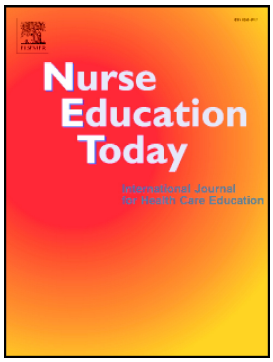

Post mortem computed tomography: An innovative tool for teaching anatomy within pre-registration nursing curricula

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POST MORTEM COMPUTED TOMOGRAPHY: AN INNOVATIVE TOOL FOR TEACHING ANATOMY WITHIN PRE-REGISTRATION NURSING CURRICULA.

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This work was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). It was also conducted with the approval of the De Montfort University Faculty Research Ethics Committee and the East Midlands Forensic Pathology Unit (University of Leicester) Research Ethics Committees (ethical permissions found at https://www2.le.ac.uk/departments/emfpu/research; last visited 23.07.18). Informed consent was obtained from the next-of-kin for the use of the PMCT images, videos and printed models (Saunders et al 2012).

ABSTRACT

Background

There is significant change throughout the world regarding Post Mortem Computed Tomography (PMCT) as an adjunct or a replacement to the traditional invasive autopsy. Of interest, is the ability to demonstrate visually two and three dimensional normal soft tissue, organ and skeletal anatomy, as well as natural disease and trauma pathology.

Objectives

The objective was to compare formal traditional methods of teaching anatomy and pathology (pictures and diagrams) to pre-registration student nurses with supplementary PMCT 2/3D generated images, videos and printed anatomical models. The specific objective was to determine if these tools would increase the students' perception of their understanding and learning experience of the subject area.

Design

A quasi-experimental within-subject design was chosen.

Setting

A School of Nursing and Midwifery within a Higher Education Institution in the UK.

Participants

Purposeful sampling of 57 voluntary informed consented pre-registration student nurses.

Method

Students were initially exposed to teaching of normal anatomy and common fractures using traditional methods. Data was then collected following the teaching session using a questionnaire entailing both quantitative and qualitative elements. The teaching session was then repeated with the same students but with the inclusion of PMCT of all the same normal anatomy and fractures. Data was then collected again using the same questionnaire. Both questionnaires were then compared.

Results

The quantitative findings proved highly significantly proved ($P = < 0.01$) that the inclusion of Post Mortem Computed Tomography when teaching normal anatomy and pathology increases pre-registration nursing students' perception of their understanding and learning experience. The qualitative results revealed three positive themes concerning visual learning, realism and patient empathy.

Conclusion

Including Post Mortem Computed Tomography imagery enables nurse academics to provide students with a virtual tour of the human body and a rich, authentic learning experience of a real individual who experienced a relevant clinical scenario that nurses are likely to encounter in their careers.

KEYWORDS

Anatomy, Curriculum, Education, Images, Nurse, Post mortem computed tomography (PMCT), Teaching and learning, Video.

INTRODUCTION

Access to cadaveric specimens is traditionally considered essential to anatomy teaching within healthcare. However, a national shortage of legally donated subjects usually restricts access to such teaching within medical schools and is in fact declining in many countries such as the United Kingdom (UK) and Sweden (Petersson 2009, Codd 2011). Hence, courses such as nursing and other allied health disciplines tend to rely upon oral lectures, instructional videos, plastic models, and printed materials for anatomy teaching. This may affect the students' learning experience and ultimately the extent of knowledge acquisition. Research therefore has been developing innovative methods to teach normal anatomy and pathology. Examples include computed generated virtual body maps, body animations, simulation, interactive anatomy models etc.

Alongside these developments, today there is ongoing significant change occurring throughout the world through the use of Post Mortem Computed Tomography (PMCT) either as an adjunct or a replacement to the traditional invasive autopsy (Rutty et al 2017, Grabherr 2018). Of interest, is the ability to demonstrate visually two (2D) and three-dimensional (3D) normal soft tissue, organ and skeletal anatomy, as well as natural disease and trauma pathologies of the whole body. Such images, videos and models are currently being used for medico legal purposes within the world of death investigation, for example to demonstrate trauma to the jury.

Hypothesis

Hence the hypothesis for this study was:

> The incorporation of PMCT 2/3D images, videos and printed models when teaching anatomy to pre-registration nursing students increases the perception of their understanding and learning experiences compared to traditional methods of books and pictures alone.

BACKGROUND LITERATURE

This literature review will begin by presenting previous research undertaken that has compared a variety of teaching tools to teach normal anatomy and pathology to medicine and allied health professionals. It will then go on to review a possible new innovative tool to replace or be an adjunct to such previous methods including cadaveric dissection for use in nurse education. The objectives of this research will then be put forward.

Computer generated models of anatomy

Codd's (2011) research evaluated the use of a 3D computer model of a human forearm compared with traditional anatomy teaching methods for human anatomy students in the UK. Three sample groups were identified (1) a control group with no previous knowledge of forearm anatomy (2) a traditional methods group who were taught using dissection and textbooks and (3) a model group taught solely using an e-resource of a 3D computer model. All three groups were assessed on the anatomy of the forearm by a ten question examination. The results showed that the students using the e-resource (3) had significantly higher examination results than the control group (1), but not than the traditional methods group (2). In addition, the traditional methods group (2) was also significantly superior to the control group (1). The study recommended that virtual anatomy learning should be used to compliment traditional teaching methods rather than replace it.

In contrast, Khot's (2013) experimental study in Canada looked at comparing a cadaveric pelvis with three formats of learning about anatomy i.e. (1) a virtual reality computer-based model (2) a static computer based module comprising key views and (3) a plastic model. The results showed there were no significant differences between the three groups of undergraduate students finding that computer-based learning resources appear to have noteworthy disadvantages compared to traditional specimens in learning about anatomy. Although it was interesting to note that students learning from a plastic model did do significantly better compared to the other two computer-based resources, it was moreover important to note that students preferred to learn from cadaveric specimens.

Computed Tomography of the living

More recently, 3D Computed Tomography (CT) in the living, which is different from previous model based virtual realities, has gained popularity in orthopaedic training for surgeons in the USA in regard to education and pre-operative planning (Garrett et al 2012). Their study which looked at acetabular fractures due to their complexity compared 3D CT with conventional radiography. The findings demonstrated there were significant improvements in classifying such fractures with the greatest benefit being found in junior doctors, concluding that 3D CT scans can be an effective educational tool for understanding complex spatial anatomy for surgeons.

A similar study by Peterson in 2009 used converted CT and Magnetic Resonance imaging (MRI) but this time integrated it into web based interactive 3D visualisations as a tool to improve anatomy learning. Students' attitudes were found to be positive compared with anatomy textbooks, but dissection remained the preferred option despite formative knowledge tests suggesting a potential beneficial effect on learning.

Most of the research shows that there are benefits to teaching and learning about anatomy with medical and allied health professionals when virtual reality computed generated models/images and those derived from the living using CT converted into 3D visualisations,. However, students most preferred option remains to be the use of cadaveric dissection (Sharma et al 2016) due to significant improvements in self-reported confidence and competence as assessed by examination. There may however be an alternative that replaces the need for cadaveric dissection, CT of the living, 3D visualisations and computer-generated models i.e. Post Mortem Computed Tomography 2/3D images, videos and printed models.

Post Mortem Computed Tomography (PMCT) in death investigation.

Conventionally, the 'gold standard' for determining cause of death has always been the invasive autopsy. This highly specialised surgical procedure comprises an external and internal examination plus relevant laboratory investigations. Donchin et al (1994) proposed for the first time PMCT as a possible replacement to the invasive autopsy. They also challenged the concept that the autopsy was not the "gold" standard by showing that in fact PMCT could identify more findings than the traditional invasive autopsy. The field as a result has grown rapidly over the past two decades including a significant increase in the quality of research available to support the use of new radiological techniques (Rutty 2017, Grabherr 2018). Despite its relative infancy, this has resulted in Post Mortem Radiology (PMR) being adopted globally to the extent that some mortuaries now have dedicated CT scanners within them. This is now enabling PMR to form a routine part of an autopsy examination (NHS 2018, O'Donnell and Woodford 2008, Rutty et al 2008) with both radiologists and pathologists training worldwide to update their skills in this new clinical initiative (Rutty 2018).

Of interest regarding PMCT in death investigation, is the ability to demonstrate visually 2/3D normal soft tissue, organ and skeletal anatomy, as well as natural disease and trauma pathologies of the whole body rather than focused studies more commonly used in clinical CT. Such images, videos and printed models are now being used not only as part of the death investigation process by forensic pathologists and radiologists, but also as demonstrable evidence in criminal and coroners' courts. This study set out to find out therefore whether such an innovation could be transferable as an inventive teaching tool within nurse education to enhance the students' perception of their understanding and learning experience

Objective of the research

The objective of this research therefore was to compare traditional methods of formally teaching normal anatomy and pathology to third year pre-registration student nurses with the innovative

method of combining the current teaching materials (pictures and diagrams) with supplementary PMCT 2/3D generated images, videos and printed anatomical models.

The specific objective was to determine whether having access to these innovative teaching tools would increase the students' perception of their understanding and learning experience of the subject area.

METHODS

Study design

A quasi-experimental within-subject design (Clifford 2013; Salkind 2010) was undertaken using purposeful sampling of third year pre-registration undergraduate student nurses within a Higher Education Institution in the UK. Data collection was via a self-administered questionnaire following the traditional teaching session of normal anatomy (i.e. anatomy that has not been affected by disease or trauma) and pathology (session 1) and then again following a repeat of the same teaching session but this time with the inclusion of PMCT 2D and 3D images, videos and printed models (session 2).

Creating PMCT 2/3D images, videos and printed models

Prior to the study a teaching scenario using a Visual Narrative Illustration (Hussein, Salyers and Osuji 2016) was developed to inform the students of causation, appearance and treatment of a so-called "open book" fracture of the pelvis with associated mid-shaft fracture of the left femur. Once the scenario had been developed, two sex matched and age matched adults unenhanced PMCT cases, consented for teaching and research through the East Midlands Forensic Pathology Unit were selected from the Unit's database, one showing normal skeletal pelvic and upper leg bone anatomy and the other showing the required pathology. Three-dimensional skeletal reconstructions (images and 360^{o} rotational images) where produced using OsiriX v8.0.1 64-bit software (Pixmeo, Switzerland) (Figure 1, videos 1-4). The two selected skeletal datasets where then exported into the open source software program Blender v2.78 (The Blender Foundation, Netherlands). From here they were scaled to 30% life-size and 3D-printed using a Form 2 desktop stereo lithography device (Formlabs, USA) (Figure 2).

Development of the questionnaire

The questionnaire was developed by the researchers after reviewing the literature in relation to student understanding and learning experience. Following demographic questions on gender and

age, the questionnaire entailed nine quantitative statements in relation to whether students perceived the teaching sessions to (1) be stimulating, (2) link theory to practice, (3) be helpful (i.e. supportive) for their learning, (4) be of good quality, (5) have good clarity, (6) assist with their understanding of anatomy, (7) be effective (i.e. successful) with their learning, (8) assist in increasing their knowledge base, and (9) identify whether they felt they needed additional learning opportunities. Each statement was answerable via a Likert scale of 1-5 i.e. strongly agree, agree, undecided disagree and strongly disagree. Question 12 asked students to state which teaching aids they preferred when learning about anatomy i.e. books, pictures, PMCT images, PMCT videos or PMCT printed models. Question 13 was of a qualitative nature asking for further comments.

Reliability and validity

Reliability and validity was then established through the five steps of (1) hypothesis generation (2) conceptualisation of variables (3) format and data analysis by agreeing the questionnaire's format and scales of measurement (4) establishing validity through readability testing by confirming it had achieved content, face and construct validity (5) establishing reliability through pilot testing. This was to ensure the questionnaire had the validity to measure what it was intended to measure and had the reliability to create an instrument that had the ability to recreate reproducible results. The process that was undertaken is presented below:

1. To establish face validity six experts (including nursing, paramedic and medical practitioners) who teach anatomy and pathology across the Faculty evaluated the questionnaire to ensure that it captured the topic under investigation. This included checking for common errors such as double-barrelled, confusing and leading questions;
2. The questionnaire was then piloted with a group of ten nursing students who were not part of the main study. This resulted in one question (n14) and its optional answers being reworded as it was highly prone to error;
3. Internal consistency of questions was then measured by checking that responses were consistent which they were.

Quality assurance was established following the TREND checklist (Centre for Disease Control and Prevention 2018).

Ethical considerations

This work was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). It was also conducted with the approval of the De Montfort University Faculty Research Ethics Committee and the East Midlands Forensic Pathology Unit (University of

Leicester) Research Ethics Committees (ethical permissions found at https://www2.le.ac.uk/departments/emfpu/research; last visited 23.07.18). Informed consent was obtained from the next-of-kin for the use of the PMCT images, videos and printed models (Saunders et al 2012).

Before the research began one cohort of third year adult nursing (n59) students were informed of an essential anatomy update (session 1) they were required to attend as part of their mandatory theoretical learning hours as deemed by the Nursing and Midwifery Council via email and university timetabling. On arrival they were then invited to partake in the research by also attending session 2. In line with approved university ethics all students who accepted the invitation were voluntary informed and consented. It included informing students not only about the research but about the images of deceased patients that they would be reviewing as part of the research during teaching session two and their right to withdraw at any time should they feel uncomfortable. Two additional nursing academics to the lead lecturer were present throughout the two teaching sessions to assist students should such a consequence occur to provide individual support, guidance and advice. Information was also provided to students regarding anonymity and confidentiality of their responses and where they may be published in the future. All data collected was secured within a password protected university server of which only the lead researcher had access in line with university regulations. All data will be destroyed once the research is published in accordance with European Union General Data Protection Regulation Compliance (EU 2018).

Sampling

Purposeful sampling was assumed for this study.

Sampling inclusion criteria included that participants must be:

- Third year full-time pre-registration nursing students;
- Undertaking the three year pre-registration “adult” nursing programme;
- Required to attend Session 1 as part of their mandatory theoretical learning hours as deemed by the Nursing and Midwifery Council UK.

Sampling exclusion criteria included that participants must not be:

- Studying pre-registration adult nursing students i.e. child, learning disability or mental health;
- In their first or second year of their pre-registration educational programme
- On extensions within the programme

- Studying dual registration programmes
- Studying part-time
- On or returning from interruption of studies
- Late for or had missed Session 1 of the study.

To determine an adequate sample size, the Raosoft Sample Size Calculator (Raosoft 2004) was used. The results showed that a minimum sample of 52 participants was required to provide a confidence level of 95% with a margin of error of no more than 5%.

Data collection

Data collection began in October 2017. All students were initially exposed to teaching of normal anatomy and common fractures by an academic lecturer within the School of Nursing and Midwifery using traditional methods (session 1) i.e. pictures and diagrams via PowerPoint presentation underpinned by a real patient scenario (Figure 3). The teaching session was of 1.5 hours duration. Data was then collected following the teaching session using a paper self-administrated questionnaire entailing both quantitative (nine ordinal questions) and a qualitative element (one open ended question).

The teaching session was then repeated (session 2), by the same academic lecturer, for the same duration, with the same students but with the inclusion of PMCT generated 2/3-D images, videos and printed anatomical models (Figure 2, 3 and on-line supplementary video resource), all of which were of the same normal anatomy, fractures and underpinning patient scenario. Data was then collected again using the same paper self-administrated questionnaire.

Data analysis

Both questionnaires were then analysed and compared. Descriptive Statistics and the Wilcoxon Non Parametric Test (Hicks 1990) were used to analyse the quantitative data (nominal and ordinal, respectfully) using the Statistical Package for Social Sciences (SPSS) version 22.0. Thematic Analysis was used to analyse the qualitative data by means of NVivo 10.

RESULTS

Demographics

A total of 59 students who fulfilled the sampling criteria consented to take part in the study. Two students withdrew their consent due to childcare commitments leaving 57 students (96.6% of the sample) who took part in session 2 and the entire study. The resulting demographics showed that

the majority of nursing students were female (91%) and aged 18-29 years (68.5%), being indicative of the UK national picture for pre-registration nurse education (Busby 2018). It is noted however when considering the results that demographics had no statistical bearing on the findings.

Quantitative

The quantitative findings significantly proved (*P* = < 0.01) in all nine questions that the use of PMCT 2/3D generated images, videos and printed anatomical models when teaching normal anatomy and pathology increase pre-registration third year nursing students' perception of their understanding and learning experience (Table 1). This was in regard to the PMCT visual aids being stimulating, helpful in their learning, of good quality and clarity, assisting with their understanding of anatomy, effective with their learning and assisting in increasing their knowledge base (see exampled charts 1-3). The hypothesis was therefore accepted.

Participants also stated that they preferred PMCT 2D and 3D images, video and printed anatomical models over books and diagrams (p = <0.01) (Chart 4). However, their most preferred option was to include all possible teaching tools rather than one over the other. This was also demonstrated through participants' comments such as:

> *"It [PMCT} gave me a much more realistic image of the bone structures than the previous diagrams. However, the two should be used in combination to ensure that all learning needs are met. In combination the two methods have increased my knowledge in different ways" (P20).*

The majority of participants strongly agreed or agreed they still needed additional learning opportunities, but less so post session 2 that incorporated PMCT 2/3 images, videos and printed anatomical models to a significance level of P = <0.02 (see Table 1 and Chart 5). It appeared therefore that students' confidence in the subject area had increased overall.

Qualitative

The qualitative results revealed three positive themed outcomes concerning visual learning, realism and patient empathy when incorporating PMCT 2D and 3D images, video and printed anatomical models (Figure 4):

Visual learning

Research tells us that the majority of students in a regular classroom need to see information from a variety of different visual aspects in order to learn from it (Frankel 2009, Beck et al 2002.). Students

that prefer learning through visual means in particular require "to see first" what they are "expected to know". This finding was conducive with this research as a number (n35) of participants commented on this feature as exampled by students who wrote:

"I think PMCT is a very interesting visual aid that helps me visualise the teaching and the impact of fractures. It also kept me very engaged throughout the session" (P40);

"I am a visual learner and this enabled me to not only gain greater in depth knowledge but it kept me engaged too, enabling me to have a better understanding of the human anatomy" (P46);

"It was good to be able to see in depth images and videos that explain what is being taught as this increased my understanding, particularly so as I have dyslexia" (P50).

Realism

Realism is about representing things in a way that are accurate and true to life. In other words, it is about demonstrating a subject matter that is truthful without artificiality and artistic licence. This is especially important in the context of nursing students that authentic learning is incorporated so that learning can be connected to real world issues that are meaningful to the learner. Participants (n28) commented on how amazed they were about the PMCT imagery and how it related to their everyday practice placement experiences as student nurses as exampled by the following comments:

"The use of skin to bone videos were amazing. It enhanced the teaching session by bringing basic anatomy classes into true life clinical situations" (P2);

"Really useful - I already use an A&P [anatomy and physiology] app with 3D images but the actual real life images with natural deterioration were much more realistic" (P6);

"Very good and like the use of PMCT images and videos. It gives a more realistic picture of fractures than using text book images" (P33).

Patient empathy

Patient empathy has been written about in regard to nursing for decades being the feeling that you understand and share another person's experience and emotions (Raillie 1995; Yu and Kurk 2008;

Marcysiak and Dabrowska 2014). Participants (n23) believed that the PMCT imagery had stimulated patient empathy into the classroom. Students' comments included:

> *"The images enabled me to more readily see things from the patient's viewpoint and experience. It was so helpful in enabling me to visualise the connections between theory and practice" (P5);*
>
> *It [PMCT] made it easier for me to relate to practice and gave me a better idea of what to expect on my next placement when caring for patients with similar problems and trauma. It made me understand and feel for patients. The next time I care for someone with a fracture pelvis and leg I will remember those [PMCT] images" (P28).*

DISCUSSION

It is imperative that all clinical nurses have a good understanding of anatomy and pathology to ensure competency in nursing practice and decision making. Hence, this subject area is a core component of all pre-registration nursing curriculums in the UK (NMC 2018) and internationally. However, students are more likely to perform poorly in these areas compared to other subjects despite the integration of multiple teaching methods to increase student engagement (Johnston et al 2015).

Previous research (Montayre and Spark 2017) has found that the complementary benefit of laboratory sessions in learning about anatomy and physiology among nursing students produces a positive perception regarding their learning which agrees with previous research (Johnston and McAllister 2008). This was also resounded within a former pilot study when post registration nurses and midwives were asked if they would like to observe an invasive autopsy when learning about anatomical content; 98% of participants responding affirmatively (Rutty et al 2016).

However, nursing students in the UK are predominately excluded from rich learning experiences such as exposure to cadaveric specimens as similarly reported in Australia (Johnston 2010). In an attempt to counter this, this study set out to find out whether such an innovation as PMCT could be transferable as a teaching tool within pre-registration nurse education so as to enhance the students' perception of their understanding and learning experience.

This study has proved that when PMCT teaching tools are incorporated into teaching sessions covering anatomical content, students' perception of their understanding and learning experiences are significantly enhanced and their confidence is knowingly raised in the subject area. In addition students perceived the use of PMCT teaching tools to be a more enriching, authentic and engaging

learning experience compared to traditional methods. In turn, this provides lecturers who teach anatomy with a powerful educational tool. It is recognised that the internet does provide an enormous resource of interactive illustrations that are clear and colourful, but PMCT teaching tools enable the visualisation of the human body from a real person who experienced a real clinical scenario resulting in students gaining additional positive learning experiences of visual learning, realism and patient empathy. This is significant as engagement efforts can impact students' current and future learning (Hudson 2015).

Finding innovative educational methods and tools to engage pre-registration student nurses can be challenging to effectively enhance the meaningfulness of content (Crookes and Walsh 2013). However, it can also be extremely valuable and worthwhile, especially when positive results are proved in regard to student learning experiences, as has this study.

Recommendations for educational development

Our recommendations for PMCT development in nurse education includes:

1. Developing a bank of anonymised PMCT 2D and 3D images, videos and printed models in collaboration with local Forensic Pathology and / or Radiological Departments;
2. Fully integrating PMCT 2D and 3D images, videos and printed models into pre-registration nursing curriculum outcomes, teaching and learning, and assessment;
3. Using computer assisted design software material to enhance the realism of the PMCT 3D generated printed models (Figure 5);
4. Developing the PMCT teaching tool further to enable its use within multiple technological platforms;
5. Engaging students further by involving them in creating imaging resources;
6. Develop and integrate the use of PMCT with human anatomy augmented reality mobile technology

Practical interventions to assist in implementing PMCT as a teaching tool

PMCT is being adopted by autopsy practitioners all over the world, thus schools/colleges of nursing could talk to their local autopsy or forensic institution (country dependent) and develop a relationship to gain access to these images, hopefully at no charge.

Alternatively, the Office of the Medical Examiner in New Mexico USA, have recently announced that they were funded by the National Institute of Justice USA, to develop an open access PMCT database. This database contains approximately 15,000 PMCT scans which can be accessed free of charge for research and teaching purposes from 2019. Thus access to PMCT images are possibly

already available, but certainly will be in the very near future to any nursing school/college and in theory will be cost free (Edgar 2018).

Recommendations for future research

Recommendations include repeating this study with allied health professional students such as midwives, radiographers, paramedics, audiologists, pharmacists, etc. It would be useful also to consider different technological platforms such as 360-degree platforms and real time imagery. Testing knowledge attainment and retention differences against specific learning outcomes rather than student perceptions of their understanding and learning experience alone would be extremely valuable to nurse education. Finally, 57 as a sample size is more than adequate to ensure reliability of inferential statistical analysis, however using an even larger sample would even better determine the average values of data and the possible avoidance of errors.

CONCLUSION

The results of this study prove that pre-registration third year nursing students' perception of their understanding and learning experience of normal anatomy and pathology can be improved in nurse education by incorporating innovative teaching tools of PMCT 2/3D images, videos and printed models. This enables the nurse academic to provide students with a virtual tour of not only the human body, but a rich, authentic learning experience of a real individual who experienced a relevant clinical scenario that nurses are likely to encounter in their careers.

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Chart 1

Chart 2

Chart 3

Chart 4

Chart 5

Figure 1: 3D PMCT skeletal reconstructions used during session 2.
A and B show images of a normal pelvis and femur from an anterior and left sided perspective.
C and D show images of an open book fracture of the pelvis with associated normal right femur and mid-shaft left femur fracture from the anterior and left view perspective

Figure 2: 3D PMCT printed model used in session 2
(a) the normal pelvis and femurs (left) and open book fracture of the pelvis with associated left mid-shaft femur (right).
(b) close up view of the mid shaft left femur fracture

Figure 3: Illustration of normal anatomy and common femur fractures used for teaching sessions 1 and 2 using traditional illustrative method.

Figure 4 – Qualitative findings

Figure 5. The PMCT generated 3D image of the normal pelvis and femurs illustraed in Figure 2 has a bone material algorithm added to it within Blender to make it appear more visualy “realistic” for teaching puroses.

Table 1 – Quantitative results			
Statements The visual aids:	Traditional methods Mean rank	Supplementary PMCT methods Mean rank	Significance level *p*
1. Were stimulating	2.07	1.53	0.00
2. Linked theory to clinical practice	1.77	1.30	0.00
3. Were helpful for my learning	1.86	1.39	0.00
4. Were of good quality	1.95	1.28	0.00
5. Had good clarity	2.02	1.32	0.00
6.Assisted with my understanding of anatomy	1.70	1.39	0.01
7.Were effective with my learning	1.86	1.40	0.00
8.Assisted in increasing my knowledge base	1.96	1.51	0.00
9. I need additional learning opportunities	2.23	2.40	0.19

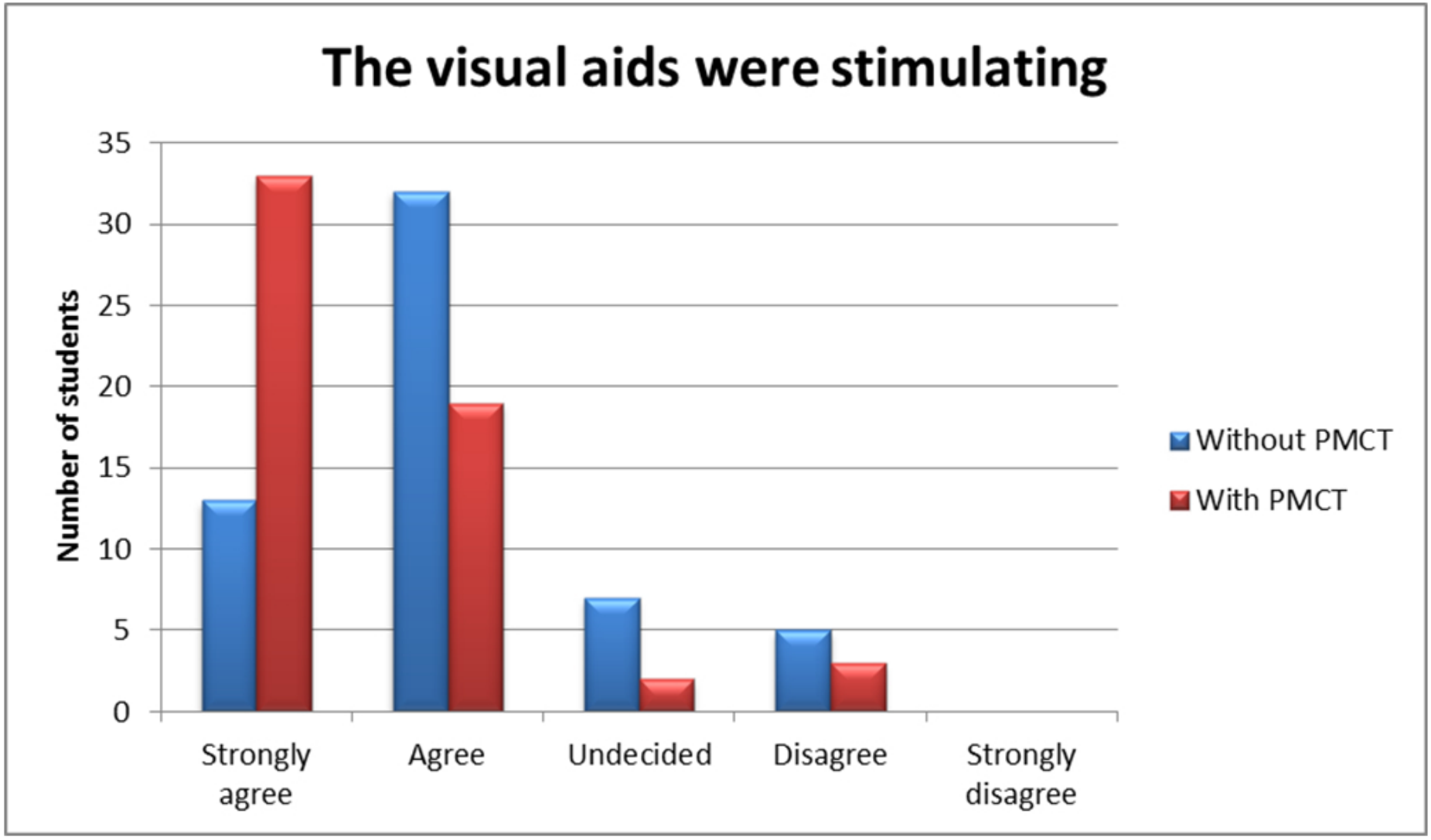

The visual aids were stimulating
Number of students
35
30
25
20
15
10
5
0
Strongly agree
Agree
Undecided
Disagree
Strongly disagree
Without PMCT
With PMCT

Figure 1

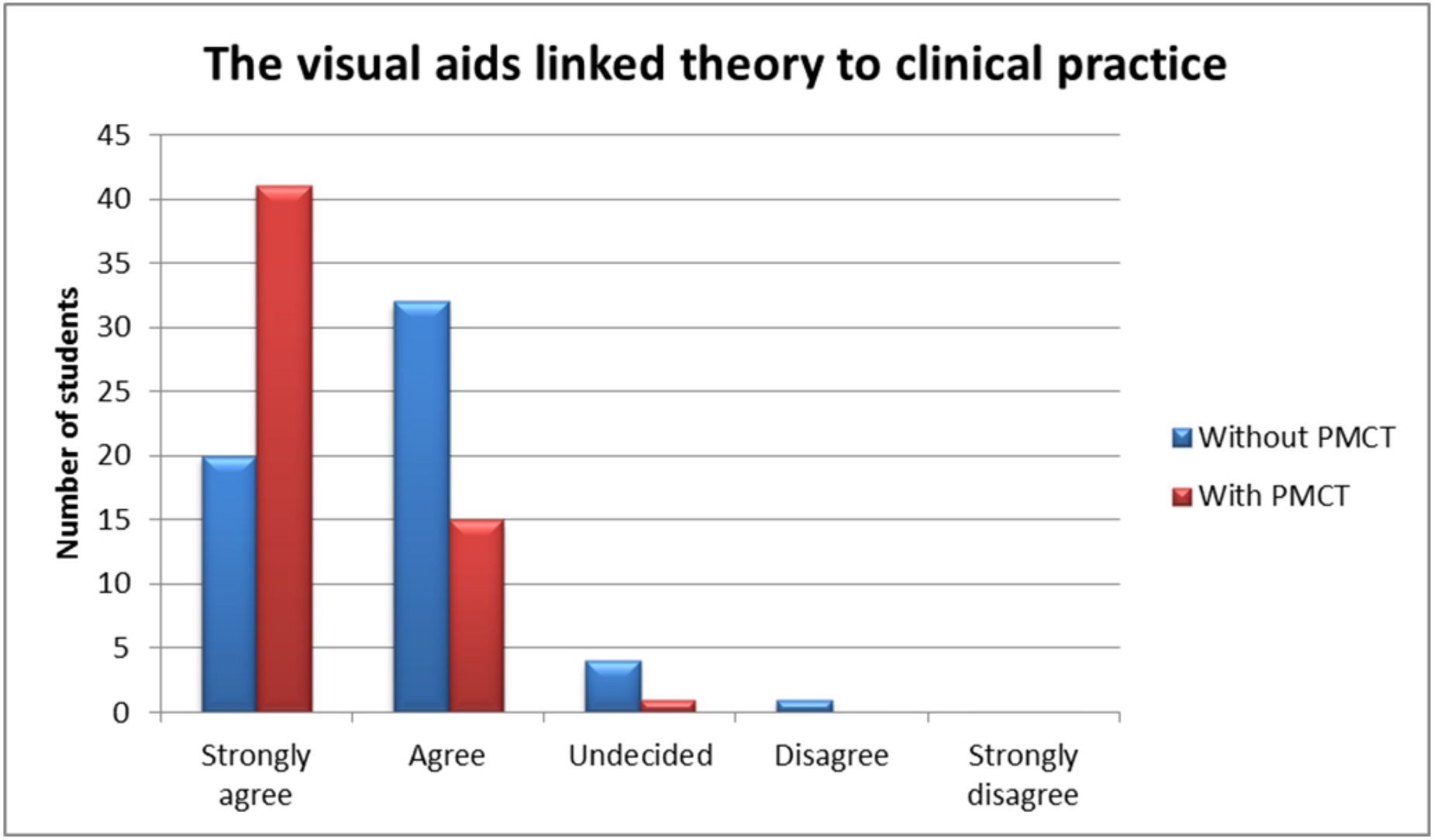

The visual aids linked theory to clinical practice
Number of students
45
40
35
30
25
20
15
10
5
0
Strongly agree
Agree
Undecided
Disagree
Strongly disagree
Without PMCT
With PMCT

Figure 2

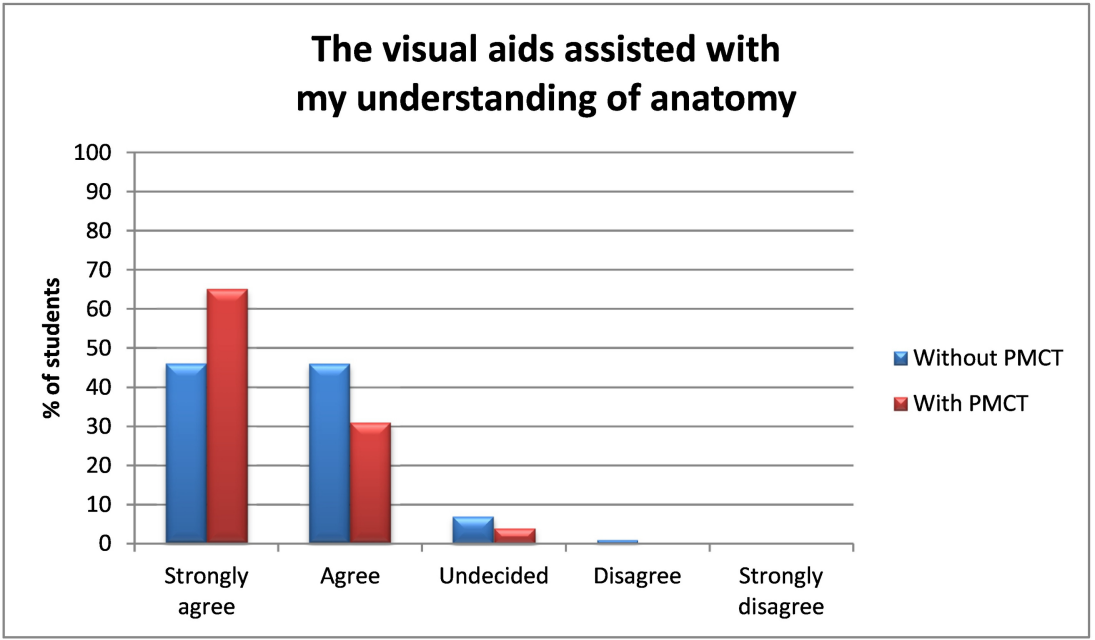

The visual aids assisted with my understanding of anatomy
% of students
100
90
80
70
60
50
40
30
20
10
0
Strongly agree
Agree
Undecided
Disagree
Strongly disagree
Without PMCT
With PMCT

Figure 3

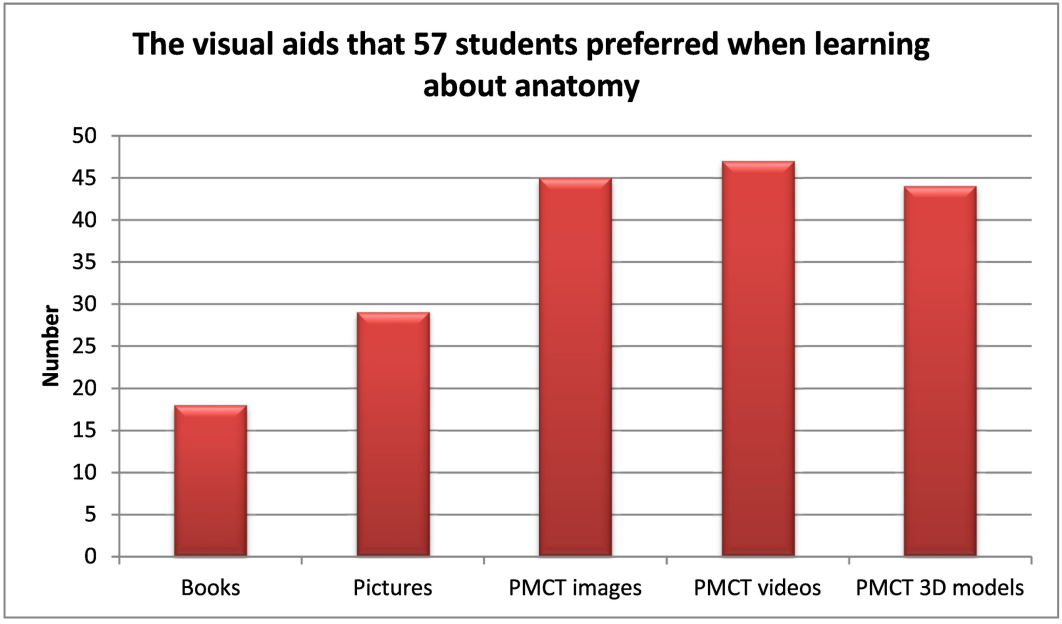

The visual aids that 57 students preferred when learning about anatomy
Number
50
45
40
35
30
25
20
15
10
5
0
Books
Pictures
PMCT images
PMCT videos
PMCT 3D models

Figure 4

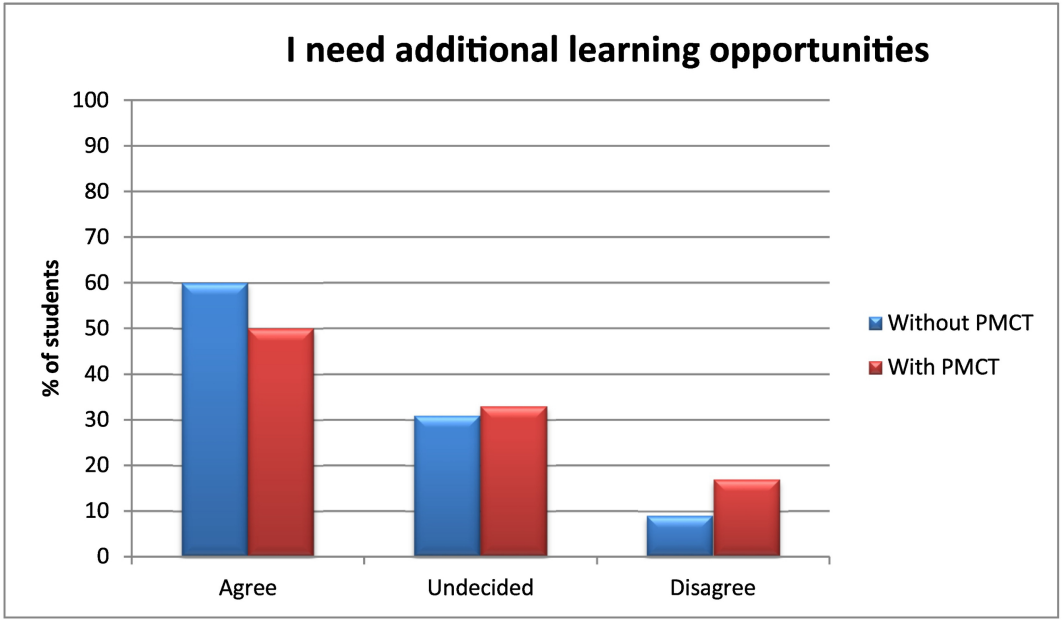
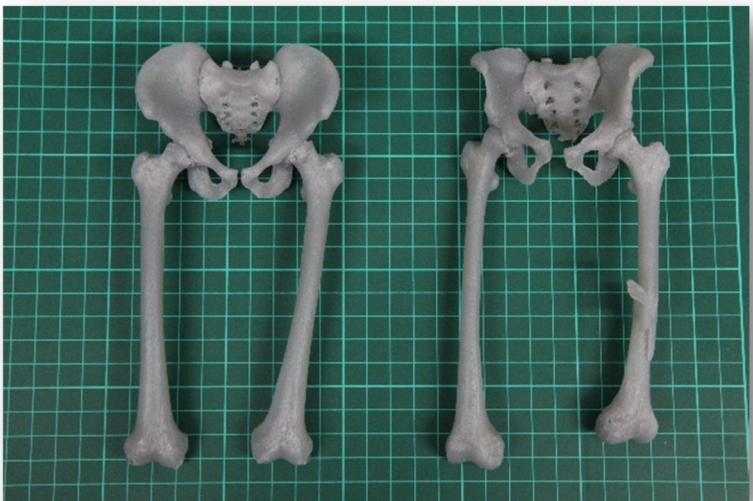

I need additional learning opportunities
100
90
80
70
60
50
40
30
20
10
0
% of students
Agree
Undecided
Disagree
Without PMCT
With PMCT

Figure 5

Figure 6

(a) the normal pelvis and femurs (left) and open book fracture of the pelvis with associated left mid-shaft femur (right).



(b) close up view of the mid shaft left femur fracture

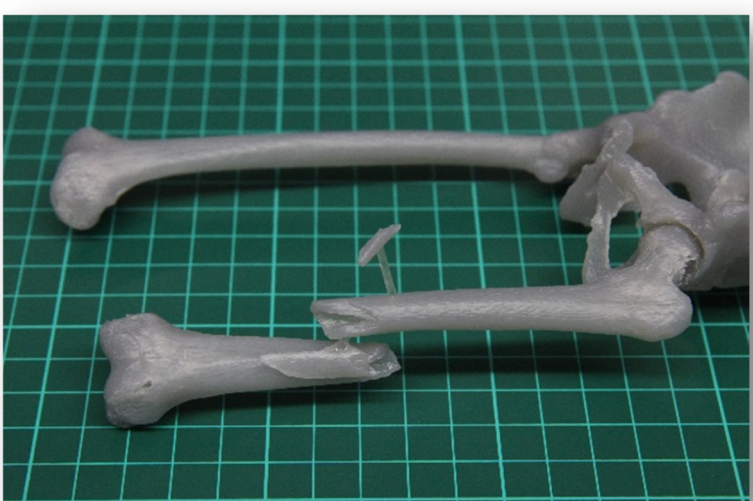
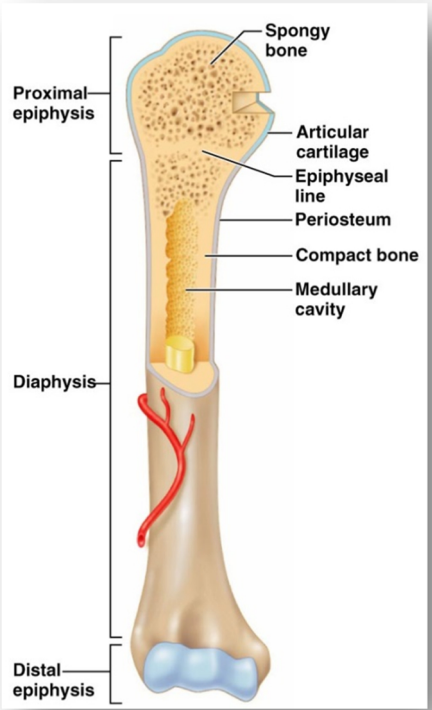


Figure 7


Spongy bone
Proximal epiphysis
Articular cartilage
Epiphyseal line
Periosteum
Compact bone
Medullary cavity
Diaphysis
Distal epiphysis

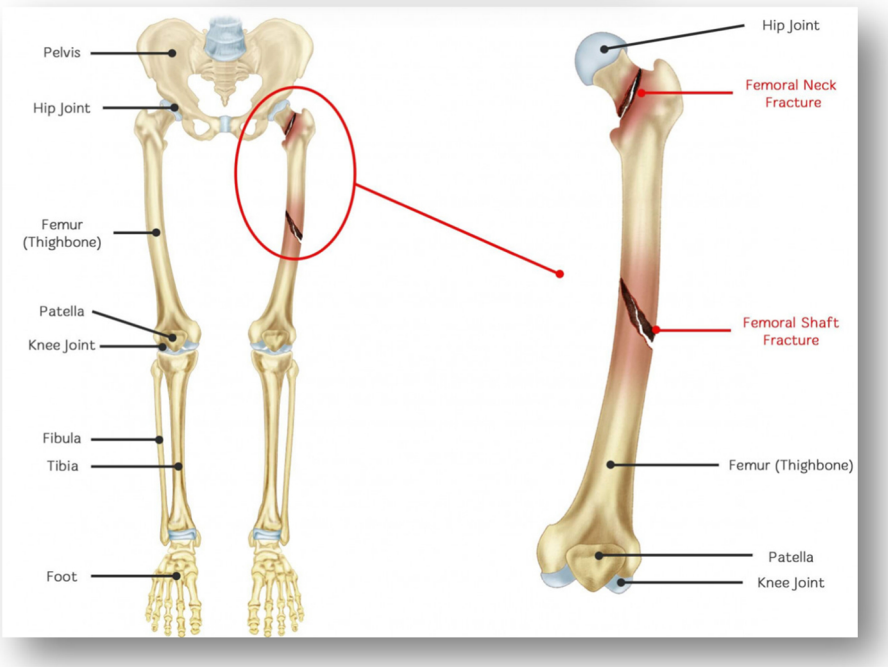

Pelvis
Hip Joint
Femur (Thighbone)
Patella
Knee Joint
Fibula
Tibia
Foot
Hip Joint
Femoral Neck Fracture
Femoral Shaft Fracture
Femur (Thighbone)
Patella
Knee Joint

Figure 8

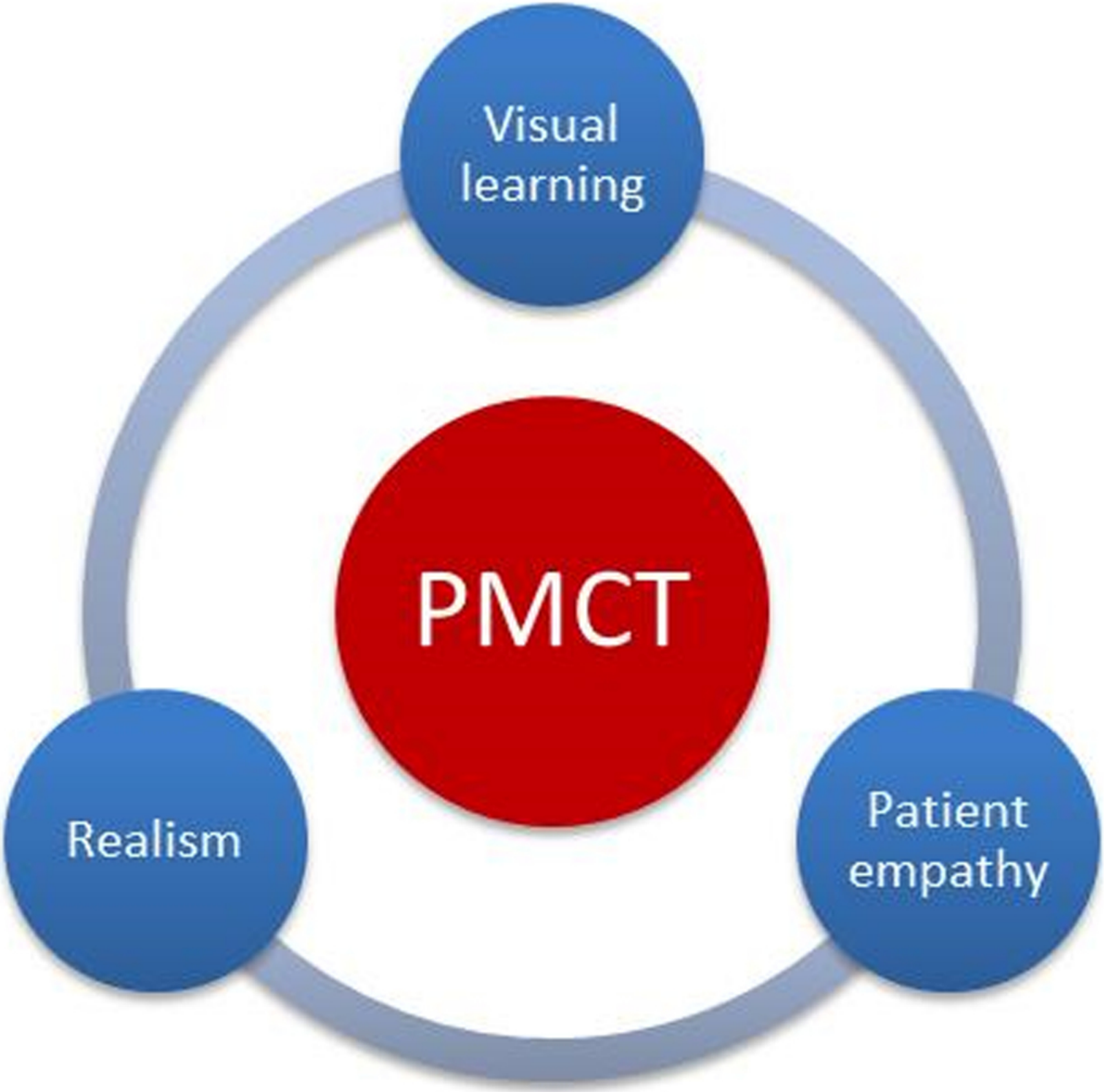


Figure 9

Figure 10