

Animal Dissection vs. Non-Animal Teaching Methods: A Systematic Review of Pedagogical Value

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ABSTRACT

Animal dissection is practiced to varying degrees around the world and is particularly prevalent in North America throughout all levels of education. However, a growing number of studies suggest that non-animal teaching methods (NAMs) (e.g., virtual anatomy tools and three-dimensional models) are better for achieving learning goals compared to dissection. We conducted a systematic review of studies published between 2005 and 2020 that evaluated the pedagogical value of NAMs versus animal dissection. Our results from 20 published studies show that in 95% of the studies (19/20) students at all education levels (secondary, postsecondary, and medical school) performed at least as well—and in most of those studies better (14/19)—when they used NAMs compared to animal dissection. These results provide compelling evidence in support of the 3Rs' principle of replacement. Given that NAMs have been demonstrated as effective for science education, steps should be taken by educational institutions to phase out animal dissection.

Key Words: *alternatives; anatomy education; animal replacement; virtual dissection.*

○ Introduction

Despite bans on animal dissection at secondary and postsecondary levels in several countries and its limited use in others (Oakley, 2012), the dissection of animals remains commonplace at all levels of education throughout North America (Osenkowski et al., 2015), even though myriad non-animal teaching methods (NAMs) are available (InterNICHE, 2021; Norecopa, 2016; USDA National Agricultural Library, 2021). Resistance to adopting NAMs (e.g., virtual anatomy tools) is often rationalized using claims about the benefits of animal dissection—for example, claims that dissection is the best way to teach anatomy and is an important tradition (Osenkowski et al., 2015); that it fosters student engagement, provides a kinesthetic experience, and supports future learning (Oakley, 2012); and that it is an important rite of passage (Solot & Arluke, 1997). While many of these claims are based on opinions or preferences, the claim that

dissection is the best way to teach anatomy is empirically testable. It is this empirical question about the pedagogical value of NAMs versus animal dissection that is the focus of our study.

Two previous systematic reviews on the pedagogical value of NAMs versus dissection (Patronek & Rauch, 2007; Zemanova & Knight, 2021) demonstrate that NAMs are at least as good as animal dissection at helping students meet their learning goals (e.g., demonstrating knowledge of anatomical systems via a course evaluation). However, these reviews include studies from as far back as 1968. While informative, the assessment of outdated technology is not necessarily relevant to today's classrooms. Therefore, we conducted a similar systematic review but limited our time frame to 2005 to 2020 to help ensure that up-to-date educational technology was used in the studies we analyzed.

Our systematic review updates previous results and validates more recent ones. We empirically explore the pedagogical value of NAMs compared to animal dissection, which is of value so that science educators can keep their teaching practices in step with the 3Rs.

The 3Rs in Science Education

The internationally accepted 3Rs principles—replacement, reduction, and refinement (Russell & Burch, 1959)—guide the ethical use of animals in science, including science education. The 3Rs form the basis of many national laws and guidelines on the use of animals in science, and they are cited as foundational principles in policy statements for the American Veterinary Medical Association (AVMA, 2021) and the American Association of Veterinary Medical Colleges (AAVMC, 2009). The 3Rs are also integral to the decision-making process of animal ethics committees.

The principle of replacement tells us that if scientific or educational goals can be achieved without using animals, then there is an ethical obligation to use NAMs. Therefore, evidence of the pedagogical value of NAMs is important for proper implementation of the principle of replacement: if there is sufficient evidence that students can use NAMs to meet desired learning goals, then animal dissection is unnecessary and teachers, schools, and institutions should actively seek out NAMs.

Study Objective

The aim of our study was to conduct an up-to-date, rigorous, systematic review to answer this question: What is the educational merit of NAMs compared with animal dissection? We selected peer-reviewed literature describing controlled studies published between 2005 and 2020 that compared the pedagogical value of NAMs with dissection through assessments of student learning (e.g., knowledge-based evaluations or hands-on, skills-based assessments). Studies from all levels of education and all fields of biological study were considered.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009) was used as a guideline for the present systematic review.

Search Strategy

We conducted systematic searches of Ovid MEDLINE (U.S. National Library of Medicine, Bethesda, Maryland), the Educational Resources Information Center (ERIC; U.S. Department of Education, Washington, D.C.), and Google Scholar. Our search terms were grouped into three concepts: the outcome (“educational merit”), the intervention (“non-animal teaching method”), and the comparator (“dissection”). These concepts formed the basis for the search terms we used for Ovid MEDLINE and ERIC, which are detailed in Supplementary Tables 1 and 2, respectively. We applied a date restriction of 2005 to 2020 to all searches.

Our gray literature search using Google Scholar consisted of searching under the terms “virtual dissection effectiveness,” “animal dissection alternative,” “computer dissection alternatives,” and “non-animal teaching methods dissection,” filtering for 2005 to 2020 and limiting the search to the first 10 pages of the results, after which there appeared to be no relevant papers. A citation analysis identified more papers for inclusion by manually searching reference lists from the studies and related review articles that were found using our search criteria.

Inclusion & Exclusion Criteria

All citations yielded by our searches went through a two-stage screening process (Figure 1). First, all citation titles and abstracts were screened, and inclusion/exclusion criteria were applied. Second, for those citations selected based on the first screening, the full text was screened, and inclusion/exclusion criteria were further applied. Citations were included if they (a) described students at any educational level who underwent an assessment of their learning outcomes (as defined by the authors of each study) after using NAMs versus animal dissection in a controlled trial, (b) reported student learning outcomes, (c) included at least one knowledge-based or skills-based evaluation to assess learning outcomes, (d) provided a clear explanation of experimental design, (e) were published in English, and (f) were available in full text. Citations were excluded if they (a) were not available in full text, (b) were a review or meta-analysis instead of an original research paper, (c) were duplicates, or (d) studied human cadaver dissection versus NAMs.

For the first screening, authors Elisabeth Ormandy, Janella Schwab, and Samantha Suiter independently assessed each citation based on the eligibility criteria, and disagreements were resolved

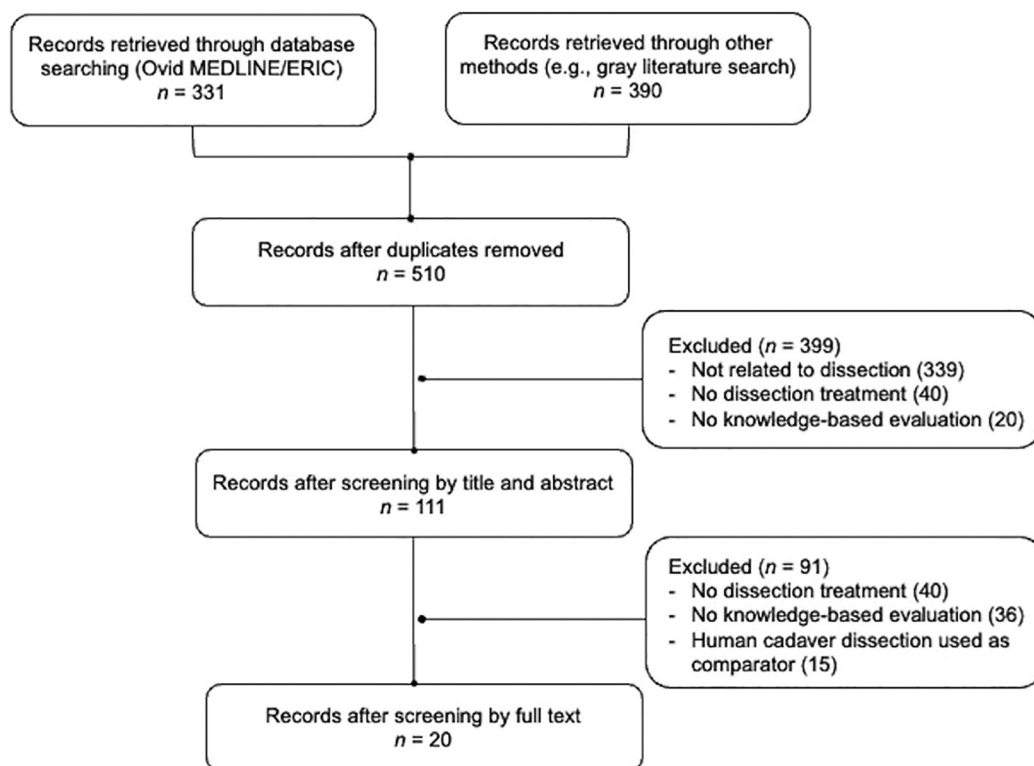


Figure 1. Screening process for our systematic review study. Flowchart created according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol.

through discussion. For the second screening, authors Ormandy and Schwab independently assessed each citation based on the eligibility criteria, and disagreements were resolved through discussion.

Data Extraction & Analysis

The following data were extracted from the studies included in the review after the two-stage screening process: first author and publication year, country, the NAM and dissection that were being compared, student education level (secondary, postsecondary, or medical school), type of class, learning objective (as defined by the authors of each study), number of students assessed, student evaluation methods, and outcome (NAMs better, NAMs and dissection equal, or NAMs worse). Descriptive analysis was performed on all studies that met our inclusion and exclusion criteria.

○ Results

Descriptive Analysis of Included Studies

Our searches in Ovid MEDLINE and ERIC yielded 331 results, while our gray literature search yielded 390 results. After the two-stage screening, 20 studies were included in our systematic review (Supplementary Table 3). NAMs were deemed more effective (i.e., students performed better on their evaluations) than animal dissection in 14/20 (70%) of the studies, while they were deemed equal in 5/20 (25%) and less effective in 1/20 (5%) of the studies (Figure 2).

The majority (11/20; 55%) of studies involved postsecondary students, followed by secondary students (7/20; 35%) and medical school students (2/20; 10%) (Figure 3). The only study where students fared worse when using NAMs compared to animal dissection was at the postsecondary level.

Our systematic search yielded 10 studies where animal specimens were being replaced with NAMs depicting human anatomy (animal-human, e.g., use of human-based clay modeling to replace cat dissection) and 10 studies where animal specimens were being replaced with species-specific NAMs (animal-animal, e.g., use of virtual frog dissection software to replace the use of real frog specimens) (Figure 4). We found no major differences in the effectiveness of NAMs between these two groups; however, NAMs seem to be slightly more effective when the learning goals are focused on human anatomy and the dissection being replaced uses an animal specimen.

Of the 20 studies yielded by our systematic review, only two assessed hands-on skills acquisition. In both cases NAMs (virtual

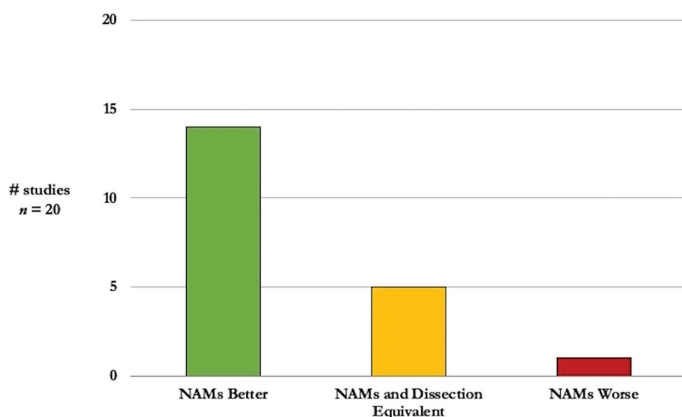


Figure 2. Results from the 20 studies included in our systematic review based on student learning outcomes.

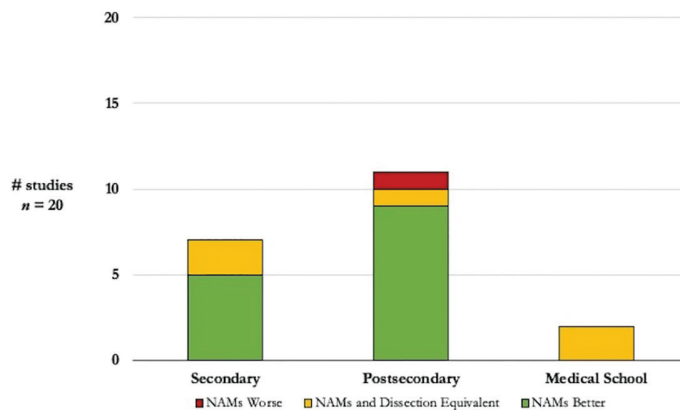


Figure 3. Educational level assessed in the 20 studies included in our review, with education level broken down by outcome parameter (educational merit: NAMs vs. dissection).

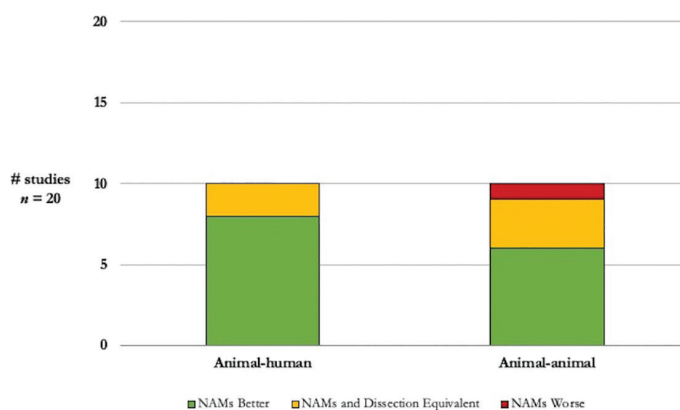


Figure 4. Breakdown of the 20 studies in our review comparing student learning outcomes when animal specimens were replaced with human-based NAMs (“animal-human,” e.g., use of human-based clay modeling in place of cat dissection) versus when animal specimens were replaced with species-specific NAMs (“animal-animal,” e.g., use of virtual frog dissection software in place of real frog dissection).

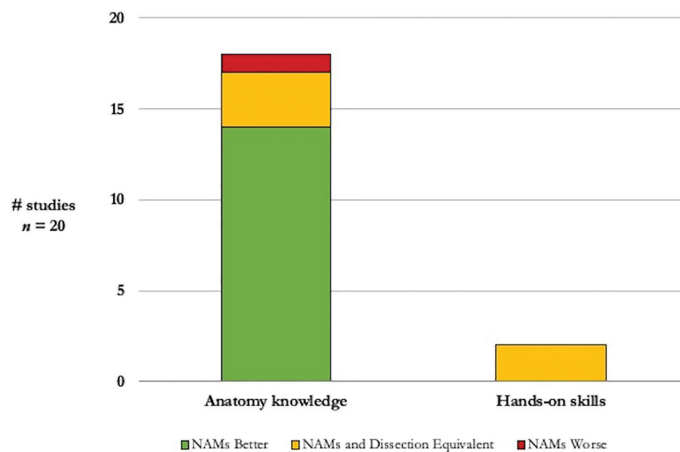


Figure 5. Breakdown of the 20 studies in our review by learning outcomes as defined by the authors in each study: anatomy knowledge and hands-on skills.

simulations) were deemed equivalent to animal specimens (pig cadavers) at helping medical students learn how to laparoscopically remove the gall bladder. The remainder of the studies in our review (18/20) assessed anatomy knowledge acquisition ($n = 18$: 14 = NAMs better, 3 = NAMs and dissection equivalent, 1 = NAMs worse) (Figure 5).

○ Discussion

Implications for the 3Rs in Science Education

Overall, our results show that in 95% of studies (19/20), students performed at least as well on course evaluations—and in many of those cases (14/19), better—when they use NAMs compared to animal dissection. NAMs were particularly effective when learning goals focused on human anatomy—this makes sense as there may be important content that is lost in translation when using animal specimens for dissection for learning goals related to human anatomy. NAMs were also shown to be effective for both anatomy knowledge acquisition and hands-on skills development. The small proportion of studies that assessed hands-on skills development makes it challenging, based on our data alone, to make a robust assessment of the value of NAMs for this purpose. However, our data do show that NAMs have pedagogical value across a range of educational levels. This is compelling evidence in favor of the 3Rs principle of replacement: if students can use NAMs to meet their learning goals, then the principle of replacement requires that NAMs be used in place of animals.

When our results are combined with data from the other systematic reviews by Patronek and Rauch (2007) and Zemanova and Knight (2021), there is a strong case to be made: NAMs should be adopted in place of dissection across all educational levels, especially where the curriculum-based learning goals are focused on anatomy knowledge. Decisions to use NAMs instead of dissection should be based on empirical evidence of pedagogical value rather than on the preferences or habits of teachers, or the view that dissection is a necessary tradition in biology education.

The Benefits of NAMs

NAMs have other benefits in addition to their pedagogical value. A full discussion of the ethics of using NAMs is outside the scope of this paper; however, some key benefits include cost savings (Animalearn, 2020a; Oakley, 2012), greener options for schools (Ammanna, 2018), and the opportunity for students to repeat exercises to consolidate learning (Oakley, 2012). NAMs were instrumental in helping teachers provide online and socially distanced classes during the COVID-19 pandemic (Jones, 2021; Osenkowski et al., 2021). Furthermore, NAMs ensure that animals are no longer killed for an educational purpose that can be achieved by other means. See Balcombe (2000); Hart, Wood, and Hart (2008), and Oakley (2009) for discussions about ethical and social considerations of dissection alternatives.

Our Evidence-Based Recommendations

Based on available empirical evidence from our systematic review and those published by Patronek and Rauch (2007) and Zemanova and Knight (2021), we make the following recommendations:

- 3Rs education should be included in science teacher training programs. An EU government-sponsored initiative now provides comprehensive 3Rs education to teachers across all EU member states so that knowledge about

the 3Rs can be included in school curricula (European Commission, 2021; Holloway et al., 2021). We recommend that all science teacher training programs include a module on the 3Rs, plus hands-on training in NAMs, especially in K–12 education where increased exposure to NAMs is needed (Green & Lewis, 2017).

- Progressive policy on dissection should be created for schools and universities. Worldwide, there are various policies and regulations regarding animal dissection, ranging from student choice policies to commitments at the school board level to phasing out dissection and from statewide laws to national dissection bans (American Anti-Vivisection Society, 2021; Animalearn, 2020b; Suiter et al., 2016; Windsorite, 2019). Against this backdrop of patchwork policy efforts, our data provide evidence in favor of cohesive national policies to restrict animal dissection.
- Position statements by professional teacher associations that encourage animal dissection should be revised to be in alignment with empirical evidence. We encourage such associations to uphold their stated commitments to evidence-based policy and adopt the perspective of organizations like the National Science Education Leadership Association (NSELA) and the International Baccalaureate Organization (IBO), both of which have position statements that are aligned with the available empirical evidence:
- “Dissection, as an instructional strategy, is discouraged in science classes” (NSELA, 2016).
- Teachers must “seek to replace animal dissection with computer simulations” (IBO, 2009).
- Animal dissection should be phased out when the learning goals outlined in science curricula are focused on anatomy knowledge acquisition. Where the curriculum requires hands-on skills acquisition, NAMs can be used in early-stage skills training (see Williams et al., 2015a and 2015b for examples of teaching animal handling and surgery skills using non-animal methods). In postsecondary education there might be cases where animal dissection is a valuable teaching tool, as evidenced by the one study in our review where students fared better when they did dissection. In these rare cases we recommend that instructors use ethically sourced cadavers (Martinsen & Jukes, 2008).

○ Conclusion

Our data show that in 95% of studies, students do at least as well—and in most cases better—when they use NAMs compared to animal dissection. These data demonstrate that, in most instances, science education goals can be achieved using NAMs. To achieve proper implementation of the 3Rs principle of replacement, NAMs should be used in place of animal dissection, especially in K–12 education. Continued use of animal dissection for purposes of providing hands-on activities or continuing traditions in biology education can no longer be pedagogically justified.

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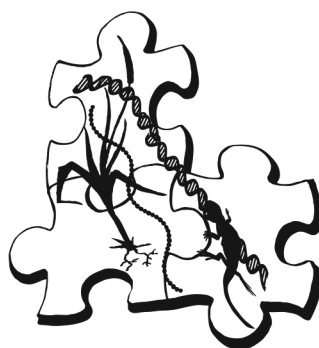
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