PROTOCOL FOR BEME TOPIC REVIEW GROUP

# COMPARATIVE ANALYSIS OF MODERN NEUROANATOMY TEACHING TECHNIQUES: A BEME SYSTEMATIC REVIEW

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**Abstract**

Learning neuroanatomy is known to be challenging due to the complexity and interconnectedness of anatomical structures. The instructional methodology is highly variable between medical schools. This raises important questions about which practices are most beneficial for knowledge acquisition and long-term retention, and how they are best implemented. Modern neuroanatomy teaching technologies such as mobile learning, mixed reality, artificial intelligence and virtual assistants have not been summarized in a previous systematic review. A systematic review with a comprehensive search strategy is required to synthesise which modern teaching techniques are available to educators and identify which are most effective. Approximately 10,700 articles among 12 databases, 4 journals and hand-searched reference lists of key articles are available. Two reviewers will code relevant information overseen by three other investigators. A final manuscript will be produced by one author. This will be critically evaluated by the remaining four reviewers with final edits being made by the primary author.

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## 2. BACKGROUND TO THE TOPIC

Learning neuroanatomy is known to be challenging for medical students, junior doctors and general practitioners due to the complexity and interconnectedness of anatomical structures.[1] The difficulty in learning neuroanatomy was summarised by Jozefowicz who introduced the term 'neurophobia' in 1994.[2]

More recently, there has been a decrease in anatomy teaching hours with associated claims of poorer knowledge of anatomy of medical students;[3-5] particularly in central and peripheral nervous systems.[3] Practically, lower levels of neuroanatomy knowledge are associated with poorer confidence of junior doctors in managing neurological conditions,[6,7] and unsafe medical practice.[3] This trend may be shifting, with a recent paper indicating a 24% increase in neuroanatomy teaching within United States medical schools.[8] However, it is uncertain whether this is reflected in increased performance of medical graduates.[8] There is not a well-defined relationship being teaching hours and effectiveness of learning, suggesting pedagogy is an important factor to consider.

Traditional teaching in laboratories involves prosected human material, plastinated specimens, models and medical imaging.[9] In efforts to improve long-term knowledge acquisition, spatial understanding and reduce neurophobia in the context of reduced teaching hours and evolving curricula, research has also been conducted into developing innovative (largely digital) teaching strategies and techniques.[10,11] No consensus for use of these tools exists, despite there being a core neuroanatomy curriculum, described by Moxham *et al.* (2015).[9,10] Without clear evidence to guide us, the curriculum content, instruction methodology and assessment are entirely at the discretion of individual institutions. It is unsurprising that methods are therefore highly variable between universities around the world.[9,12] This raises important questions in global neuroanatomy education about which practices are most beneficial for knowledge acquisition and long-term retention, and how they are best implemented.

Two systematic reviews have been conducted into this area of research. Arantes *et al.* (2018) reviewed 29 papers that assessed the impact of using 15 methods of teaching on student's learning of neuroanatomy as a guide for curricular improvements.[11] The second, by Sotgiu *et al.* (2019), reviewed 16 papers covering eight teaching techniques in an attempt to identify the most effective method to teach neuroanatomy. Arantes *et al.* were more inclusive in their population being investigated, while Sotgiu *et al.* excluded all but undergraduate students. Both reviews commented on the heterogeneity between studies as being the main barrier to identifying the most helpful tool. At this stage, it seems unlikely based on the quality of evidence available that a single most effective tool is identifiable. Sotgiu *et al.* recommended a combination of multiple pedagogical resources are advantageous when teaching neuroanatomy.

The implementation and measurement of educational interventions is complex. The traditional 'systematic review', which the two reviews on this topic so far have utilised, is too specific and inflexible for complex implementation interventions; which is perhaps why neither were able to give definitive answers to their research questions.

A realist synthesis involves identifying underlying causal mechanisms and exploring how they work under what conditions.[13,14] A realist synthesis of neuroanatomy teaching techniques that seeks to not only identify and compare available teaching techniques, but offers reasons for why they work in some contexts and not others, would form a useful guide for educators and researchers into modern practises and their application.

Neither paper commented on content and/or description of educational tools to any great detail. If neuroanatomy educators understand in what context the educational tool was being investigated (in terms of curricula alignment and learning outcomes being assessed), they are better placed to apply the research into practise. Further, collaborative research is encouraged when studies are placed in context.

A further limitation of both studies is the most recent types of teaching technology, including augmented or virtual reality, were not included. Arantes *et al.* noted 83% of studies included were published in the last eight years and both papers illustrated this is a fast-moving area of research. The annual HORIZON Report describes emerging technologies in higher education that are likely to have an impact on teaching and learning. The most recent 2019 report suggests four relevant technologies will have a major impact in the next five years: mobile learning, mixed reality, artificial intelligence and virtual assistants.[15]

These are important educational tools that are increasingly used in neuroanatomy education, and have continuously appearing in the literature, even since publication of these previous reviews.[16-24] New educational technologies offer highly realistic learning experience supportive of complex learning and transfer, and their application in neuroanatomy teaching is of much interest to educators.[25] A review that updates educators on the value of these recent technologies in how they have been applied to neuroanatomy is required.

Therefore, this review aims to be a realist synthesis of available neuroanatomy teaching techniques. Furthermore, the paper aims to systematically review modern neuroanatomy techniques that utilise mixed reality, mobile technology, artificial intelligence or virtual assistants to update educators on available resources.

Specific terms:

Artificial intelligence: "the theory and development of computer systems able to perform tasks normally requiring human cognition. In education, this relates to technologies that personalize learning experiences and reduce workloads"

Augmented reality: "adding digital elements to a live view"

Curriculum: "a prescriptive term that defines subjects comprising a course of study"

Effectiveness: "the ability of an educational tool to enhance student's neuroanatomy knowledge in an appropriate, cost-effective, timely manner. Often used relative to other education tools."

Mixed reality: "intersection between digital technology and the real world. Current available technologies are augmented reality or virtual reality. Holographic devices are emerging in this space."

Mobile learning: "education or training conducted by means of portable computing devices such as smartphones or tablet computers."

Modern teaching techniques: "novel teaching techniques researched with regards to their application to neuroanatomy, particularly in the last 10 years. Examples include those mentioned in the HORIZON report such as AR, VR, mobile technology, artificial intelligence and virtual assistants.

Neurophobia: "a fear of the neural sciences and clinical neurology that is due to the students' inability to apply their knowledge of basic sciences to clinical situations." [2]

Performance: “in the context of neuroanatomy education, this will refer to student’s knowledge acquisition, ability to understanding the content and the long-term retention of information.”

Virtual assistant: “the use of spoken commands, voice recognition and a natural user interface to connect students to the virtual environment”

Virtual reality: “implies a complete immersion experience and shuts out the physical world”

**3. REVIEW QUESTION, OBJECTIVES AND KEY WORDS**

For undergraduate and graduate health science students:

Primary review questions:

- Which modern teaching techniques maximise knowledge acquisition of neuroanatomy?
- Which modern teaching techniques maximise long-term retention of neuroanatomy?

Secondary questions:

- What teaching methods are available for neuroanatomy? How can they be applied?
- Which teaching strategies encourage 'deep' levels of learning?
- What other factors are important for students learning neuroanatomy? (spatial ability, motivation, anxiety etc.)
- Can we influence these factors by adapting our teaching methods?
- Why are particular teaching strategies better than others?

**Objectives**

This is a mixed methods/mixed studies systematic review of modern neuroanatomy teaching techniques. We will review the primary literature and include studies reporting on modern teaching methods, student learning and knowledge acquisition/retention of neuroanatomy for undergraduate and graduate health students. We will describe relevant teaching interventions according to the context in which they were investigated (population, curriculum, etc.). This will be in a qualitative format and form the basis of the realist synthesis component of the review.

Authors will then report on any assessment of their effectiveness either in knowledge acquisition and/or retention, along with other secondary outcomes. We aim to provide a resource for neuroanatomy educators to select teaching methodologies for specific neuroanatomy content, provide direction for future research, and identify what is required for a teaching methodology curriculum to be designed for neuroanatomy courses.

In terms of how this review will change current practise, it will be the first of its kind to synthesise available literature comparing the most recent neuroanatomy teaching techniques and providing a description of their application. This will be a useful tool for neuroanatomy educators in selecting appropriate methodology for specific neuroanatomy subject areas. Further, the review provides the basis for an instructional curriculum to be written, a need evidenced by the variability in current instructional methodologies.

**Key words**

Neuroanatomy, cranial anatomy, pedagogy, student, teaching, mixed reality, artificial intelligence, mobile technology, virtual assistants, learning

**4. STUDY SELECTION CRITERIA**

**Inclusion Criteria**

Population: human, student, trainee, undergraduate, medical and allied health, doctor, junior doctor, resident, registrar, senior doctor, physiotherapy / physiotherapist, chiropractic, dentist/ dental, podiatry/ podiatrist, occupational therapy/ occupational therapist, nurse/ nursing / health professional

Intervention: learning methods in conjunction with: dissection, prosection, laboratory, lectures, tutorials, workshops, technology, mixed reality, virtual reality, augmented reality, artificial intelligence, virtual assistants, mobile learning, mentoring, feedback, small group learning, problem-based learning, case-based discussion, clinical learning, clinical application, other structured teaching methods, computer-assisted instruction/methods, asynchronous learning, educational models, memory, retention, cognition, curriculum, assessment

Comparison: Any comparison of teaching methods described under the inclusion criteria that assess knowledge acquisition and retention in neuroanatomy

Outcome:

- Primary: quantitative/qualitative assessment of knowledge acquisition and retention from Kirkpatrick's hierarchy.
- Secondary: description of teaching methods, analysis of learning styles (surface, strategic, deep)

Source: Primary literature from 2015 to 2020. The last decade has been described as a major period of advancement for neuroanatomy teaching techniques and most papers have been published within this period. Specifically, technologies such as mobile technology, mixed reality, artificial intelligence and virtual assistants have emerged in the last decade with regards to neuroanatomy education. Salient points relevant to the narrative of neuroanatomy teaching techniques from before 2015 may be extracted from the previous two reviews.

Educators would like to hear about the current capacity of the most recent educational technologies. This lends itself to selecting a timeframe in the last 1-2 years. However, the previous reviews did not cover AR or VR technology. As such, our rationale for extending the timeframe to 5 years is balancing the need for use-able, up-to-date technology that educators can use while remaining comprehensive enough to include papers that are guiding this area of research.

**Exclusion Criteria**

Population: nil
Intervention: nil
Comparison: comparison must be made between educational interventions. This is to give context to the sample population so they can be compared to other studies.

Outcome: i) studies merely describing a teaching intervention (must be able to place value on an educational intervention relative to others) ii) not providing an assessment of learning from Kirkpatrick's hierarchy iii) not focussed on the teaching of neuroanatomy

Other: editorial material, proceeding papers, notes, letters to the Editors and meeting abstracts, studies not written in English, duplicate papers. Enough peer-reviewed journal articles are available on this topic to form an adequate review, and it ensures a sufficient quality of evidence. Unfortunately, the review team do not have the funding or resources available to perform translations of non-English studies.

Provided a study meets the criteria that it applies an educational intervention to teach neuroanatomy and compares this method to another using a measurement of Kirkpatrick's hierarchy, it would be useful for the purposes of this study.

This criterion has been left purposefully broad, as similar reviews have not been comprehensive enough to date.

## 5. SEARCH SOURCES AND STRATEGIES

### *Databases*

PubMed, Cinahl, ERIC, Academic OneFile, ProQuest Central, Sage journals, Scopus, Web of Science, Medline, Current Contents Connect, KCI and Scielo Citation Index.

### *Search Terms*

| **Neuroanatomy** | **Teaching** | **AND Effectiveness** |
|---|---|---|
| OR cranial anatomy | OR learning | OR instructional effectiveness |
| OR skull base anatomy | OR method | OR knowledge |
| OR brain anatomy | OR pedagogy | OR retention |
| OR head anatomy | OR teaching/trends | OR memory |
| OR central nervous system anatomy | OR education | OR understanding |
| OR peripheral nervous system anatomy | OR technology | OR application |
| OR cranial nerves | OR mixed reality | OR enhance |
| OR peripheral nerves | OR virtual reality | |
| OR spinal cord | OR augmented reality | |
| OR deep brain structures | OR mobile technology | |
| | OR virtual assistants | |
| | OR artificial intelligence | |
| | OR computer-assisted instruction/methods | |
| | OR computer simulation | |
| | OR simulation | |
| | OR educational models | |
| | OR web-based learning | |
| | OR curriculum | |
| | OR instructional methods | |
| | OR androgogy | |

In addition, we will hand search the references of all included studies and any relevant reviews. Further, we will hand search key journals in medical education including: *Medical Teacher, Medical Education, Academic Medicine, Anatomical Sciences Education*.

Grey literature will not be used. This review is intended to be an educational tool, and as such requires a high quality of literature to analysed and included (i.e. peer review papers). Experts will not be contacted to minimise disruptions to the literature search.

**Scoping Search**

A scoping search was conducted to test the strategy using one database (PubMed). The following search strategy was input into the database:

'[neuroanatomy OR cranial anatomy OR skull base anatomy OR brain anatomy] AND [(teaching OR learning OR method[a] OR pedagogy OR teaching/trends OR education OR technology OR mixed reality OR virtual reality OR augmented reality OR mobile technology OR virtual assistants OR artificial intelligence OR computer-assisted instruction OR computer simulation[a] OR simulation OR educational models OR web-based learning OR curriculum)]} AND [(effective[a] OR instructional effectiveness OR knowledge OR retention OR memory OR understanding OR application OR enhance[a])].'

Superscript "a" indicates truncation to allow for variation of the root word.

A total of 10,700 search items were identified, published in the last 5 years.

An initial list of 13 studies identified using the search criteria were extracted after reviewing the first 5,000 search items, identifying relevant titles and then reviewing the abstracts. Titles are including in appendix A.

The two previous systematic reviews conducted in this area had 29 and 16 studies respectively, not including papers with augmented/virtual reality.[11] A targeted search for neuroanatomy AR/VR strategies identified 5-10 papers. With the 5-year timeframe, we expect approximately 20-25 papers in total.

**Project timetable**

| | Anticipated duration | Proposed scheduling |
|---|---|---|
| Refining Data Coding Sheet | 1 month | July – August 2019 |
| Literature search | 2 months | August – September 2019 |
| Data extraction and coding | 2 months | October – November 2019 |
| Draft report | 2 months | December – January 2020 |
| Final report | 2 weeks | February 2020 |

## 6. PROCEDURE FOR EXTRACTING DATA

The reviewers HN and AM will read all titles to include or exclude at the first level. HN and AM will obtain, and review, abstracts of all titles identified to determine possible inclusion for the study. SC, NP and TW will oversee this process to ensure fidelity of the methods.

Accruing data for secondary synthesis will involve simultaneously extracting the data and appraising the quality of the work. For this purpose, a BEME data coding sheet has been designed (attached) based on three categories of data: administrative, topic-related, research-related. HN and AM will extract all relevant data according to the coding sheet.

As a pilot, all members will independently code five papers to validate the data sheet for utility and completeness. Two reviewers will then code all papers identified in the search strategy. The reviewers will identify references cited in these papers that may of interest to the review and obtain these if appropriate. For any disagreements regarding coding of data, SC will arbitrate and make a final decision.

***Proposed procedure to resolve differences in coding of studies?***

HN and AM will compare both the lists of studies to be included, as well as coding sheets. Extra studies, or studies omitted by the other party, or disagreements in the coding of studies will be discussed.

In the event of a dispute regarding the suitability of inclusion of a study or extraction of data that cannot be resolved by discussion between HN and AM at resolution of each step, SC will arbitrate and make a final decision.

If consistent issues in coding arise, these issues will be discussed in an internal review by SC, TW and NP. If issues are still present after discussion, authors will seek the advice of the BICC.

## 7. APPRAISAL OF STUDIES

According to Colthart *et al.* ’s (2008) method of judging the quality of primary studies, the two reviewers will also independently score each paper on a scale of 1 to 5 for the strength of their findings.

Gradings of strength of findings of the paper:

- Grade 1: No clear conclusions can be drawn. Not significant
- Grade 2: Results ambiguous, but there appears to be a trend
- Grade 3: Conclusions can probably be based on the results
- Grade 4: Results are clear and very likely to be true
- Grade 5: Results are unequivocal.

Papers graded as a 1 or a 2 will not be considered further. Papers will also be appraised for their risk of bias according to PRISMA guidelines.

PRISMA Guidelines are a set of preferred reporting items for systematic reviews or meta-analyses developed by an international group including experienced authors and methodologists. They consist of a 27 item checklist and 4 step flow-diagram. The checklist includes items deemed essential to report in a systematic review.

The specific risk of bias tool to be used is the Cochrane RoB 2. RoB 2 is structured into a fixed set of domains of bias, focussing on different aspects of trial design, conduct, and reporting. Within each domain, a series of questions ('signalling questions') aim to elicit information about features of the trial that are relevant to risk of bias. A proposed judgement about the risk of bias arising from each domain is generated by an algorithm, based on answers to the signalling questions. Judgement can be 'Low' or 'High' risk of bias, or can express 'Some concerns'.

## 8. SYNTHESIS OF EXTRACTED EVIDENCE

Data tables will be constructed in Microsoft Excel spreadsheets detailing study design; population characteristics; interventions and comparisons; and results and conclusions. The lead reviewer, HN, will synthesise extracted data in a manuscript form from these tables.

We predict that the majority of the studies included in this review will demonstrate heterogeneity in study design and outcome measures. If this is so, we will qualitatively analyse data where appropriate to draw comparisons. As such, a method to synthesize evidence of quantitative data is not described.

There will be an internal appraisal of the review prior to submission to BEME for peer-review.

If accepted by the BEME Collaboration, this would be published in a highly read and impactful forum. This study is designed to be a useful tool for educators to apply modern teaching technologies to their practise, and researchers in identifying current trends and gaps in the literature. A systematic review that summarises current evidence would be useful in generation of an instructional curriculum that could be employed by national medical councils globally. This would be used to optimize instruction of neuroanatomy in medical students where currently a deficit exists.

## CONFLICT OF INTEREST STATEMENT

Nil.

## PLANS FOR UPDATING THE REVIEW

We intend to update the systematic review after three years of the date of the review.

## CHANGES TO THE PROTOCOL

1. A more specific focus on new technologies such as mobile technology, mixed reality, artificial intelligence and virtual assistants not included in previous reviews has been applied.
2. A more comprehensive description for this review's use by educators and researchers has been added
3. Specific terms have been described.
4. Search terms related to 'neuroanatomy' have been broadened to be more inclusive, and 'technology' broadened to target modern techniques.
5. Exclusion criteria have been refined, and explained.
6. HN and AM will discuss to resolve any disagreements before being arbitrated by SC.
7. The tool for measurement of bias has been described.

**Appendix A**

13 titles identified after review of the first 5,000 search items.

1. Allen LK, Eagleson R, de Ribaupierre S. Evaluation of an online three-dimensional interactive resource for undergraduate neuroanatomy education. Anatomical sciences education. 2016;9(5):431-439.
2. Morris N, Lambe J, Ciccone J, Swinnerton B. Mobile technology: students perceived benefits of apps for learning neuroanatomy. Journal of Computer Assisted Learning. 2016;32(5):430-442.
3. Greville WJ, Dymond S, Newton PM. The student experience of applied equivalence-based instruction for neuroanatomy teaching. Journal of Educational Evaluation for Health Professions. 2016;13.
4. Drapkin ZA, Lindgren KA, Lopez MJ, Stabio ME. Development and assessment of a new 3D neuroanatomy teaching tool for MRI training. Anatomical sciences education. 2015;8(6):502-509.
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8. McBride JM, Drake RL. National survey on anatomical sciences in medical education. Anat Sci Educ. 2018;11(1):7-14.
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10. Moxham B, McHanwell S, Plaisant O, Pais D. A core syllabus for the teaching of neuroanatomy to medical students. Clin Anat. 2015;28(6):706-716.
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