An Approach to Economic Evaluation in Undergraduate Anatomy Education

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Medical education research is becoming increasingly concerned with the value (defined as “educational outcomes per dollar spent”) of different teaching approaches. However, the financial costs of various approaches to teaching anatomy are under-researched, making evidence-based comparisons of the value of different teaching approaches impossible. Therefore, the aims of this study were to report the cost of six popular anatomy teaching methods through a specific, yet generalizable approach, and to demonstrate a process in which these results can be used in conjunction with existing effectiveness data to undertake an economic evaluation. A cost analysis was conducted to report the direct and indirect costs of six anatomy teaching methods, using an established approach to cost-reporting. The financial information was then combined with previously published information about the effectiveness of these six teaching methods in increasing anatomy knowledge, thereby demonstrating how estimations of value can be made. Dissection was reported as the most expensive teaching approach and computer aided instruction/learning (CAI/L) was the least, based on an estimation of total cost per student per year and assuming a student cohort size of just over 1,000 (the United Kingdom average). The demonstrated approach to economic evaluation suggested computer aided instruction/learning as the approach that provided the most value, in terms of education outcomes per dollar spent. The study concludes by suggesting that future medical education research should incorporate substantially greater consideration of cost, in order to draw important conclusions about value for learners. Anat Sci Educ 14: 171–183. © 2020 The Authors. Anatomical Sciences Education published by Wiley Periodicals LLC on behalf of American Association for Anatomy.

Key words: gross anatomy education; medical education; undergraduate education; cost of education; financial evaluation; educational value

INTRODUCTION

Economic evaluations are attempts at measuring value (Levin et al., 2017). With value defined as “outcomes per dollar spent” (Mattick and Baumfield, 2016), the outcomes of economic evaluations aim to permit more efficient use of resources and increase what can be achieved on a finite budget (Levin et al., 2017; Maloney et al., 2017). Different approaches to economic evaluations exist, but all require information about financial costs and a specific measured output (Levin et al., 2017; Lin et al., 2017). A common output measure is effectiveness (Levin et al., 2017), defined as the ability of an intervention to achieve a certain outcome (Losco et al., 2017). This measure is necessary for decisions to be made regarding the appropriateness of interventions, but it is insufficient without consideration of financial cost (Gray et al., 2011). Often effectiveness is considered without financial cost (Levin et al., 2017), and this limits the utility and application of these research reports to estimate actual value (Foo et al., 2019).

For example, Graziose et al. (2017) demonstrate the benefit of economic evaluation through use of cost-effectiveness analysis as justification for the utility of a national public health intervention. The decision to continue the intervention would have been unlikely if effectiveness was considered alone (Gray et al., 2011). Muennig and Bounthavong (2016) argue that economic evaluation can enable positive change to healthcare, and
the World Health Organization’s “Choosing Interventions that are Cost-Effective” (WHO-CHOICE) project utilizes existing data to indicate the most cost-effective approaches to managing global health problems (WHO, 2020). This is particularly beneficial to resource-poor countries where maximizing outcomes for a given spend is both prudent and necessary. Given recent financial pressures, the utility of economic evaluation has begun to be recognized in the field of medical education (Foo et al., 2019).

Medical education and training are expensive but critically important. The financial cost of education is extremely topical and as the Chancellor of Newcastle University remarked, “...those funding the education of our doctors will no longer tolerate an approach of quality at any cost” (Donaldson, 2010). Lindor et al. (2010) demonstrated that positive educational outcomes can develop independently of financial investment but stressed the importance of considering financial cost. The peer-reviewed literature exploring the effectiveness of interventions on educational outcomes is well established and growing in size and quality, yet judgments about value are typically implicit due to inadequate information available on cost (Walsh et al., 2013; Walsh, 2014a, b; Mättick and Baumfield, 2016; Foo et al., 2019). Cook et al. (2012) and Zendejas et al. (2013) both undertook literature reviews that highlighted cost as an under-researched factor in medical education. Cook et al. (2012) identified 92 studies discussing the comparative effectiveness of simulation with only five taking financial cost into consideration, albeit inadequately for an economic evaluation. Meanwhile Zendejas et al. (2013) found that only 59 out of 967 comparative effectiveness studies detailed cost, but this was also lacking detail.

Some studies of effectiveness have concluded that cost must be researched for informed curricula decisions to be made (Murad et al., 2010; Cook et al., 2013; Brown et al., 2016). Brown et al. (2015) provide a good example of informative accurate and transparent cost-reporting but do not combine this with existing effectiveness data meaning that value judgments cannot be made. This demonstrates Levin et al.’s (2017) observation that cost and effectiveness results are often considered separately.

The research in the field of anatomical sciences portrays a similar inadequacy as other medical education fields (Walsh and Jaye, 2013). This is amplified by a rekindling of interest in the effectiveness of anatomy teaching methods (Yammine and Violato, 2015, 2016; Malhotra et al., 2016; Deng et al., 2018) as stakeholders attempt to maximize learning outcomes (Bergman et al., 2014) in the fewer contact hours that are being considered, albeit inadequately for an economic evaluation. Meanwhile Zendejas et al. (2013) found that only 59 out of 967 comparative effectiveness studies detailed cost, but this was also lacking detail.

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Therefore, this study used an existing cost-reporting approach to provide cost information about six popular anatomy teaching methods for which existing effectiveness data are available regarding short term outcomes in undergraduate students. The cost and effectiveness data were subsequently used to demonstrate a process by which estimations of value can be made.

The primary aims of this study are to report cost of six popular anatomy teaching methods, and to demonstrate an approach to estimating their comparative values. The methods investigated were (1) computer-assisted instruction/learning (CAI/L); (2) dissection; (3) plastic models; (4) plastinated (resin-preserved) human tissue; (5) simulation; and (6) virtual dissection tables (see Table 1 for definitions and examples). The secondary aim is to undertake this approach to estimating value as transparently as possible, so that individual institutions can and should combine it with their own unique and contextualized cost and effectiveness data. The null hypothesis of this research report is that no difference in value will be found between the six teaching methods investigated.

MATERIALS AND METHODS
Definitions

Walsh (2014b) highlighted the importance of clarity in economic terms due to the frequency of medical education literature using incorrect or inappropriate vocabulary. For this study, the following definitions were used:

- **Financial Cost:** The price that institutions or individuals pay for equipment or services, totaled with the depreciation of equipment in monetary value (Sugden and Williams, 1978).
- **Effectiveness:** The ability of an intervention to achieve a certain educational outcome (Levin et al., 2017).
- **Educational Outcome:** For this study, the educational outcome of interest was improved knowledge acquisition, since this is the most common measurement for studies of effectiveness in the anatomy teaching literature (Losco et al., 2017).
- **Educational Value:** Defined as “educational outcomes per dollar spent” (Mättick and Baumfield, 2016), although for this study £ British Pound (GBP) was used.

Identification of Teaching Methods

Six popular approaches to anatomy teaching were chosen for this study (Table 1). The choice was informed by an existing best evidence medical education (BEME) literature review (Losco et al., 2017) as it is a contemporary summary of the available anatomical sciences effectiveness literature. However, for the current study, Losco et al.’s (2017) category of “models” was further separated into plastinated (resin-preserved human) prospected specimens and molded plastic models since there is a marked expected cost difference between them, in addition to a suggested difference in anatomical accuracy (Tamura et al., 2014), which may be reflected in the effectiveness literature.

Virtual dissection tables, for example, the Anatomage Table™ (Anatomage Inc., San Jose, CA) or Sectra Table™ (Sectra AB, Linköping, Sweden) are large multi-touch screens...
that enable visualization and interactive learning in the anatomy field by translating multiple two-dimensional (2D) images into three-dimensional (3D) anatomical structures (Darras et al., 2017; Macchiarelli et al., 2017; Shi et al., 2019). These visualization tools were also included due to their increasing popularity (Gross and Masters, 2017; Paech et al., 2017; Preim and Saalfeld, 2018; Darras et al., 2019; Keenan and ben Awadh, 2019).

**Study Type**

This study demonstrated the comparison of the costs and consequences of six approaches to anatomy teaching, thereby defining this approach as an economic evaluation (Lin et al., 2017). For this, a systematic cost-reporting approach was identified.

**Cost-Reporting Approach**

Although there has been limited work undertaken in the economics of medical education, the broader field of education economics does offer some potentially useful costing frameworks, such as Levin’s framework for educational cost-effectiveness (Levin et al., 2017), which highlights five fundamental cost-components that categorize typical educational costs: equipment and materials, personnel costs, facility costs, required client inputs, and other program inputs. An earlier iteration of this framework was used by Zendejas et al. (2013) within medical education, who developed subcategories for the original five components. This study used the same approach described by Zendejas et al. (2013) but excluded 10/23 subcategories since these costs were highly specific to individual institutions, for example, donated equipment, volunteer time, facility costs; or were only available for some of the teaching approaches, for example, inflation rates, delivery charges (see Table 2).

The costs associated with each subcategory were reported for each anatomy teaching method (see Supplemental Material Tables A-F), allowing total cost per student per year of each approach to be calculated. The cost analysis included the cost of an annual training day for staff and additional time was included as an initial expenditure associated with unfamiliar software or new pieces of equipment.

**Estimating Financial Cost**

In order to complete the cost-reports for each teaching approach, data were collected from the available published or grey literature, or other publicly available sources. Since every medical school is unique and basing this cost-report on a particular institution would have diminished its utility, this report created and used a case study of a “typical” United Kingdom (UK) medical school, based on available literature to inform the assumptions underpinning the model (see Appendix 1).

Results for the cost-reports were given as cost per student per year over a five-year period, using Great British Pounds (GBP/£) as the currency. At the time of the study (2018), £1

| Approach | Description | Example used in this study |
|----------|-------------|-----------------------------|
| CAI/L    | Computer-assisted instruction/learning is defined as learning in which computers play a central role as the mean of information delivery with direct interaction with learners (Hu et al., 2016). | Anatomy. TV™, an online subscription teaching resource relevant to healthcare professionals (Primal Pictures Ltd., London, UK). |
| Dissection | Dissection is a practical teaching approach, described as essential to anatomy teaching (Rizzolo, 2002). | Full human cadaveric dissection with downdraft tables (Shoepe, 2008). |
| Plastic Models | Scaled plastic anatomy models are commonplace in the anatomy classroom (Raftery, 2007; Patel et al., 2015). | Plastic models supplied by Adam Rouilly Ltd. (Adam Rouilly Ltd., Sittingbourne, Kent, UK). |
| Plastinated Specimens | Play a similar role to plastic models but consist of resin-preserved actual human tissue (Tamura et al., 2014) more authentic than plastic models. | Plastinated specimen (von Hagens Plastination, Gubener Plastinate GmbH, Guben, Germany). |
| Simulation | Simulation consists of any activity that simulates examination or procedure that students are likely to encounter in their practice (Losco et al., 2017). This includes using models for invasive procedures or using medical imaging databases for interpretation. | Models suitable for simulation (Adam, Rouilly Ltd., Sittingbourne, Kent, UK). |
| Virtual Dissection Tables | A specific type of CAI/L whereby a large multi-touch screen visualization tool is used to render three-dimensional images (Macchiarelli et al., 2017), which can be used to simulate normal dissection processes without the need for a cadaver (Afsharpour et al., 2018). The Sectra Virtual Dissection Table™ is an alternative to the virtual dissection table used in this study (Sectra AB, Linkhöping, Sweden). | The Anatomage Table™ (Anatomage Inc., San Jose, CA). |

CAI/L, computer aided instruction/learning.
British Pound (GBP) was approximately $1.34 in United States Dollars (USD), $1.75 Australian Dollars (AUD), and €1.14 Euros (EUR) (XE, 2020). For each teaching approach, the cost-reports were recorded and justified. This transparency allows readers to replace the assumptions made within the model presented here with data specific to their education context. These results were then summarized as “cost per student per year” for ease of comparison.

The teaching interventions were given a five-point rating based on the cost per student per year. This presentation
format was aligned to that used by the Teaching and Learning Toolkit for primary and secondary education (EEF, 2018), which provides an “accessible summary of educational research” (Higgins et al., 2012). The five-point scale was established by considering the extremes of results as the extremes of the scale, proportionally divided with equal weighting between thresholds.

Estimating Effectiveness

In order to demonstrate an approach to economic evaluation, a synthesis of relevant outcome data was necessary. As such, contemporaneous effectiveness data were drawn from Wilson et al.’s (2018) meta-analysis and the 29 articles cited in Losco et al.’s (2017) systematic review. These two papers were contemporary, but they did not include virtual dissection tables, therefore Afsharpour et al.’s (2018) comparison of this teaching approach with plastic models and dissection was used. This provided further effectiveness data on plastic models and dissection that was not included in Losco et al.’s (2017) or Wilson et al.’s (2018) review.

Plastinated specimens were not explicitly included in any of the aforementioned reports, so literature was identified that compared this approach with one of the other approaches included in this economic evaluation (Chytas et al., 2019).

Effectiveness data were presented in different formats across each source (Losco et al., 2017; Afsharpour et al., 2018; Wilson et al., 2018; Chytas et al., 2019); therefore, a method was devised for uniformly summarizing the conclusions of each study. For each study, all teaching approaches were given an effectiveness rating out of five by initially assigning them to the midpoint of the scale (3/5), and then amending their scores to accommodate each paper’s conclusion. For example, if a paper had ranked all five teaching approaches from most to least effective, with significantly different outcomes between each approach, the most effective would have been awarded five points and the least, no points. The average rating from each paper equated to an overall effectiveness rating out of five, which was used in the value-estimations.

Estimating Value

Walsh et al. (2013) stated that a teaching “approach cannot be cost-effective in and of itself.” Through extrapolation, this suggests that an approach cannot be “good value” in and of itself, but only of more or less value than an alternative. As such, comparisons in value permit conclusions on value. The approach of Lin et al. (2017) was adopted, who suggest that value-comparisons can be made by mapping cost and effectiveness comparisons onto Black’s Cost-Effectiveness Plane (Black, 1990). Alternatives are compared with a control, and the quadrant onto which the alternative is mapped corresponds to differing conclusions on value. Alternative teaching approaches can be more costly with reduced outcomes (Quadrant II), less costly with improved outcomes (Quadrant IV), increased cost and effectiveness (Quadrant I), or reduced cost and effectiveness (Quadrant III). Evaluation is not simple for the two latter conclusions, as increased cost or reduced effectiveness may be an acceptable outlay for improved effectiveness or reduced cost, respectively—but this approach provides data on which these judgments can be based. As recommended by O’Day and Campbell (2016) and Lin et al. (2017) the incremental cost-effectiveness ratio (ICER) was used to calculate the cost per knowledge acquired—the chosen unit of effectiveness—for those teaching approaches that were mapped onto the areas of Black’s (1990) cost-effectiveness plane with unclear conclusions on value (Quadrants I and III).

\[
\text{ICER} = \frac{(\text{Cost}_A - \text{Cost}_B)}{\left(\frac{\text{Effectiveness}_A - \text{Effectiveness}_B}{\text{Effects}_A}ight)}
\]

Raw data were used to calculate ICERs where possible but utilized the five-point rating to standardize units of effectiveness from the existing effectiveness literature.
## Table 4.
### Synthesis of Published Effectiveness Information

| Intervention                      | Losco et al. (2017)                      | Wilson et al. (2018)                      | Afsharpour et al. (2018)                     | Chytas et al. (2019)                      |
|----------------------------------|-----------------------------------------|------------------------------------------|---------------------------------------------|------------------------------------------|
|                                  | Rating | Rationale                                                                 | Rating | Rationale                                                                 | Rating | Rationale                                                                 | Rating | Rationale                                                                 | Overall |
| CAI/L                            | 5      | “CAI/CAL... demonstrated better results overall compared to traditional teaching methods.” | 3      | “Student performance scores were found to be statistically equivalent when comparing traditional dissection to other laboratory methods.” | N/A    | Not discussed.                                                            | N/A    | Not discussed.                                                            | 4       |
| Plastic Models                   | 2      | “Both studies, looking at alternative dissection methods, showed positive... outcomes when compared to... incorporating the use of plastic models.” | 3      | [See above]                                                                | 3      | [See below]                                                               | 2.75   |
| Plastinated Specimens            | N/A    | Not discussed.                                                            | 3      | [See above]                                                                | N/A    | Not discussed.                                                            | 2.67   |
| Simulation                       | 4      | “…simulation demonstrated better results overall compared to traditional teaching methods.” | 3      | [See above]                                                                | N/A    | Not discussed.                                                            | N/A    | Not discussed.                                                            | 3.5     |
| Virtual Dissection Tables        | N/A    | Not discussed.                                                            | N/A    | Not discussed.                                                            | 4      | “...and cohort 3 [virtual dissection table] (85.1%).”                     | N/A    | Not discussed.                                                            | 4       |
| Summary                          |        | CAI/L and Simulation were described as superior to the traditional approaches such as dissection. Simulation was deemed more effective than dissection, but CAI/L was superior to this. Plastic models were suggested to be less effective than dissection. This led to the four-tier ranking summarized above. |        | All modalities were ranked insignificantly different with regards to effectiveness. Therefore, they were all awarded the midpoint of the effectiveness rating. |        | This study suggested ranked virtual dissection tables, plastic models and dissection in the order reflected by the ratings above. |        | This review found that dissection and plastinated specimens did not have significantly different impacts on educational outcomes, thereby provided no reason for either approach to deviate from the baseline of three. |

For each study, all teaching approaches were given an effectiveness rating out of five by initially assigning them to the midpoint of the scale (3/5), and then amending their scores to accommodate each paper's conclusion. For example, if a paper had ranked all five teaching approaches from most to least effective, the most effective would have been awarded five points and the least, one point. The average (mean) rating from each paper equated to an overall effectiveness rating out of five. CAI, computer aided instruction; CAL, computer aided learning.
Ethical Approval

This study was approved by a subgroup of the University of Exeter Medical School Research Ethics Committee (UEMS REC), and was provided by the policy set out in UEMS REC Application Number 17/11/147.

RESULTS

The following results section details the cost results, effectiveness results and then synthesizes these into a series of value-estimations.

Cost Results

The cost per student per year of each teaching approach over a five-year period can be ranked from least to most expensive as follows: CAI/L, plastic models, virtual dissection tables, simulation, plastinated specimens, dissection. Table 3 presents a summary of each cost-report with full details provided in Supplemental Material Tables A-F.

While CAI/L had the lowest initial cost, the lowest recurring cost was shared by plastinated specimens and plastic models. In contrast, dissection had the largest recurring cost, while plastinated specimens had the largest initial cost.

Effectiveness Results

The conclusions from Losco et al. (2017), Wilson et al., (2018), Afsharpour et al. (2018) and Chytas et al. (2019) enabled numerical rankings to be assigned to each teaching approach (Table 4). The mean of the rankings for each approach provided overall effectiveness ratings from most to least effective: CAI/L and virtual dissection tables (4), simulation (3.5), plastinated specimens (3), dissection (2.75), plastic models (2.67). Resources permitting further statistical analysis were not available.

Synthesis of Cost and Effectiveness Information

The cost results generated through the current study and previously published effectiveness results were synthesized into two five-point scales that when presented alongside each other permit quick comparisons of the cost and effectiveness of different anatomy teaching approaches (Fig. 1). In order to maximize the accessibility of these results, the results figure (Fig. 1) was based upon an existing summary of education research (EEF, 2018), which has previously been regarded as an accessible, manageable and practical tool (Higgins et al., 2012).

Value Information

In the demonstrated approach to economic evaluation, using the assumptions made by the case-study model, CAI/L appears to be better value than the included alternatives, since all alternatives were mapped to Quadrant II on Black’s (1990) cost-effectiveness plane when CAI/L was the control (Fig. 2), suggesting they have reduced effectiveness for a given spend. In this comparison, virtual dissection tables are not mapped to Quadrant II, but as they have the same effectiveness for a greater spend, they are also deemed less cost-effective.

Dissection can be interpreted as lesser value than the included alternatives because it most commonly mapped onto Quadrant II when compared with each control, and because most alternatives are mapped to Quadrant IV (less expensive and more effective) when dissection is the control (Fig. 2). Teaching with virtual dissection tables appeared to be of better value than with plastic models because they mapped on the similar plane of cost but markedly different planes of effectiveness, suggesting that despite incurring similar costs, virtual dissection tables were markedly more effective.

Simulation, plastinated specimens and dissection can be ranked in this respective order of diminishing value. This is based on ICERs calculated for dissection, plastinated specimens and simulation when each compared with plastic models since simple graphical interpretation is not straightforward when interventions are mapped to quadrants I or III of Black’s (1990) cost-effectiveness plane. Dissection, plastinated specimens and simulation cost an additional £675.00, £136.36 and £21.00 per unit of effectiveness gained per student per year when compared with plastic models, respectively.

Of the two least effective approaches to anatomy teaching, plastic models appear to be better value than dissection. This is because when compared with CAI/L, the ICERs show that plastic models and dissection cost £4.51 and £48.00 per unit of effectiveness lost per student per year. This is an unusual comparison because the control, in this instance, is better value than both interventions. However, the ICERs of the two interventions suggest plastic models to be better value as for a similar reduction in effectiveness, the costs incurred are much smaller.

DISCUSSION

The aims of this study were to investigate the cost, and then demonstrate an approach to comparing value, of six popular anatomy teaching methods. The teaching approaches were ranked from most to least expensive as follows: dissection, plastinated specimens, simulation, virtual dissection tables, plastic models and CAI/L. This order does not reflect the suggested comparative value of each approach, since it does not incorporate effectiveness information, only the costs incurred over a five-year period at a typical UK medical school (Appendix 1).

Since value is determined by both cost and a measurable outcome (Mattick and Baumfield, 2016), this report then demonstrated how cost information can be combined with existing effectiveness data to estimate value. This process suggested CAI/L as providing the greatest value, in terms of education outcomes per dollar spent, since it had highest scores for effectiveness as well as the lowest scores for cost; and dissection as providing lowest value, when the educational outcome measure is knowledge acquisition at least, due to its high cost.

These findings regarding CAI/L are in contrast with existing literature that considers effectiveness alone (Clunie et al., 2018; Wainman et al., 2018, 2020) but, when effectiveness is considered with cost, which is much lower for CAI/L, different conclusions may be drawn about relative value.

Due to the lack of cost-reporting in the evaluation or comparison of approaches to teaching in medical education (Walsh et al., 2013; Walsh, 2014a, b; Mattick and Baumfield, 2016), the suggested findings of this economic evaluation cannot easily be compared to the existing literature. For example, Chang Chan et al. (2019) iterated the diminished economic feasibility of dissection compared with CAI/L, despite highlighting the educational merits of both; however,
Figure 1.
Comparative cost and effectiveness of the different approaches to anatomy teaching considered in this study. This format is based on the Teaching and Learning Toolkit (EEF, 2018) and, using five-point summaries of cost and effectiveness, it provides a simple and accessible synthesis of the data presented in Tables 3 and 4, permitting quick and easy comparison of the costs and effectiveness in short-term knowledge acquisition of different teaching approaches. The five-point scale for cost was established by considering the extremes of results as the extremes of the scale, proportionally divided with equal weighting between thresholds. In this figure, the number of shaded pound sterling icons represents a different cost bracket for the total cost of interventions per student per year: £ ≤ £376.00; ££ = £376.00-£395.99; £££ = £396.00-£415.99; ££££ = £416.00-£435.99; £££££ ≥ £436.00. At the time of the study (2018), £1 GBP was approximately $1.34 in United States Dollars (USD). The five-point effectiveness ratings were calculated by originally assigning all teaching approaches to the midpoint of the scale (3/5), and then amending their scores to accommodate each paper’s conclusion. For example, if a paper had ranked all five teaching approaches from most to least effective, with significantly different outcomes between each approach, the most effective would have been awarded five points and the least, no points. The average rating from each paper equated to an overall effectiveness rating out of five, which is both represented pictorially by the number of colored stars and numerically, rounded to one decimal place, in the following column. This figure, therefore, shows that of the included teaching approaches, dissection is the most expensive, followed by plastinated specimens, and then simulation. Plastic models and virtual dissection tables are shown to cost a similar amount, which are the second most inexpensive approaches. Computer aided instruction/learning (CAI/L) is the least expensive teaching approach included in the report. The approach taken raises the apparent costs of approaches that have high initial expenses and low recurring costs or those that have a lifespan greater than the five-year period assumed by the model. For example, if plastic models had a lifespan of 20 years, the cost per student per year would be greatly reduced, which would explain their common use in anatomy teaching laboratories (Raftery, 2007; Patel et al., 2015). Despite excluding some cost subcategories to maintain generalizability, the cost-reporting relates to a specific setting. Efforts were made to maximize generalizability by creating and utilizing a model of a typical medical school (Appendix 1), but the assumptions made in this model may vary substantially from the costs to individual institutions. For example, learner group size may be based on other evidence or local constraints, and therefore may not align with Chan and Ganguly’s (2008) and Appaji and Kulkarni’s (2012) suggestions; the available teaching and holiday time of academic clinicians may not be the same as Christmas et al. (2010) and BMA (2019), respectively suggest; there may be a significant disparity between the cohort size and the UK average used here (MSAG, 2020); and curricula may not be reviewed as regularly as the World Health Organization recommended (WHO, 1985).

Inevitably there were also some limitations. Only 13/23 cost subcategories were included since the remaining ten were highly specific to individual institutions. For example, a significant subcategory that was excluded was that of “shared costs,” which could significantly reduce financial costs if additional cohorts of learners could utilize, and therefore share the financial expenses of teaching resources.

Despite excluding some cost subcategories to maintain generalizability, the cost-reporting relates to a specific setting. Efforts were made to maximize generalizability by creating and utilizing a model of a typical medical school (Appendix 1), but the assumptions made in this model may vary substantially from the costs to individual institutions. For example, learner group size may be based on other evidence or local constraints, and therefore may not align with Chan and Ganguly’s (2008) and Appaji and Kulkarni’s (2012) suggestions; the available teaching and holiday time of academic clinicians may not be the same as Christmas et al. (2010) and BMA (2019), respectively suggest; there may be a significant disparity between the cohort size and the UK average used here (MSAG, 2020); and curricula may not be reviewed as regularly as the World Health Organization recommended (WHO, 1985).

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The report also relied on specific suppliers when costing each teaching approach, but alternative suppliers might...
Figure 2.

Mapping of anatomy teaching approaches included in this study to Black’s cost-effectiveness planes (Black, 1990). Black’s (1990) cost-effectiveness plane is a model that compares the cost and effectiveness of interventions with a control in order to draw conclusions on their comparative cost-effectiveness. Using Black’s methodology, each separate plane shows an anatomy teaching approach as the control (i.e., when it is at the center of the plane) and compares it with the cost (y-axis) and effectiveness (x-axis) of other teaching approaches. When approaches are mapped to specific quadrants, conclusions can be easily established: Quadrant II—less cost-effective, or more expensive and less effective, than the control; Quadrant IV—more cost-effective, or less expensive and more effective, than the control. However, teaching approaches mapped to quadrants I and III require further consideration: Quadrant I—more expensive and more effective than the control; Quadrant III—less expensive and less effective than the control. The planes show that all teaching approaches are less cost-effective than computer aided instruction/learning (CAI/L; as they are mapped to quadrant II) except virtual dissection tables, which while more expensive is equally effective. They also show that all approaches are more cost-effective than dissection (as they are mapped to quadrant IV) except plastic models (mapped to quadrant III), which while less expensive are less effective. Incremental cost-effectiveness ratios (ICERs) were undertaken for interventions that were mapped to quadrants I or III. CAI/L, computer aided instruction/learning.
The accessible summary of cost and effectiveness could be criticized as over-simplistic and the point-thresholds chosen could make a significant difference to the conclusions drawn, but the methodology is deliberately transparent so that it can be repeated and altered as necessary.

While attempts were made to collate effectiveness data on the included teaching approaches from contemporary literature reviews and meta-analyses (Losco et al., 2017; Wilson et al., 2018), these sources did not include effectiveness data on virtual dissection tables and plastinated specimens. As such, lower level evidence, defined by the “Hierarchy of Evidence” (CEBM, 2009), was used (Afsharpour et al., 2018; Chytas et al., 2019). These sources of effectiveness data were selected as they compared the less-documented teaching approaches with other approaches included in this report, which allowed the data to be easily incorporated. This identification process can, therefore, not guarantee that all of the relevant publications were included in this demonstration to economic evaluation.

Furthermore, this study attempts cost-reports and demonstrates value-estimations of individual teaching approaches while some authors have recommended a blended anatomy curriculum that combines the different pedagogies (Kerby et al., 2011; Estai and Bunt, 2016). A blended approach was not included since the exact combinations are highly institution specific.

Another limitation of this study is that there were other approaches to teaching anatomy that could have been included, such as using predissected (prosected) specimens as part of cadaveric observation. Additionally, the only outcome considered is knowledge acquisition, whereas other outcomes, or combinations of outcomes, might be (more) important (Mattick and Baumfield, 2016; Pickering and Joynes, 2016), which has been raised previously as a limitation of cost-effectiveness analyses (Owens, 1998).

**Impact on Policy and Practice**

This study has provided a novel approach to estimating value that contributes to the required identification for alternative approaches to economic evaluation (Baumfield and Mattick, 2016), which can be utilized or developed by others. Furthermore, this study has demonstrated the simplicity of accurate cost-reporting, which may empower those investigating learning outcomes to include cost as an outcome in their research reports. In turn, this would enhance the available research, thereby aiding value judgments.

Studies utilizing this approach can enable policy makers to make recommendations based on evidence. Consensus building with key stakeholders can then move beyond a conversation that focuses on effectiveness at any cost to more nuanced conversations about maximizing value when resources such as time or money are limited (as is likely to be the case in most medical schools).

The findings suggested by this study could be used by existing medical schools to review their anatomy teaching methods, tailoring the information used in this transparent approach to their own context. It could also be used by new medical schools to make informed choices regarding their curriculum, which is particularly relevant for the UK, where a number of new medical schools are currently being established (Rimmer, 2018). This may also be of interest to other health professions and perhaps education beyond health.

**Future Research**

Further research could both benefit this specific report and the wider field of academia. The approach taken here to synthesizing the effectiveness data did not warrant statistical analysis, since this was not necessary to achieve our aims (“to report cost of six popular anatomy teaching methods and to demonstrate an approach to estimating their comparative values”) and might suggest a level of precision that we did not feel was appropriate in this first paper of its kind. However, future research building upon this methodological approach could also consider including statistical analysis to assess the uncertainty of the outcome data (Baio et al., 2017), which would strengthen conclusions made on effectiveness and, therefore, value.

In the wider field, Walsh and Jaye (2013) recommended examining cost and value of one aspect of medical education at a time. This study focused on anatomy teaching in medical schools but similar approaches to other areas of medical education are needed. Future research into anatomy teaching might consider other educational outcomes, or combinations of outcomes.

Research studies that describe educational interventions might also include more information about financial costs and journals might require authors to critically evaluate both effectiveness and value of identified educational resources. Baio (2018) recommended this expansion of standard statistical assessment to full economic assessment in health interventions, this can and should also apply to education interventions.

**CONCLUSIONS**

In conclusion, computer aided instruction/learning appeared to have the highest value of the included anatomy teaching approaches, and dissection appeared to have the lowest value due to its high financial cost for a given unit of effectiveness. These suggested findings could be strengthened by further research that utilizes this approach to economic evaluation with the addition of meta-analyses and higher tier statistical analysis.

This report may be limited by the relative infancy of education economics, but it adds to a growing field, of which this report has stressed the importance. If educators could use research such as this to maximize the value of anatomy teaching, students and ultimately patients stand to benefit. The approach demonstrated here could easily be applied to other aspects of medical education and beyond.

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APPENDIX 1.

CASE STUDY.

A Typical Medical School in the United Kingdom

The fictional, yet typical, medical school in the United Kingdom has a five-year medicine program with 203 students per year group. It was founded ten years ago but is looking to introduce a new approach to teaching anatomy. In the five-year curriculum, the course dedicates 149 hours to anatomy teaching per student. Teaching takes place in small groups of approximately ten students, so there are 20 groups per cohort. Therefore, there is 2,980 hours of anatomy-teaching per academic year.

The institution dedicates 1 hour of preparation to a one-hour teaching session. As each prepared session will be delivered 20 times, 3,129 hours are dedicated to preparing and delivering the teaching sessions. Since the typical academic clinician works 977.6 hours either preparing or teaching, four (3.2) academic clinicians would be needed to cover the appropriate workload at the medical school in an academic year. However, as this equates to 15.6 hours of work per day, seven (6.4) academic clinicians are employed to reduce the academic clinicians’ daily working hours to an acceptable amount. At any given moment of the working day, a maximum of two groups are being taught simultaneously, therefore, requiring double the standard amount of most teaching resources.

This typical medical school revises their curriculum every five years on average, so any cost calculations will consider the costs incurred over a five-year period.

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aThe average (mean) cohort size of UK Medical Schools (calculated from data from The Medical School Applications Guide (MSAG, 2016));
bThe average time dedicated to anatomy teaching in UK Medical Schools (Gogalniceanu et al., 2009); cRecommended size for small-group teaching (Chan and Ganguly, 2008) and the ideal number of students per cadaver in dissection (Appaji and Kulkarni, 2012); dAcademic clinicians spend 52% of their working hours in the academic environment (Christmas et al., 2010) and they typically work 47 5-day weeks per year (BMA, 2019); eIn a 40-week academic year; fThe World Health Organization recommends curricula reform every five years (WHO, 1985).