van Gogh (1888): Oil on canvas

Empathy is known to be essential in clinical environments with some medical researchers concluding that increasing empathy in consultations can in fact create enhancements to patient's health conditions as well as simply creating a more pleasant environment (Howick *et al.*, 2018). Jeremy Howick in particular supports this information as his work life and research focuses on the power of empathy within doctor consultations ('Jeremy Howick | Evidence-Based Empathy for Healthcare Transformation', n.d.) (*Jeremy Howick*, n.d.). The power of empathy combined with positive patient expectations has even been found to reliably lessen pain or stress slightly (Mistiaen *et al.*, 2016). In addition, psychological conditions of patients have a huge effect on their health with one qualitative paper finding that 80% of patients that became ill had experienced some sort of negative psychological state (Engel, 1965). Therefore, empathy in medical education is crucial to advance the improvement and development of patient conditions. These results prove that medical students should be trained in empathy as part of their teaching and based on the paper above (Shapiro, Rucker and Beck, 2006), art observation within a clinician curriculum is an excellent tool for increasing empathy.

Explorations of art observation in medical learning occasionally highlight this critical role of empathy. One study that achieved this involved medical students practicing observation in an art museum and discussing portraits in detail, with a focus on the face (Bardes, Gillers and Herman, 2001). The students were asked to describe pictures of patients at the start and end of the study with the aim of identifying any alterations in their observational skills after studying the portrait paintings. This was similar to the study previously discussed (Dolev, Friedlaender and Braverman, 2001), however the students were requested to examine the same set of photos during the pre and post-test. The results of this paper may therefore not be as valid as 'Use of Fine Art to Enhance Visual Diagnostic Skills' due to external factors that could have affected the results such as retained memory of the images (Dolev, Friedlaender and Braverman, 2001). The faculty of the museum and medical school concluded that student's responses to the patient photos changed after discussing the portraits in the gallery. In the post-test, students described the patient's physical attributes in more depth but also gained an increased awareness of emotions, such as the thoughtful consideration of how the patient might be feeling and why. This suggests that practice of art observation can increase empathy as clinicians will likely become more considerate of patient emotions which is known to be valuable to patient health (Howick *et al.*, 2018).

Art observation within medical practice as well as education has been successful in advancing clinical skills, visible in the work of Jean-Martin Charcot. Charcot was a prolific professor of Neurology in the 1800s and was known for using art in his work and as a medical teaching tool (Goetz, 1991). He created what he referred to as the 'clinicoanatomic method' to be used within medical practice and involved two parts. The first part focused on the physical account of a neurological disease. Charcot created many patient drawings which would display the initial indicators of mild or more serious medical issues. This would sit alongside in-depth notes that would complement the drawings (Figure 2.3).

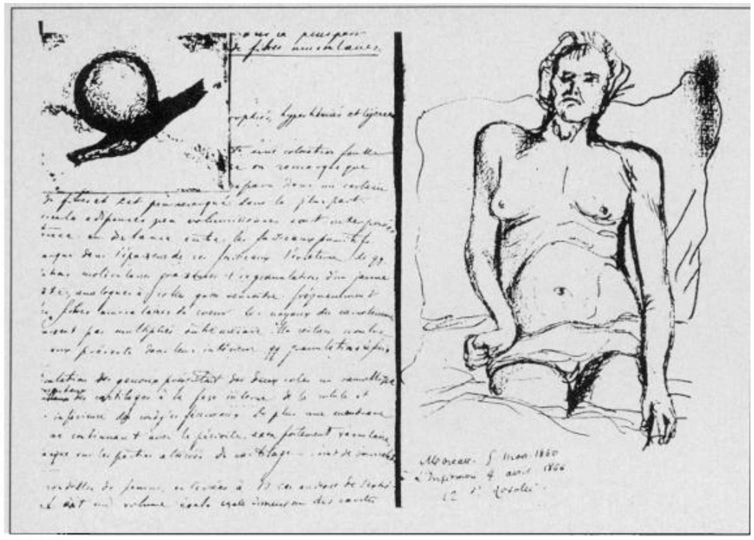

Figure 2.3: 'Visual Art in the Neurologic Career of Jean-Martin Charcot' in Christopher G. Goetz (1991): Drawing of clinicoanatomic method part 1

The aim of the second part of the method was to examine the patient microscopically after death if they had suffered from a fatal condition. Charcot would then draw what he saw from the cadaver such as tracing lesions within the neuroaxis (see Figure 2.4). His visual library was momentous in demonstrating the microscopic changes of conditions such as multiple sclerosis and amyotrophic lateral sclerosis, progressing knowledge in the field of medicine.

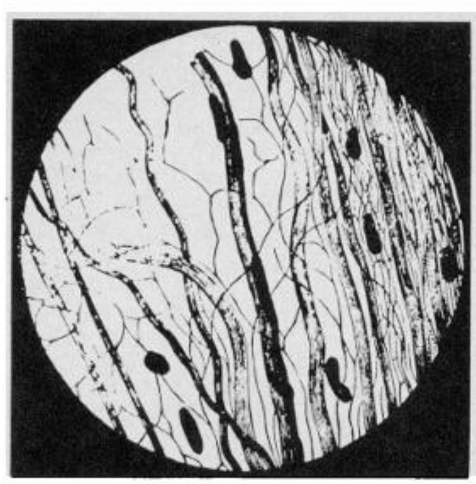

Figure 2.4: 'Visual Art in the Neurologic Career of Jean-Martin Charcot' in Christopher G. Goetz (1991): Drawing of clinicoanatomic method part 2

In one of his books *Nouvelle Iconographie de la Salpêtrière* (Société de neurologie de Paris, 1888) the editors of the work wrote that 'with the aid of this immediate record, we are able to freeze the abnormality' (Goetz, 1991, p.422). This refers to the first part of Charcot's method that points to the importance of creating a visual, either a photograph or drawing of the patient as soon as possible. This allowed for the visual capture of the symptoms to compare and study, to provide the best possible diagnosis and treatment. It eventually became a regular practice at Salpêtrière hospital, the location of Charcot's studies, to take photos of patient's evolving conditions. Thousands of photos were taken which complimented written notes and followed Charot's Clinicoanatomic method to create holistic case studies. Even after Charcot's death, the practices of photography and recording patient visuals continued at Salpêtrière hospital demonstrating its success in medical practice.

Charcot was always passionate about Dutch Realism artists and it can be argued that his fascination with looking at Realism paintings and creating his own drawings has influenced his successful observation and diagnostic abilities. This is extremely relevant to the articles previously discussed that suggest that frequent art observation can improve clinical observational skills (Bardes, Gillers and Herman, 2001; Dolev, Friedlaender and Braverman, 2001).

Charcot eventually became a faculty member of Salpêtrière himself and through his visual teaching methods, he helped the popularity of the medical course grow more every year. Students were fascinated by his teaching which involved the implementation of photos, detailed notes, statues and medical patients present. There is a belief that the artwork used in the medical classroom of Charcot communicated information in an effective way as it created mental images that make information easier to remember (Goetz, 1991). Charcot is clearly using the method of active learning and engagement as discussed in the previous chapter (Graffam, 2007). Similarly to *Use of Fine Art to Enhance Visual Diagnostic Skills* (Dolev, Friedlaender and Braverman, 2001), Charcot's teaching offers a process of looking and discussing which has been found to improve observational skills. Therefore, it is reasonable to suggest that active learning with the inclusion of visuals can contributes to improved observational skills in clinical education.

In recent years, collecting visual materials of patients has evolved through emerging technologies in the medical world explored further in the following chapter. However there is an argument that with these new technological methods, there is a reduction in the training of basic observational skills in medical curricula (Boudreau, Cassell and Fuks, 2008). Unfortunately, there is rarely a medical program that fully focuses on training basic observational skills (Boudreau, Cassell and Fuks, 2008). It is clear that art observation in the form of studying paintings as well as active learning can both advance the essential observational skills needed as a clinician. Within clinical skills more generally, art observation also has the ability to improve empathy which can benefit patient health. The lack of value in training observational skills in education is concerning due to its necessity in medical practice hence this training must become more frequent in medical pedagogy.

<u>Chapter 3: How Technological Visualisation and Science Art Improve medical learning and public engagement</u>

The growth of technologies in the digital age, specifically technological visualisation has played a key role in the progression of understanding in the medical world. It can be argued that artists can also play a similar role in the expansion of medical learning and the sciences more generally. Through artist's incorporation of visual technologies to create engagement and interest within the viewers, artwork as well as technological visualisation encourages change or progression in medical learning.

The textbook *Biomedical Visualisation* (Rea, 2020) discusses the incredible advancements of technology used in the medical world and how involvements of data visualisation and imaging improve physician's ability to visualise. This demonstrates that technological visualisation is important in medical research, practice and education.

Technological visualisation in medical research can create an opportunity to use new techniques or even make new discoveries that can increase learning towards the progression of the field of medicine. Very recently in 2024 for example, the first ever video was captured of ovulation within a mouse follicle (Cooke, 2024). Ovulation is an entirely internal event so there has been a limited understanding of the exact processes that occur, until now. Knowing about these limitations, *ex vivo* imaging techniques were implemented in this study which involves keeping the mouse follicles outside the body *in vitro* and nurtured within a lab (Thomas *et al.*, 2024). This visual technique was key to finally having the ability to visualise ovulation through live imaging (Figure 3.1). However, there was no guarantee that this technique would be successful as it was unknown if a single follicle separate from the body would be able to complete ovulation. The video captured proves that the information needed for egg release during ovulation is kept within the follicle itself rather than orchestrated by the ovary and it can be validated through the ability to see it happening with our own eyes (Thomas *et al.*, 2024). This form of technological visualisation in medical research, *ex vivo* imaging, was ground-breaking due to the ability to see ovulation happening for the first time resulting in new information being discovered. This demonstrates the technological development of medical learning since Vesalius and

Da Vinci's (Jones, 2012; Vesalius 1543) discoveries and that fundamentally visual observation has been the key to these discoveries. Consequently, new information learnt about the body can then consistently allow for more effective forms of patient care or treatments to be put in place.

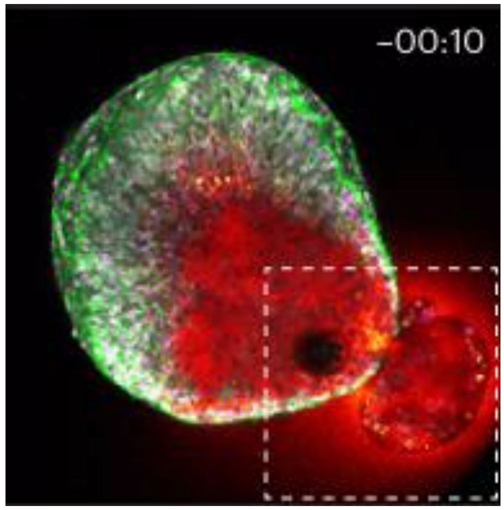

Figure 3.1: '*Ex vivo* imaging reveals the spatiotemporal control of ovulation' in Christopher Thomas. et al. (2024): *Ex vivo* imaging

An upcoming technological method within medical practice is 3D capture of the body, discussed in *Biomedical Visualisation* (Rea, 2020). This operates through handheld scanners that project patterns onto the surface of patient's bodies whilst taking multiple pictures. These pictures can then be digitally replicated to produce the accurate shapes and texture of the body. A direct advantage of this technological visualisation is the development of prostheses designed specifically for individuals through 3D capture (Rea, 2020). 3D capture is successful due to the creation of a visual that the computer is then able to incorporate into a custom design for patients. The combination of visualisation and the wide capabilities of technology is clearly effective here and demonstrates the direct benefits towards patient care. Another use for 3D capture is the development of teaching tools towards medical education. Through 3D scans of anatomy, online models have been designed and used often within current medical learning. An online source recommended to students of the University of Edinburgh (*Anatomy TV | Library*, 2024) and the University of Edinburgh (*LibGuides: Nursing and Health Sciences Subject Guide: Streaming, Anatomy TV & PressReader*, no date) is Anatomy TV

(*Anatomy.tv Titles*, no date) which is evidently valued towards learning. Roughley states that 'thinking in 3D when learning about and simulating the human body is paramount to increasing learning and understanding' (Rea, 2020, p.143). In addition, as previously discussed, visualisation allows information to be absorbed with more ease (Agosti *et al.*, 2013). Therefore, these online sources clearly help students' ability to back up their knowledge with visuals and creates a space for amplified engagement and learning.

However, some have contrasting opinions, instead believing that online anatomical resources are replacing opportunities for dissection. Hanna and Tang believe that dissection in gross anatomy labs allows students to gain clinical context through observation and discussion, suggesting that it cannot be undervalued in anatomical learning (Hanna and Tang, 2005). Chapter 1 of this dissertation also argues the importance of anatomical dissection towards learning, although it is worth understanding certain limitations of dissection to evaluate its effectiveness in education. As seen historically such as Vesalius's time, cadavers used for dissection were often criminals (Saunders and O'Malley, 1973), whereas nowadays people will donate their bodies for scientific education so ethical standards must be put in place accordingly. Some of these ethical standards in medical curricula include no photography of cadavers and limited access to view them (Nawras *et al.*, 2023). It is essential to treat these donor bodies with respect; however, this limits student learning, therefore technological visualisation offers a way for students to fill any gaps in knowledge. A combination of dissection and additional 3D anatomical models can provide the clinical context of studying real cadavers and the ability to view anatomy whenever desired and practice knowledge.

Another concern about the use of technological visualisation within medical education is its correlation with an absence of observational skills training (Boudreau, Cassell and Fuks, 2008). As discussed in the previous chapter, observational skills training can produce more accurate clinical diagnostic skills yet medical schools rarely if ever include specific observational skills training in curricula (Boudreau, Cassell and Fuks, 2008). Engel suggests that with the rise of technology there is a reduction in the training of basic observational skills and that these skills need to be reintroduced to medical learning (Engel, 1965). However, Engel does not propose that technology hinders medical advances in any way, explaining that there are benefits of it in a practical setting. Engel's opinion has merit as technological visualisation clearly influences medical practice and research seen in the examples above (*Anatomy.tv Titles*, no date; Rea, 2020; Thomas *et al.*, 2024). There should also be a concern towards the current lack of observational skills training in education. Though, it is also imperative to see the value of using technological visualisation within medical education such as online anatomical resources (*Anatomy.tv Titles*, no date) but it is apparent that basic observational skills must be practiced considerably more frequently in addition. As discussed in the previous chapter, studying paintings is an excellent way to train and improve observational skills thus an inclusion of this interdisciplinary teaching method would greatly benefit medical education.

The concern that technology decreases observational skills does not solely apply in medical education either, the same concern exists in medical practice. For instance, the use of Artificial Intelligence (AI) is growing more prevalent in multiple academic settings including healthcare. AI within the field of medicine has the ability to examine visual medical images and visuals for clinicians, therefore allowing them to diagnose patients quickly and precisely (Thacharodi *et al.*, 2024). As helpful as this is to patients who receive more efficient treatment, it could become damaging to clinicians who are not actively practicing their observational and diagnostic skills. As mentioned in the first chapter, the process of active learning is successful at improving understanding and retainment of information (Graffam, 2007). This provides reasoning that active learning within medical practice is vital for clinicians and that AI needs to work in partnership with clinicians, not as an alternative. This suggests that used in the wrong way or too often, technology could be harmful to medical learning. It is imperative that technology remains a tool in medical practice to improve visualisation and observational skills, not become a necessity.

An alternative advantage of technological visualisation is its ability to induce public engagement which can then subsequently expand medical knowledge beyond individuals in the field. Dr Elisabeth Kugler who is both a biomedical image analyst and science artist believes that visual media is crucial for the representation of scientific studies and equally for appealing to the public (Barresi *et al.*, 2021). She proposes that visuals can make challenging information easier to engage with and that people are more likely to be drawn to visual representations rather than text (*Visuals and Illustrations | Kugler Elisabeth*, no date). This demonstrates the power visual technology can have towards influencing public interest.

Similarly, science art, understood as artwork inspired by science created with or without technology, has the same ability to grow engagement across all areas of scientific research. The science artist, Christina Seely, feels from her experience that art can expand knowledge through interdisciplinary integration and create positive change in research of various scientific fields (Seely, no date). The initiative, *Culture for Climate Scotland* (*Arts into climate - Culture for Climate Scotland*, no date) believes that the arts can successfully influence engagement on the topic of climate change and they see great utility in cultural organisations including libraries and museums due to their capacity to create a space where audiences can learn collectively. This highlights the significance of a venue for more effective learning, an exhibition displaying science art could therefore be an ideal environment for this reason. Another ideal environment for learning is *The Science Museum* in London (*Art and Science | Science Museum*, no date) which unquestionably values art due to the museum's belief that art can make people consider scientific concepts in a new way. The museum also consistently showcases artworks through exhibitions, a permanent gallery and commissions. These various examples clearly create an understanding that art can impact learning of wider audiences as well as encouraging developments in scientific fields which could easily apply to medicine.

Kugler's own work displays this idea successfully through microscopic images, created via a Zeiss AiryScan microscope, that represent neurovascular unit formation in zebrafish retinas which Kugler researched during her post-doctoral work (Figure 3.2). This research aims to understand retina development and disease (The Node, 2021).

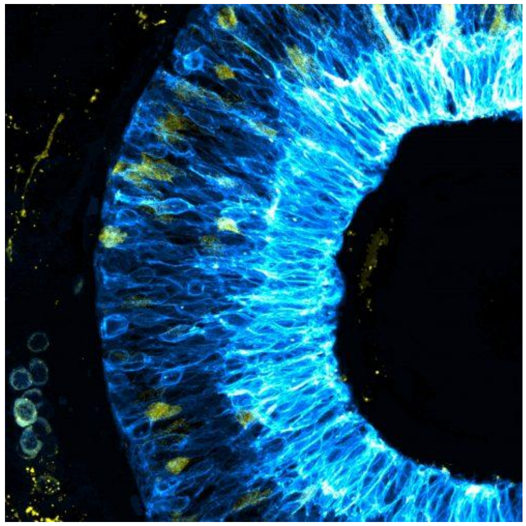

Figure 3.2: 'SciArt profiles: Elisabeth Kugler' in the Node (2021): Zeiss AiryScan microscopic image.

She went on to exhibit these microscopic images as science art in multiple exhibitions partly for their astonishing beauty yet also with the purpose of engaging people with her work (The Node, 2021). It can be suggested that Kugler's science art exhibitions create an environment for amplified public engagement of her research subject.

Kugler's work also demonstrates the involvement of visualisation technology within an artistic context and its use towards increasing interest and understanding of scientific research. It can be assumed that when creating science art, an artist may be likely to incorporate technology at some stage during the making of the work. This can be based on the fact that a lot of information in biological subjects including medicine, has been made visual through technology such as microscopic images (Barresi *et al.*, 2021). Louise Mackenzie, an artist that primarily explores scientific research through her art, believes that technology can act almost as 'extensions of our own body' to allow an expansion of understanding (Seely and Mackenzie, 2025, 1:04:39). She feels that equipment such as hydrophones or microscopes allows us to hear and see things that we are not usually able to with our existing senses (Seely and Mackenzie, 2025, 14:24). Like Kugler, she uses technology in some form in her artwork which portrays the wonders technological visualisation contributes to scientific research.

Working together (Figure 3.3) was a project and residency for Mackenzie at Northumbria University supported by The Cultural Negotiation of Science and Northumbria University Department of Applied Sciences (BLACK BOX3 – The Cultural Negotiation of Science, no date). A short film displaying key moments from the project was exhibited in Black Box[3], a permanent exhibition space at the 4th floor Ellison Lab at Northumbria University. This film of *Working Together* discusses the project's collaboration with various students within the Department of Applied Sciences who were encouraged by Mackenzie to observe the visual beauty of their research. Mackenzie wanted this consideration of the visual to remind them of the wonders of what was being achieved and contributed to the world through their research. One of the collaborators whose study focused on panels of various cancer cell lines describes the wonderful pink gradients revealed when cell samples die in a 96 well plate (seen in figure 3.3).

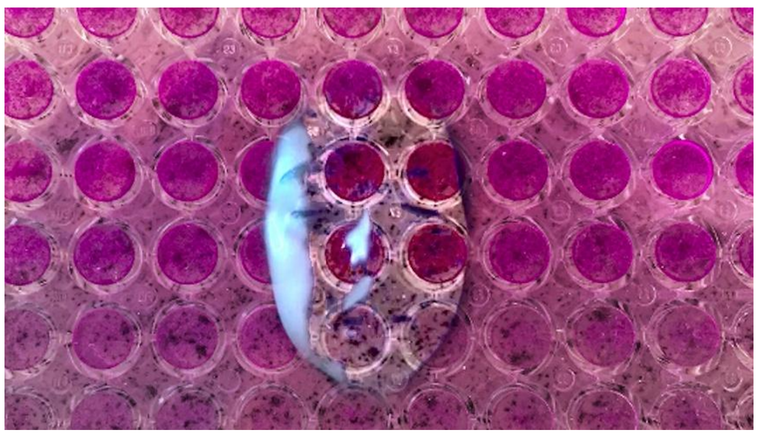

Figure 3.3: *Working Together* by Louise Mackenzie (2021): Film.

By completing working together, Mackenzie is able to impact public engagement with visualisation and technology in the research completed at the university. This includes the collaborator's work on cancer research which could have a huge impact on healthcare. This can be implied due to the knowledge of an intertwined relationship between what the public engages with and what research progresses in the scientific world (Yin *et al.*, 2022). Additionally, successful communication of research has been found to promote public funding (Yin *et al.*, 2022). Therefore, the role of Northumbria University is key in broadening audience engagement hence possible funding opportunities through their value of artwork to communicate scientific research within a permanent exhibition space. The visuals seen in Mackenzie's film succeed at communicating information creating an opportunity for a wider audience to learn about scientific concepts. Funding, if granted, would then directly contribute to advancements of knowledge and learning within a scientific field such as medicine. However, it was found recently that the humanities and the arts are far more efficient at engaging public attention than STEM subjects suggesting that there needs to be more focus on visual communication to promote scientific research such as medicine (TNS BMRB and Policy Studies Institute, 2015).

It is clear that visualisation technology and artwork can both progress learning in the field of medicine within each aspect of medicine and more generally to the public. Within medical pedagogy specifically, it can be argued that both dissection when possible and technological 3D resources are required to allow the most amount of knowledge to be learnt and retained. This use of visualisation technology in education will also help clinicians prepare for the ever growing and valuable technologies used in the medical world today. However, it is imperative to understand how technology is being implemented in medical practice and ensure its use does not limit the observational skills or learning of healthcare professionals. Towards broader engagement and learning, science art can be an excellent tool to portray the wonderous advancements of technological visualisation. This increase in public engagement can then help encourage funding which would consequently enhance the knowledge within various scientific fields such as medicine.

Conclusion

This dissertation has initially demonstrated how art observation and current artistic methods in medical curricula, have contributed to improved anatomical learning throughout history. Study of paintings has then been explored emphasising its ability to improve observational skills that are indispensable for effective clinical practice. Finally, discussions of both technological visualisation and science art demonstrate their influence in progressing medical learning including wider public engagement.

The information throughout has provided reasoning to support the use of frequent art observation within medical pedagogy. Historically, dissection has been a significant tool for learning in the field of medicine (Saunders and O'Malley, 1973) however there are ingrained limitations such as limited access to cadavers and the fact that photography is strictly not permitted (Nawras *et al.*, 2023). Therefore, a combination of dissection and 3D anatomical sources can provide clinical context of studying real cadavers yet allow students to fill any gaps in anatomical knowledge and practice this knowledge whenever desired. Artistic methods in medical pedagogy whether that is studying paintings and discussing them or engaging in art activities can improve basic but essential observational skills needed towards clinical diagnostic skills and overall proficiency. To conclude, an involvement of dissection, technological visualisation, the study of paintings and artistic methods within medical pedagogy would benefit medical learning and clinical proficiency.

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