EVALUATION OF MEDICAL STUDENTS' LEARNING PERFORMANCES, ENGAGEMENT, AND COGNITIVE LOAD IN OSPE-BASED ANATOMY PRACTICAL SESSION

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LIST OF ABBREVIATION AND SYMBOLS

%	Percentage
et al.	And others (Latin: et alii)
<	Less than
>	More than
=	Equal to
α	Significant level
d	Cohen effect size
p	p-value
n	Number of subjects
df	Degree of freedom
χ2	Chi-Square
CI	Confidence Interval
CL	Cooperative learning
GAP	Group application problem
IQR	Interquartile Range
I-RAT	Individual readiness assurance test
LEMQ	Learner's engagement and motivation questionnaire
LQ	Learning quotient
MUET	Malaysian University English Test
OSPE	Objective structured practical examination
PBL	Problem-based learning
SD	Standard deviation
SPSS	Statistical Package for the Social Sciences
TBL	Team-based learning

PENILAIAN PRESTASI PEMBELAJARAN, PENGLIBATAN DAN BEBAN KOGNITIF PELAJAR PERUBATAN DALAM SESI AMALI ANATOMI BERASASKAN OSPE

ABSTRAK

Latar Belakang: Pendidikan anatomi manusia secara konvensionalnya bergantung kepada pembedahan mayat tetapi kekangan daripada masa pengajaran yang terhad, kurangnya ketersediaan mayat, dan batasan kaedah tunggal. Ini telah mendorong penerokaan pendekatan inovatif yang mengekalkan kekuatan konvensional sambil menangani kekangan moden. Penyepaduan prinsip Peperiksaan Amali Berstruktur Objektif (OSPE) ke dalam sesi praktikal menawarkan kaedah yang berstruktur, interaktif, menyediakan maklum balas segera dan meningkatkan penglibatan pelajar. Pusat Pengajian Sains Perubatan Universiti Sains Malaysia telah beralih daripada pembedahan kadaver kepada pengajaran multimodal, melaksanakan sesi praktikal berasaskan OSPE sejak tahun 2015.

Objektif: Tujuan kajian ini adalah untuk menyiasat kesan sesi praktikal anatomi berasaskan OSPE terhadap prestasi pembelajaran, penglibatan dan beban kognitif pelajar.

Metodologi: Kajian percubaan kawalan rawak (RCT) ini merekrut 117 pelajar (57 selesai) yang diperuntukkan 1:1 kepada sama ada intervensi praktikal berasaskan OSPE atau kumpulan kawalan pengajaran konvensional melalui rawak berstrata. Intervensi melibatkan kuliah selama 1 jam, penilaian pra-praktikal selama 30 minit, dan sesi amali selama 1 jam 40 minit. Kumpulan praktikal berasaskan OSPE terlibat dalam tugas pengenalan anatomi dengan perbincangan rakan sebaya/pensyarah, manakala kawalan menggunakan model plastik untuk taklimat pensyarah kanan dan pembelajaran bebas. Data selepas praktikal termasuk penilaian 30 minit, tinjauan *Burch Engagement*, skala beban kognitif yang disahkan dan maklum balas dalam talian. Data dianalisis menggunakan SPSS 29.0 dengan statistik deskriptif, ujian-t bebas/berpasangan, dan ujian *Mann-Whitney U* mengikut kesesuaian.

Keputusan: Kedua-dua kumpulan menunjukkan peningkatan ketara sebelum hingga selepas penilaian dalam skor psikomotor dan kognitif. Kumpulan praktikal berasaskan OSPE menunjukkan peningkatan beban kognitif yang ketara berbanding kumpulan konvensional, walaupun tiada perbezaan ditemui dalam psikomotor atau skor keseluruhan. Tiada perbezaan ketara antara kedua-dua kumpulan dalam beban kognitif atau domain penglibatan. Maklum balas pelajar menunjukkan kepuasan yang tinggi dengan sesi praktikal anatomi berasaskan OSPE.

Kesimpulan: Pendekatan berasaskan OSPE menunjukkan kelebihan sederhana dalam meningkatkan prestasi kognitif, dengan hasil yang setanding dalam peningkatan psikomotor, beban kognitif, dan penglibatan pelajar berbanding kaedah konvensional. Walaupun perbezaan pra-intervensi dan keciciran penyertaan yang tinggi mungkin mengehadkan kebolehgeneralisasian, penambahbaikan dalam kumpulan dan maklum balas pelajar yang positif telah mengesahkan nilai pedagogi penilaian praktikal berasaskan OSPE yang bagus dan berstruktur dalam pendidikan anatomi.

EVALUATION OF MEDICAL STUDENTS' LEARNING PERFORMANCES, ENGAGEMENT, AND COGNITIVE LOAD IN OSPE-BASED ANATOMY PRACTICAL SESSION

ABSTRACT

Background: Human anatomy education conventionally relies on cadaver dissection but faces challenges from limited teaching time, decreasing cadaver availability, and single-method limitations. This has driven exploration of innovative approaches that retain conventional strengths while addressing modern constraints. The integration of Objective Structured Practical Examination (OSPE) principles into practical sessions offered structured, interactive, provides immediate feedback, and enhances student engagement. Universiti Sains Malaysia's School of Medical Sciences transitioned from cadaveric dissection to multimodal teaching, implementing OSPE-based practical session since 2015.

Objective: The purpose of this study is to investigate the impact of OSPE-based anatomy practical session on students' learning performances, engagement, and cognitive load.

Methodology: This randomised control trial (RCT) study recruited 117 students (57 completed) who were randomly allocated 1:1 to either OSPE-based practical intervention or conventional teaching control groups via stratified randomization. The intervention involved a 1-hour lecture, 30-minute pre-practical assessment, and a 1 hour and 40 minutes practical session. The OSPE-based practical group engaged in anatomical identification tasks with peer/lecturer discussion, while controls used plastic models for senior lecturer debriefing and independent learning. Post-practical data included a 30-minute assessment, Burch Engagement survey, validated cognitive load scale, and online feedback. Data were analysed using SPSS 29.0 with descriptive statistics, independent/paired t-tests, and Mann-Whitney U tests as appropriate.

Results: Both groups showed significant pre- to post-assessment improvements in psychomotor and cognitive scores. The OSPE-based practical group significantly enhanced cognitive performance compared to the conventional group, though no differences were found in psychomotor or overall scores. No significant between-group differences emerged in cognitive load or engagement domains. Student feedback indicated high satisfaction with the OSPE-based anatomy practical sessions.

Conclusion: The OSPE-based approach demonstrated a modest advantage in enhancing cognitive performance, with comparable outcomes in psychomotor gains, cognitive load, and student engagement relative to conventional methods. While pre-intervention differences and high participation dropout may limit generalizability, within-group improvements and positive learner feedback affirm the pedagogical value of structured, scenario-based practical assessments in anatomy education.

CHAPTER 1

INTRODUCTION

1.1 Title

Evaluation of medical students' learning performances, engagement, and cognitive load in OSPE-based anatomy practical session.

1.2 General Overview

Human anatomy is the scientific study of the structure and organization of the human body. It involves examining the various components of the human body, including tissues, organs and various body systems and understanding how they are arranged and interact to perform bodily functions (McLachlan&Patten, 2006). A solid understanding of anatomy is crucial for diagnosing and treating various medical conditions. In addition, detailed anatomical knowledge is important during any surgical procedures to minimize the risk of injury to vital structures such as blood vessels and nerves. Knowledge of anatomy is also important in interpreting imaging studies such as X-rays, computerised tomography scan and magnetic resonance imaging (Estai&Bunt, 2016). Therefore, the study of anatomy is essential for all medical students to ensure adequate competency and to promote safe medical practice.

The evolution of human anatomy in medical curriculum has undergone significant changes over the centuries. In ancient times, anatomical knowledge was limited, primarily based on cadaveric dissections (Saverino, 2021). With the rapid development of modern medicine in the 20th century, anatomy has gradually moved towards specialisation and refinement, integrating a variety of advanced teaching methods and combining tradition with modern technology. New teaching concepts, technologies and tools continue to emerge, and anatomical education has also begun to gradually move away from conventional cadaver dissection and turn to more diversified teaching methods (Roxburgh&Evans, 2021).

Anatomy is taught through a variety of methods to enhance learning and comprehension including lectures, cadaveric dissection, prosected specimens, anatomy models and technology-assisted tools. Anatomical dissection as a widely recognized teaching method, allows students to directly contact human body providing them with a unique opportunity to explore the complexity of human structures. Through interaction with actual human tissues, students can deepen their understanding of anatomy by gaining hands-on experience that enhances their ability to visualize and comprehend the three-dimensional structure of the body which reinforce their theoretical knowledge (Ghosh, 2017). The study by Kochhar et al. emphasized that cadaver dissection is essential in deepening anatomical knowledge and improving practical skills (Kochhar et al., 2023).

However, in recent years, due to the changing times, anatomical education has faced challenges such as the gradual loss of cadaver dissection as the main method of anatomical teaching, the reduction of available teaching time, the emergence of new subjects in medical courses, and the limited number of cadavers (Guimarães et al., 2017). Therefore, many medical institutions are looking for more effective teaching strategies to replace conventional teaching programmes.

Currently, it is believed that incorporating assessments into the learning process can help students learn in depth. Incorporating formative assessments into the learning process not only provide timely feedback but also improve students' participation and motivation in class. Based on these advantages, some institutions have adopted objective structured practical examinations (OSPEs) as a structured, interactive practical teaching method (Malik et al., 2024). OSPEs enable students to learn practically through learning sites organized by teachers in advance, which not only test knowledge but also reflect learning priorities to a certain extent and are a viable alternative to conventional cadaver dissection teaching.

1.3 Anatomy teaching practice in Universiti Sains Malaysia

In the School of Medical Sciences, Universiti Sains Malaysia (USM), anatomy is taught through lectures and practical sessions. Typically, anatomy lectures last for one hour while practical sessions span 2 to 3 hours. Since its inception in 1979, the USM department of Anatomy has focused exclusively on cadaveric dissections in its particle sessions. Over time, the teaching approach has evolved to incorporate more versatile methods, including live demonstrations of anatomical structures using plastic models, plasticated specimens, and prosected specimens. These demonstrations are broadcast via multiple television monitors positioned throughout the laboratory. Following the live demonstrations, students are given the opportunity to study the specimens or models independently for the remainder of the practical session.

Starting in 2015, a significant change was introduced to the anatomy practical with the implementation and integration of the OSPE-based anatomy practical. The content of the practical materials is carefully designed to meet the learning outcomes. The main goal of this change was to enhance student engagement during practical and make the practical sessions more interactive and enjoyable for the students.

1.4 Justification and benefit of the study

Conventionally in medical course, OSPE-based questions are designed to be part of summative examination often held at the end of the course. The marks obtained in this examination are crucial for determining the student's eligibility to pass the course. Previous study has shown that OSPE-based examinations is a reliable assessment tool for many courses (Kumar&Rahman, 2022). On the other hand, OSPE-based anatomy practical as practiced here in USM is designed to enhance students' anatomical practical skills. It integrates conventional anatomy assessments, such as specimen identification and microscope observation, with interactive OSPE-based questions, making the learning process more structured and engaging (Belovarac et al., 2021). The OSPE-based anatomy practical is a form of formative assessment which aims to not make formal assessment but to teach and impart anatomy-related psychomotor as well as the cognitive skills to students.

Although the OSPE-based anatomy practical has been implemented in recent years at the medical school of USM, no research has yet been conducted to assess its effectiveness in comparison to the conventional practical method. This research gap makes us unclear about the specific role of OSPE-based anatomy practical in improving students' learning outcomes, promoting knowledge application and practical skills development. At the same time, whether the advantages of conventional anatomy practical, such as having more time for self-learning, can be continued under the new teaching model is also a question worth exploring. Therefore, it is necessary to conduct a comprehensive comparison of the two practical methods through in-depth research to determine whether the OSPE-based anatomy practical model can better meet the needs of medical education and provide more effective improvement directions for anatomy education. However, OSPE has been used as an assessment tool in other countries' anatomical specialties for some years (Lakshmipathy, 2015). The present study aims to conduct a comparative analysis study between OSPE-based and conventional anatomy practical, assessing their impact on students' knowledge and skill performance, student engagement and cognitive load.

For students, finding more suitable learning styles can increase their interest in learning, reduce their learning pressure to a certain extent. For teachers, finding efficient ways for students to learn can save time and cost without reducing learning tasks, optimise the use of teaching resources, enhance students' participation and motivation, improve teaching effectiveness and promote professional development. If this study can make students more interested in and effective at acquiring anatomical knowledge and skills, it could be adopted as a new teaching model in more universities.

1.5 General objectives

The study aims to investigate the impact of OSPE-based Anatomy practical session on students learning.

1.6 Specific objectives

1. To investigate the differences of students’ Anatomy - knowledge and skill performances between OSPE-based and conventional practical groups.
2. To investigate the improvement of students’ Anatomy knowledge and skill performances within OSPE-based and conventional practical groups.
3. To investigate the differences in students’ learning engagement scores between OSPE-based and conventional practical groups.
4. To investigate the differences in students’ cognitive load scores between OSPE-based and conventional practical groups.
5. To evaluate students’ experience and feedback on the assigned practical session.

1.7 Research questions

1. What are the differences in students' s cognitive performance score between OSPE-based group and conventional group?
2. What is the improvement of students' psychomotor performance score between OSPE-based group and conventional group?
3. What are the differences in engagement scores of students in between OSPE-based group and conventional group?
4. What are the differences in the students' cognitive load scores after attending OSPE-based group and conventional group?
5. What is the students' motivation on the assigned practical session?

1.8 Research hypothesis

1. The students' Anatomy knowledge and skill performances for the OSPE-based group is higher compared to the conventional group.
2. There is an improvement in the knowledge and skill performance within the OSPE-based group.
3. The students' engagement score in OSPE-based group is higher than the conventional group.
4. The cognitive load of the OSPE-based group is lower than the conventional group.

1.9 Operational definitions

Cognitive performance

Cognitive performance refers to an individual's ability to perform mental tasks that require processes such as attention, memory and comprehension. It involves the effective use of cognitive functions to acquire, process, and apply knowledge (Bennett et al., 2003).

Psychomotor performance

Psychomotor performance refers to the ability to coordinate mental processes with physical movements to perform tasks that require both cognitive and motor skills. It involves the integration of perception, attention, decision-making, and physical action to complete tasks accurately and efficiently (Krathwohl, 2002).

Learning engagement

Learning engagement refers to the degree of attention, interest, motivation, and active involvement that a student demonstrates while participating in the learning process. It encompasses the emotional, cognitive and behavioural aspects of learning (Fredricks et al., 2004).

Cognitive load

Cognitive load refers to the mental effort required to process information and perform tasks in working memory. It describes the number of cognitive resources (such as memory) needed to understand, learn, or solve a problem. Cognitive load can be divided into three types: Intrinsic cognitive load, Extraneous cognitive load and Germane cognitive load (Sweller, 2024).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the development of anatomical education will be explained based on time, including its history, evolution and characteristics. First of all, Anatomy, as the cornerstone of medical education, requires robust and objective anatomical experiments to connect theoretical knowledge and experimental classes. Evaluating the teaching completion and student feedback of anatomy laboratory courses requires a series of indicators, including learning performance, student engagement, and cognitive load. As an assessment tool, the Objective Structured Practical Examination (OSPE) has become an innovative tool in anatomy laboratory classes. It can solve the shortcomings of conventional laboratory classes and the limitations of conventional assessment methods, providing structured, objective and competency-focused assessment. Then the background and development of OSPE will be explained. Although OSPE is increasingly adopted globally, there is limited research on its impact on student performance, engagement, and cognitive load. Ultimately, there is a need for a theoretical understanding of student performance, engagement, and cognitive load.

2.2 Teaching and Learning Methods in Anatomy

2.2.1 Overview of teaching and learning methods in anatomy

Dissection has long been regarded as the cornerstone of medical education, playing a pivotal role in the understanding of human anatomy. The methods of acquiring anatomical knowledge have evolved significantly across different eras and regions. A historical overview reveals the following progression: In ancient times, Egyptian embalmers acquired significant anatomical knowledge through the practical handling of human remains during the mummification process. It was also discovered that human dissection was practiced in ancient India, Greece, and China, with Greeks also combining theological principles and animal dissections. During the Middle Ages, human dissection declined, replaced by animal dissections in Europe. The Renaissance period reignited interest in human dissection, with new experimental methods emerging in the 17th century and autopsies in the 18th. The 19th century introduced microscopy and anatomical sections, while the 20th century expanded to include medical imaging, observational studies, and molecular techniques. Today, 21st-century anatomy is dominated by technology-driven approaches such as advanced imaging and digital tools, reflecting a continuous shift toward precision and innovation(Ghosh, 2022).

2.2.2 Lectures

Since the advent of modern medicine, the anatomy curriculum has undergone significant changes. Researchers have summarized the evolution of anatomy education into several distinct phases. In the early phase (1905–1922), the medical school which adopted the British system, relying on cadaver-based instruction with anatomy taught during the first two years of study. From the mid-1960s to the mid-1990s, the anatomy course extended to one and a half years with an emphasis on clinical application and professional relevance. During this period, teaching was delivered via two formats: large-class lectures to introduce and preview key structures encountered during dissection, and small-group tutorials to reinforce the learning objectives. In the late 1990s and early 21st century, the curriculum was revised to a one-year course with significantly reduced contact hours, though large lectures, small-group tutorials, and dissection sessions were still maintained (Wong&Tay, 2005).

The outbreak of the COVID-19 pandemic in 2020 prompted medical schools worldwide to shift to online classes. Studies have shown that approximately 75% of students preferred conventional teaching methods, while about 50% found online anatomy classes equally satisfactory. Nonetheless, most students felt that distance education was less popular and effective compared to conventional methods. Although the advent of online education has fostered increased student engagement in anatomy courses, it has also been linked to lower test scores. These findings suggest that while online education can serve as a supplementary tool in anatomy teaching, it cannot fully replace conventional methods (Totlis et al., 2021).

Originally, anatomy education was based primarily on conventional cadaveric practice and lectures. Over time, however, modern teaching modalities—such as models, imaging technologies, simulated anatomy, and online resources—have been introduced. Despite these innovations, the prominence of anatomy within the medical curriculum has gradually diminished, with some universities even eliminating anatomy courses altogether. Although the direction of curriculum reform varies among institutions, the most effective learning strategy appears to be a multimodal approach that combines conventional cadaver-based instruction, multimedia teaching, procedural anatomy, clinical anatomy, and imaging technologies. The reduction in anatomy class hours, however, may negatively impact educational quality. Research indicates that teaching strategies should preserve the benefits of conventional anatomy while judiciously integrating modern technology to achieve balanced educational outcomes (Sugand et al., 2010).

2.2.3 Cadaver dissection

Before exploring the relationship between conventional medical education and modern innovative technologies, it is essential to understand the concept of "conventional cadaver dissection" in anatomical education. This teaching model usually takes direct manipulation of human remains as the core and allows students to understand the structure and function of the human body more intuitively by allowing them to perform dissections by themselves. In addition, in the practical operation classroom, it is combined with the guidance and explanation of the teacher. This practical teaching method can enhance students' perception of the three-dimensional structure of the human body, master practical operation skills, and have a deeper understanding of the complexity and variability of the human body (McLachlan&Patten, 2006). From this perspective, in addition to imparting anatomical knowledge, conventional cadaver dissection can also cultivate students' hands-on practical skills and enable students to have a deeper understanding of the complexity of the real human anatomical structure (Riederer, 2016). Studies have shown that the emergence of modern technology has provided a variety of teaching aids for anatomical teaching, but conventional cadaver dissection still has irreplaceable unique advantages in knowledge transfer and skill training and is the core content of anatomical teaching in many medical schools. In theory, conventional cadaver dissection is essentially a model in which students are the mainstay and teachers provide theoretical support and practical guidance. However, due to the scarcity of cadaver resources worldwide and due to various considerations such as safety, many institutions limit students' opportunities to participate in actual dissection operations, resulting in a shortened dissection course (Habbal, 2009).

Medical education has undergone significant changes at the dawn of the 21st century, with the first being the shift from conventional cadaver dissection methods to student-centred, integrated, and clinically oriented teaching methods. Despite the development of new methods, we still have to face the problem of limited cadaver resources, and many countries have adopted supplementary teaching tools to address this issue. Cadaver dissection is widely considered to be key to building clinically relevant anatomical knowledge and cultivating interdisciplinary skills necessary for the modern healthcare system (Ghosh, 2017). Of course, relying solely on cadaver dissection is not enough to provide students with a rich source of knowledge and learning experience. Innovative teaching methods should be proposed to meet the needs of contemporary medical education. Researchers emphasize that combining cadaver dissection with modern educational strategies can enhance the learning experience and promote innovation and improvement in anatomical education to meet the needs of today's medical field.

2.2.4 Prosection

Cadaver dissection is important in medical education. Prosections also play a big role in anatomical teaching. Experienced anatomical technicians make them ready. They put them in formalin or other things to save them. They are used for teaching demonstrations and student learning observations. How they are used is different from students' hands-on dissection (McLachlan et al., 2004). These items are made well. They show body parts clearly. So, people use them a lot in labs and museums. They help a lot with teaching and tests. Students can learn body structure better with these items.

Prosections have many good points in anatomy teaching. First, prosections show body parts in a standard, good way. Students can see different body parts and how they connect. This helps avoid mistakes that happen when students in dissection (Mitrousias et al., 2020). Studies have shown that dissection of human cadaver specimens is a conventional, effective, and highly respected way to learn anatomy. Second, using prosections makes teaching faster. It saves class time. This is key for today's busy medical schools. Also, prosections last a long time. They can be used again. So, they give schools steady teaching tools (Ghosh, 2017). Many studies show that students learn well from these items. They learn just as well as dissection, even if they do not touch the body parts much (Kerby et al., 2011). Prosections help students learn if they do not get to cut body parts often. They add to learning.

Prosections teaching also has some limits. Students who only use prosections may not get real experience. They may not get deep space understanding from dissections (Ghosh, 2017). Fine hand skills and touch sense come from dissections. These are important for doctors. It is hard to get these skills with prosections (Burgess&Ramsey-Stewart, 2015). Studies say conventional dissections let you see diseases and body differences. They help to build skills. They help to care for people and understand death. However, they still have limit in reaching some learning goals (Choi-Lundberg et al., 2016). Prosections also need chemicals to stay good. Making, keeping, and caring for them costs a lot. It also has safety risks. This means schools need more money and better management (Henry et al., 2016).

2.2.5 Plastic models

Plastic models are three-dimensional, representations of human anatomical structures, designed to copy the size, shape, and spatial relationships of real body parts. These models are often display different colours and labelled, providing a visual and hands-on aid for students learning human anatomy (Peterson&Mlynarczyk, 2016). They range from real models of organ systems to detailed copies of specific organs, bones, or joints. Modern plastic models have become important teaching tools that help medical educators present anatomical structures in better methods than cadavers, to move away from the clutter, discomfort, and complexity of a cadaveric dissection. (Triepels et al., 2020).

In current anatomy education, plastic models are widely used in medical, nursing, and other health programs. They are common in undergraduate and preclinical courses, where students first need to study human anatomy (Wilson et al., 2018). Plastic models are used in classroom demonstrations, anatomy practical, and self-directed learning environments. They are also used in examinations such as Objective Structured Practical Examinations (OSPE), where students must identify anatomical structures under timed conditions (Moxham&Plaisant, 2007).

Research shows that anatomical models serve as excellent active learning, teaching, and demonstration tools for those seeking to understand human anatomy and kinesiology (Maresky et al., 2019).

The advantages of plastic models include their durability and reusability. Unlike cadaveric materials, plastic models do not break down over time and can be handled repeatedly without significant wear (Estai&Bunt, 2016). They are also clean and safe, posing no biological or chemical risks, making them suitable for classrooms without specialized ventilation or preservation systems. Additionally, plastic models are often simplified and color-coded, helping learners identify and distinguish anatomical features more easily.

Plastic models also offer practical benefits for educational institutions. They provide cost-effective teaching resources that can be used repeatedly without the ongoing expenses associated with cadaver procurement and maintenance (Yammine&Violato, 2015). Furthermore, they eliminate ethical concerns related to the use of human remains and are readily available without the supply limitations that often affect cadaveric specimens (McLachlan&Patten, 2006).

However, plastic models also have important limitations. Research indicates that plastic models are less effective in knowledge acquisition but could be valuable when preparing for cadaveric laboratories. They lack the natural variability and complexity of real human tissues, which may prevent the development of practical dissection skills and the ability to recognize anatomical differences in real-life clinical settings (Mitrousias, Karachalios et al., 2020).

The texture, colour, and flexibility of plastic do not copy the feel of real human tissue, reducing the sensory and emotional depth of the learning experience ((Ghosh, 2017). Human cadaveric prosections are a conventional, effective, and highly appreciated modality of anatomy learning, while plastic models cannot provide the same level of realistic tissue properties and anatomical variation that students will encounter in clinical practice.

Furthermore, overreliance on models may lead to shallow understanding if not supplemented with other resources like cadaveric specimens or digital anatomy platforms (Pawlina&Lachman, 2004). Studies have shown that there was no solid evidence that the use of 3D models is superior to conventional teaching, suggesting that plastic models should be used as supplements rather than replacements for conventional anatomical education methods.

Research comparing different teaching modalities has found that while plastic models have their place in medical education, they should be part of a mixed approach. The targeted use of each learning modality is essential for a modern medical curriculum, emphasizing that plastic models work best when combined with other teaching methods rather than used alone.

2.2.6 Plastination

Plastination is a preservation technique in which water and fat in biological tissues are replaced by curable polymers, such as silicone, epoxy, or polyester. The technique of plastination was developed by Dr. Gunther von Hagens in the late 1970s and has since become an important tool in modern anatomy education (Von Hagens et al., 1987). This method allows for the permanent preservation of human tissues and organs, creating specimens that maintain their three-dimensional structure while being completely dry and stable.

Nowadays, there is an increase usage of plastinated specimens in medical schools, universities, and public anatomy exhibitions. They are utilized in practical sessions and small group discussions to teach gross anatomy by providing long-lasting and realistic representations of human structures from multiple angles (Riederer, 2014). The plastination process results in dry, odourless, and durable anatomical specimens that can be handled without gloves or special storage conditions, making them particularly suitable for educational environments.

Plastination offers several significant advantages in anatomical education. Plastinated specimens are highly durable, allowing repeated use over many years without degradation. The specimens require no refrigeration or chemical preservation, making them safe, clean, and easy to store and transport. This eliminates the need for specialized ventilation systems or hazardous chemical handling that is required with conventional wet specimens.

Research has demonstrated the educational effectiveness of plastinated specimens. Studies have shown that compared with wet specimens, students find that plastination specimens are easier to use and help them distinguish structures and understand complex anatomical relationships more clearly (Atwa et al., 2021). The knowledge gained from plastination has been found to be comparable to that gained through other established teaching methods, indicating that plastination can serve as an effective alternative or supplement to conventional anatomical teaching approaches ((Goh et al., 2024).

However, plastination also has important limitations that must be considered. The production of plastinated specimens is time-consuming, labour-intensive, and expensive, limiting accessibility for some institutions (Riederer, 2014). The high costs associated with the plastination process and specialized equipment may make it difficult for smaller educational programs to implement this technology.

The rigid nature of some plastinated tissues may also reduce the ability to demonstrate functional movement or tissue flexibility, which can be important for understanding anatomical function (Latorre et al., 2007). This rigidity limits the educational value when teaching about joint movement, muscle flexibility, or organ elasticity.

Additionally, because plastination fixes specimens permanently, it removes the opportunity for students to perform dissections themselves—a valuable skill in medical training that helps develop fine motor skills and spatial understanding (Reed et al., 2014). Studies have indicated that while plastination results in good student performance, it may be somewhat limited compared to hands-on dissection experiences that provide tactile learning and procedural skills development.

2.2.7 Advanced technology-based anatomy learning tools

The COVID-19 pandemic has further limited the access to face-to-face instruction and human endowment resources, exacerbating challenges in anatomy education. To address these issues, educators have adopted technologies such as virtual reality, 3D anatomy apps, 3D printing, and AI chatbots, which have greatly enhanced students' learning experience and knowledge retention. Researchers emphasize that each technology has specific advantages and limitations and is suitable for different learning scenarios. However, the most effective teaching results are achieved through the integration of multiple modes (Yang, 2023).

2.3 Learning Performances

The term Learning Performances was initially developed by Joseph Krajcik and Katherine L. McNeill in the science education community. Learning performance refers to the measurable outcomes of a learner's engagement with any educational activities. It indicates how well a person has understood, retained, and can apply the knowledge, skills, or attitudes acquired through instruction or experience (Krajcik et al., 2007).

As an important vehicle for linking teaching goals, curriculum, and assessment, it takes high-level learning goals, like national science standards, and breaks them down into observable actions students might perform. In ensuring students integrate knowledge in science with the skills in real contexts, the Learning Performances push them beyond memorizing detached facts or concepts, leading them towards deeper learning and the application of science principles (Krajcik, McNeill et al., 2007). In the context of anatomy learning, learning performance includes students' ability to identify anatomical structures, understand spatial relationships and apply anatomical knowledge in clinical settings.

Learning performance in anatomy education is especially important in medical curricula because anatomy forms the foundation of clinical practice. A clear understanding of human anatomy is essential for diagnosis, surgical procedures, physical examinations, and interpreting medical imaging. Poor anatomical knowledge can lead to clinical errors, making high learning performance in anatomy a crucial objective for future healthcare professionals. It also supports the integration of other disciplines, such as physiology, pathology, and radiology, ensuring that students can connect theoretical knowledge with real-world applications.

There are several methods to assess learning performance in anatomy. Written exams such as multiple-choice questions (MCQs) and short essay questions, are commonly used to evaluate theoretical knowledge or cognitive level. Practical assessments, such as OSPE and identification tasks using cadavers or plastic models assess students' psychomotor ability to recognize and identify anatomical structures. Additionally, performance in group discussions, presentations, and case-based discussion can assess the communication skill of students

There are many variables affecting learning performance. One factor is social variables.

Studies show that social influence such as from peers' and teachers' interactions, and social media usage—have positive impacts on learning and participation, consequently on student learning performance.

With the continuous development and improvement in teaching models, collaborative learning and participation, based on social influences, can enhance students' active participation in learning activities. It points towards the need for incorporating teamwork and other participative methodologies into teaching models in order to advance students' scholastic development. Social influences play an important part in advancing students' learning experiences and outcomes, providing empirical support for the planning of teaching approaches and the usage of educational technology.

2.4 Engagement

Learning engagement refers to the degree of attention, interest, motivation, and active involvement that a student demonstrates while participating in the learning process. It encompasses the emotional, cognitive and behavioural aspects of learning (Fredricks et al., 2004). The concept of "engagement" has its roots in multiple disciplines. In the field of education, the earliest research on student engagement dates back to the late 1970s and early 1980s. Bloom's seminal work, Human Characteristics and School Learning (1976), explored the relationship between students' time investment in the classroom and their learning outcomes. In the 1980s, Fred M. Newmann and colleagues began to systematize engagement as a critical component of learning (Fredricks, Blumenfeld et al., 2004).