Theories of Blended Learning:

A Novel Approach to Tertiary Neuroanatomy

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Abstract

Anatomical dissections and prosected cadaveric specimens are currently believed to be the most beneficial delivery method for tertiary anatomy education. However, there is increasing demand within the tertiary medical education community for alternative delivery methods to complement current teaching practices, particularly in the complex field of neuroanatomy. To ensure that students learning of neuroanatomy is effective, it is necessary to take an evidenced-based approach. Therefore, this review will compare and contrast the different factors involved in learning neuroanatomy and the different modalities that can be used to teach this complex topic. Further, this review will also highlight the differences between individual and mixed-model delivery systems, which may influence the current pedagogies surrounding tertiary neuroanatomy in the dynamic educational setting.

Keywords: neuroanatomy, anatomy and medical education, teaching of neuroscience/neuroanatomy

1. Introduction

Doctors, Nurses, Physiotherapists and Occupational Therapists are involved in the management of patients presenting with pain and/or movement disorders (Farrell et al., 2015). A coherent understanding of the anatomy of the nervous system is fundamental for accurate assessment, diagnosis, and evidence-based management of such patients (Farrell et al., 2015; Harvey, 2016; McFarlane-Parrott, 2002; Nielsen et al., 2015; Nijs et al., 2014).

The current consensus is that teaching through anatomical dissection or prosected human cadaveric specimens is most beneficial to students learning anatomy (Aziz et al., 2002; Iwanaga et al., 2020; Saltarelli et al., 2014; Sriram & Thenmozhi, 2020; Van Wyk & Rennie, 2015). The use of human cadavers allows the learner to develop an appreciation of the fragility of tissues and organs in addition to understanding the size and relative positions of anatomical structures in the multidimensional body (Aziz et al., 2002; Brenton et al., 2007; Hisley et al., 2008; Moore, 1998; Schofield, 2014). Furthermore, Aziz et al. (2002) argues that the use of cadavers is essential to instil ethical and humanistic awareness in future health professionals. However, many believe that there is a requirement for alternative delivery styles when teaching anatomy due to issues such as the expenses involved in maintaining human cadaveric facilities, increasing student numbers, time constraints within the classroom, psychological issues, adapting to a post-pandemic setting and, in some areas, the limited availability of cadavers. (Anderton et al., 2020; Brenton et al., 2007; Hancock et al., 1998; Saltarelli et al., 2014). In addition, students may find the cadaveric experience emotionally stressful, inducing adverse psychological and/or physical reactions (Chia, et al., 2020; Horne et al., 1990; Wisenden et al., 2018), which may hinder their learning (Watkins & Moulds, 2007; Wisenden et al., 2018). Alternative delivery styles, such as online tutorials, may provide a less traumatic and more cost-effective option (Iwanga et al., 2020; Palomera et al., 2014).

Online tutorials allow students to work around varying schedules and to learn at a pace that best suits their learning style (Howlett et al., 2011; Picciano, 2017; Raymond et al., 2016). Additionally, interactive online tutorials provide students with the benefit of instant and formative feedback based on how they respond to questions, allowing for misconceptions to be rapidly eliminated (Wong et al., 2015). Importantly, by minimising the variability in both anatomical examples and pedagogical approaches, online tutorials may reduce the level of extraneous cognitive load, which is the difficulty associated with how the material is presented (Leppink & van den Heuvel, 2015). This allows students to devote more of their mental effort on coping with the intrinsic cognitive load, the degree of difficulty associated with the content itself, avoiding a state of cognitive overload (Leppink & van den Heuvel, 2015). Online modules allow for the creation of schemas, allowing multiple elements of information to be grouped into one category (Chi et al., 1981). The use of schemas reduces the load on working memory in more proficient learners and facilitates greater understanding of core concepts in less proficient learners (Leppink & van den Heuvel, 2015; Sweller, 1988).

The use of online learning is proposed as an adjunct to, rather than a replacement for, learning of anatomy with human cadavers (Iwanga et al., 2020; Parry, 1989; Toth-Cohen, 1995; Van Wyk & Rennie, 2015). Arguably, the two methods used in conjunction achieve optimal learning for the student (Biasutto et al., 2006; Iwanga et al., 2020; Parry, 1989; Toth-Cohen, 1995; Van Wyk & Rennie, 2015). The existing research heavily focuses on gross human anatomy and the musculoskeletal system, with a tendency to neglect smaller subsets, such as neuroanatomy (Biasutto et al., 2006). Due to its high complexity and complicated structures, neuroanatomy has been regarded as one of the more difficult areas of anatomy to learn (Javaid et al., 2018). This review will cover what we know regarding different learning modalities for broader human anatomy and provide recommendations as to how these modalities could be applied for neuroanatomy.

The mixed-model delivery of neuroanatomy learning activities, online interactive tutorials and practical classes using human prosected specimens, offers students autonomy through the ability to learn via the avenue that they find most suitable, and their integration may further increase the benefits offered by each model. With the ever-changing educational setting in the COVID world (Anderton et al., 2020) and the associated difficulties (Singh et al, 2021), it is imperative to reassess teaching and learning strategies, to ensure the most effective and efficient methods are being used. Therefore, this review aims to analyse some of the major factors that contribute to neuroanatomy learning, including working memory, cognitive load theory and expertise reversal effect, while also reviewing the current available learning modalities.

2. Factors Influencing Knowledge Retention

2.1 Working Memory

Working memory is conceptualised as the cognitive structure in which we process information (Kirschner et al., 2006) and is critical in the process of neuroanatomy study. Learning occurs when working memory is rehearsed sufficiently that it begins to transfer into our long-term memory (Baddeley, 1992). Our working memory has a limited ability to hold novel information, less than 30 seconds, unless that new information is rehearsed frequently, making repetition an important aspect of anatomy study and knowledge retention (Barrouillet et al., 2009; Kirschner et al., 2010; Peterson & Peterson, 1959). Moreover, while learning new information, our working memory has a restricted capacity of approximately seven elements (Miller, 1956). As such, working memory is a critical element to consider in the design of a teaching program for neuroanatomy.

2.2 Cognitive Load Theory

The Cognitive Load Theory involves the way in which cognitive resources are allocated and used in the processes of learning and problem solving (Chandler & Sweller, 1991). This theory implies that teaching methods should be designed in a way that does not surpass this capacity, thereby preventing cognitive overload, a situation where the learner has received excessive stimulus and is unable to process any further information (Leppink & van den Heuvel, 2015; Sweller et al., 1998; Wong et al., 2015). Cognitive load is composed of three subtypes: intrinsic cognitive load, the amount of effort brought on by the nature of the material being learned; extraneous cognitive load, the effort generated depending on how the material is presented; and Germane cognitive load, the cognitive effort contributed to processing new information into schemas (Sweller, 1988; Sweller et al., 1998).

Although the number of elements that can be processed in working memory is limited, there is no constraint on the size or complexity of each element (Sweller, 1988). Proficient learners reduce the load on the working memory via the recognition of patterns within novel information and the development of ‘schemas’. Schemas are used to organise multiple elements of new information into categories such that, despite their level of complexity, they are treated as a single element, allowing for more information to be processed in working memory (Chi et al., 1981; Leppink & van den Heuvel, 2015; Sweller, 1988). For novice learners, developing schemas places a higher intrinsic cognitive load on their working memory as they are unfamiliar with the individual elements of information (Leppink & van den Heuvel, 2015). Therefore, similar to the limit that working memory places on neuroanatomy learning, cognitive load theory must be considered when designing an adequate teaching program.

2.3 Intrinsic Cognitive Load

Intrinsic cognitive load is the difficulty presented by the complexity of the material, with processing more difficult or unfamiliar concepts creating greater intrinsic cognitive load (Sweller, 1988; Sweller et al., 2019). In order to minimise the level of intrinsic cognitive load experienced by a learner and to facilitate learning, an instructor could begin with a simple task and gradually increase either the complexity or fidelity of the task (Leppink & van den Heuvel, 2015). Significantly, with any given number of elements, a novice learner will experience greater intrinsic cognitive load than a more adept learner due to their lower efficiency in processing new elements (Leppink & van den Heuvel, 2015). Ayres (2001) argues that formative assessment items with more incorrect responses from students may indicate concepts with higher intrinsic cognitive load. Consequently, if the complex nature of neuroanatomy imposes a greater intrinsic cognitive load on the student, a greater number of errors should be expected.

2.4 Extraneous Cognitive Load

The degree of difficulty associated with the presentation of information to learners is described as extraneous cognitive load (Sweller, 1988). Poorly designed instructions or tasks create difficulty in understanding the material, increasing extraneous cognitive load, lowering the threshold to overload (Sweller et al., 1998; Sweller et al., 2019). The extraneous cognitive load experienced by a novice learner can be minimised by supporting novice students through guided instruction (Rana & Burgin, 2017; Schilling, 2017). This level of support became more difficult during the current pandemic crisis with COVID-19 and the shift to more online learning, leading to dynamic changes in pedagogical approaches to all fields of teaching with a focus on remote and online learning (Dhawan, 2020; Singh et al., 2021). Initially this was associated with a higher extraneous cognitive load, but with continued change and entering a post-vaccine world this load is reducing as we embrace and adapt to a more blended learning model. Most recently Dhawan (2020) and Singh et al. (2021) demonstrated that a blended learning model enhanced relationships between educator and learner as well as creating a more interactive environment with improved student retention and knowledge. This has also been demonstrated in the field of neuroanatomy. Whilst some tutor assistance is provided, additional extraneous cognitive load is inherent in some neuroanatomy practical classes due to the degree of self-direction required in the selection, orientation, and navigation of appropriate prosected specimens (Sunde et al., 2018). In contrast, online tutorials present organised information directly to the learner (Hall and Border, 2020); However, it has been demonstrated to be beneficial to decrease support as learners become more proficient due to the 'expertise reversal effect' (Kirschner et al., 2006; Leppink & van den Heuvel, 2015). In order to reduce extraneous cognitive load in neuroanatomy and in general, instructors and academic institutions need to focus on building appropriate infrastructure to support these blended learning models, which will provide meaningful and engaging learning experiences.

2.5 Germane Cognitive Load

Germane cognitive load is the process of redistributing working memory resources from extraneous activities to activities directly relevant to learning by dealing with information intrinsic to the learning task (Sweller et al., 2019). Through this process it allows the development of mental models and schemas, committing them to memory, and facilitating a positive learning experience (Cierniak et al., 2009; Klepsch et al., 2017; Sweller et al., 1998). Klepsch et al., (2017) describes that undertaking activities, such as self-explanation and active note taking, increase a learner's level of germane cognitive load and lead to achieving a higher academic outcome. This higher academic outcome is thought to be due to an increase in effortful cognitive load and engagement and mental resources used in linking new information with previously established schemas, aiding in committing this information to working memory (Kalyuga, 2011; Klepsch et al., 2017; Leppink, 2017). To promote the optimal learning experience for the student, the design of the learning material should aim to reduce the amount of extraneous cognitive load to enable a greater percentage of redistribution through germane cognitive load to working memory associated with the task, thereby reducing the difficulty associated with processing poorly designed information and maximising schema organisation and recall (Cierniak et al., 2009; Sweller et al., 1998; Sweller et al., 2019; Zukic et al., 2016)

2.6 Expertise Reversal Effect

Providing novice learners with extensive guidance is initially beneficial for their learning, however, the advantage regresses, and guidance may become detrimental to later performance once students improve their understanding (Kirschner et al., 2006; Schilling, 2017). Learning in an environment of excessive guidance may impair a student's ability to independently retrieve information from their memory, thus affecting their task performance (Bernstein et al., 2003). This concept has been termed the expertise reversal effect: guidance is required for novice learners due to the lack of information stored in their long-term memory, but it should be lessened as the learner becomes more proficient and their ability to withdraw information from long-term memory replaces need for external guidance (Kalyuga et al., 2003). Online modules can be designed to cater for novice and proficient students by providing varying levels of scaffolding which are optional for the student to choose or ignore, creating an environment that is effective and appropriate for their knowledge base (Gillett-Swan, 2017; Raymond et al., 2016).

3. Learning Modalities

3.1 Traditional Teaching

Traditionally anatomy is taught via a combination of lectures and through cadaveric specimens, though it is widely believed that teaching through anatomical dissection or prosected human cadaveric specimens is the most beneficial method (Aziz et al., 2002; Moore, 1998; Saltarelli et al., 2014). Cadaveric learning allows the learner to develop an understanding of the physical properties within the body as well as have exposure to the variability of organic structures in humans that may not be present in plastic models or textbooks (Aziz et al., 2002; Brenton et al., 2007; Hisley et al., 2008; McLachlan et al., 2004; Moore, 1998). Aziz et al. (2002) argues that learning via the use of cadavers instils the students with an ethical awareness, which is essential for future health professionals. Many believe that due to issues involved with the maintenance of human cadaveric facilities, increasing student numbers, time constraints within classes, psychological issues, and the limited availability of cadavers, that an alternative delivery method is required (Brenton et al., 2007; Hancock et al., 1998; Saltarelli et al., 2014). It has been argued that students may find the cadaveric experience to be emotionally stressful, which may cause them to experience adverse psychological and/or physical reactions including anxiety and depression (Horne et al., 1990), which may have a negative impact on student learning (Watkins and Moulds, 2007). Palomera et al. (2014) hypothesises that the use of alternate delivery styles, such as the implementation of online tutorials, may provide a less traumatic and more cost-effective option than learning via cadaveric specimens.

3.2 Minimally Guided Learning

One of the major challenges for teaching anatomy is the time and resource constraints (Findlater et al., 2012). These limitations can be reduced by the implementation of minimally guided learning, or self-directed learning, relying on students to direct some of their own learning. However, minimally guided learning, such as problem-based learning, can increase extraneous cognitive load in novice learners at the expense of intrinsic cognitive capacity, resulting in increased time needed to perform a task and a decrease in task accuracy (Leppink & van den Heuvel, 2015). Essentially, minimally guided learning leads to more of our working memory being used to understand the way content is delivered, allowing less cognitive effort to be used on processing the information itself. Interactive online tutorials provide instant feedback and guided instruction, in turn reducing the extraneous cognitive load on the learner, allowing them to attend to more elements of novel information (Leppink & van den Heuvel, 2015). The implementation of online tutorials resulted in improved student performance and engagement when compared to minimally guided learning (Fisher et al., 2018; Green et al., 2018; Ismail et al., 2018; Wong et al., 2015). This phenomenon was seen in both undergraduate and postgraduate university settings across science and non-science courses.

3.3 Online Interactive Tutorials

Online interactive tutorials deliver content and guided instruction with the aim of providing the learner with efficient and immediate feedback in response to their actions (Wong et al., 2015). The use of online tutorials can enable students to study at a pace that best suits their learning style and allows them to work around other commitments, providing them with access to information at times most convenient to their situation (Howlett et al., 2011). Wong et al. (2015) evaluated the effectiveness of learning diagnostic imaging using online tutorials, establishing that the benefits are greater than that of classroom learning, which had low efficacy, but somewhat less than learning from face-to-face teaching from tutors to smaller groups of students, which had the greatest benefit.

Ideally, the implementation of online tutorials may reduce the intrinsic cognitive load on students, as components of neuroanatomy can be presented as specific categories of information, or schemas, thus requiring less working memory capacity (Chi et al., 1981; Sweller, 1988). This allows for more cognitive effort to be spent on intrinsic cognitive load as fewer new elements need to be processed by the learner (Leppink & van den Heuvel, 2015). However, if online tasks are too easy for students, boredom may overcome the potential benefits of completing the task (Young & Stanton, 2002).

3.4 Blended Learning

Insufficient feedback in learning can lead to the development of misconceptions, as students become confused and subsequently frustrated (Brown & Campione, 1994; Rich et al., 2017; Wolfe, 2019). This can prove troublesome for first year university students, as they need to adjust to university education and expectations and, as novices, require more guidance (Kalyuga et al., 2003; Poulos & Mahony, 2008; Vitali et al., 2020). The use of online tutorials in health sciences including anatomy have been found to have similar benefits to traditional method of teaching (Cook et al., 2008; Iwanga et al., 2020), allowing students to study in their own time and at their own pace (Howlett et al., 2011) while still receiving the benefits of timely feedback, reducing prior misconceptions (Gillett-Swan, 2017; Raymond et al., 2016; Wong et al., 2015).

One important factor to consider is that online tutorials do not allow students to develop the kinaesthetic facet of anatomy, which is pivotal for students studying health professions where learning anatomy is aimed at enhancing clinical practice (Dyer & Thorndike, 2000; Preece et al., 2013; Saltarelli et al., 2014; Vitali et al., 2020). Learning with human cadavers develops a sense of organ and tissue strength and fragility, along with the spatial awareness of the human body (Moore, 1998). Students learning human anatomy and physiology exclusively via online tutorials were unable to transfer their knowledge to human cadavers, affecting their performance in assessment (Saltarelli et al., 2014). However, when used in conjunction to some practical exposure, the combination is more beneficial than either method in singularity (Biasutto et al., 2006; Iwanga et al., 2020; Toth-Cohen, 1995; Van Wyk & Rennie, 2015). Consequently, implementation of a blended approach, combining online learning with traditional methods of delivery, should allow students to benefit from the accessibility, guidance and feedback afforded through online tutorials, whilst developing the haptic aspect of anatomy through the cadaveric experience observed in a study by Veneri and Gannotti (2014). They evaluated integration of online tutorials with the use of prosected cadavers for studying neurologic rehabilitation, demonstrating that students who took part in the blended delivery of the course outperformed on assessment compared to students who learnt exclusively via the prosected method. The integration of online learning was therefore an effective supplement to student learning.

3.5 Blended Learning in Neuroanatomy

Although some research has been conducted examining the benefits of using a blended delivery of course content in anatomy, these studies have mostly focused on human musculoskeletal or visceral anatomy, neglecting the more complex areas such as the brain (Biasutto et al., 2006; Ponraj, 2017). One study has evaluated the effectiveness of a blended delivery of neuroanatomy, but it was exclusively focused on neurologic rehabilitation, rather than neuroanatomy learning in general (Veneri & Gannotti, 2014). It is accepted that the use of cadavers in learning anatomy is ideal as it provides the students with a coherent understanding of the three-dimensional concepts of the different anatomical structures (Rizzolo, 2002). In addition, online tutorials are beneficial for learning neuroanatomical structures, as they support understanding of the complex structures and their relative spatial positioning (Naaz et al., 2014).

3.6 Problems caused by the COVID-19 Pandemic

The COVID-19 Pandemic has greatly impacted the education sphere, forcing many education centres to close or rapidly shift towards an online delivery (Dhawan, 2020; Rapanta et al., 2020; Singh et al., 2021). There is research to suggest that when in a face to face learning environment, students are more motivated, and teachers are able to more easily pick up on nonverbal cues, and make changes to their teaching curriculum and methods more easily (Kemp & Grieve, 2014; Paul & Jefferson, 2019). The rapid transition delivery method of teaching has been found to cause significant stress in those who had had little to no prior experience in working with such technology as well as a reduction in connection with other staff and students (Course Hero, 2020; Flaherty, 2020). This, along with personal grief and loss due to COVID-19 can lead to a higher rate of burnout (Course Hero, 2020; Flaherty, 2020; Singh & Matthees, 2021). The students are also susceptible to difficulties from a rapid shift to an online environment, including technical difficulties that may affect one individual or the whole class, impeding the teaching dynamic (Favale et al., 2020). Online teaching is almost all theoretical, greatly affecting any content that requires students to practice any practical components (Dhawan, 2020). The fishbone analysis (diagram 1) further illustrates the multitude of difficulties faced in the rapid move to online learning enforced by COVID-19 itself.

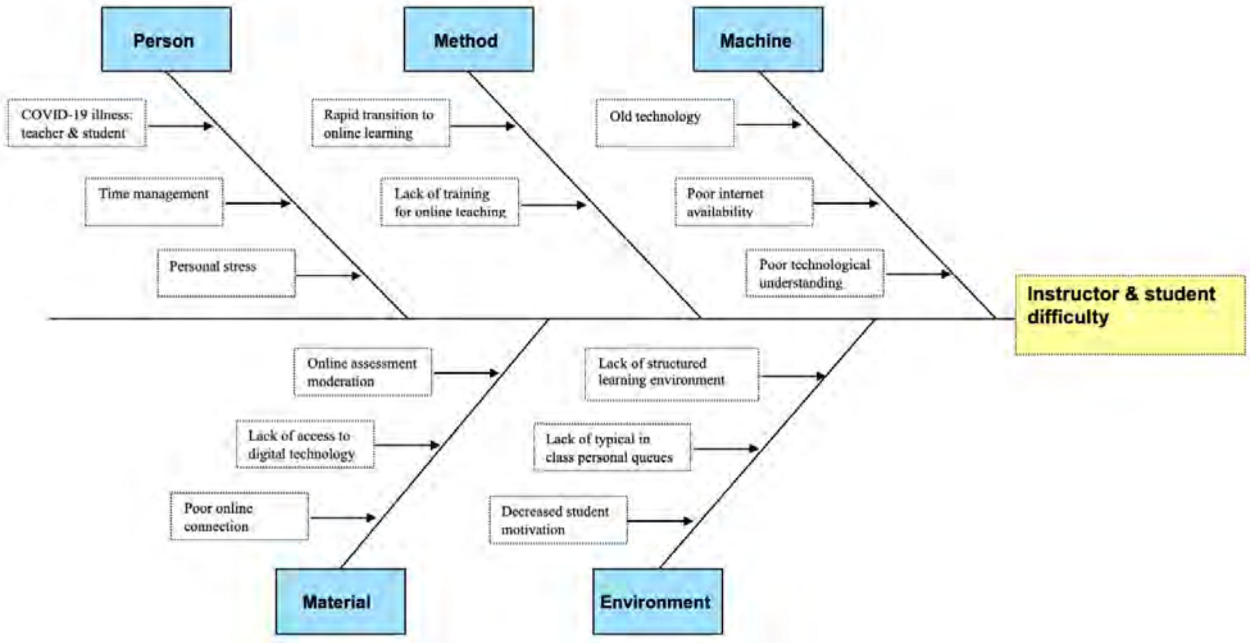

Diagram 1. Fishbone diagram illustrating factors contributing to instructor and student difficulty in the rapid adaptation of online learning due to COVID-19

4. Conclusion

It has been shown that delivering course content through a blended approach, using online modules in conjunction with traditional methods with prosected cadaveric specimens is more beneficial than prosected specimens alone (Biasutto et al., 2006; Iwanga et al., 2020; Toth-Cohen, 1995 Van Wyk & Rennie, 2015). Although this benefit has been well documented in current literature regarding musculoskeletal anatomy, there is a paucity of evidence when it comes to the complexities of neuroanatomy. The findings from this review suggest a blended or mixed-model approach in the delivery and learning of tertiary neuroanatomy provides the greatest opportunity for most students. This review suggests that by incorporating neuroanatomy learning activities, online interactive tutorials and practical classes using human prosected specimens, students are offered the benefits of autonomy through the ability to learn via the avenue that they find most suitable. The integration of these models may also further increase the individual benefits offered by each model when utilised independently. Finally, further investigation is needed regarding the pedagogies of tertiary neuroanatomy to develop the most efficient delivery strategy for students in the current dynamic educational setting, to produce higher quality graduates.

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