
SPECIAL ARTICLE

Editors' Note

Acknowledging the publication of his recent book on dissection (Balcombe, 2000), we invited Balcombe to present a brief argument on the comparative pedagogical studies of dissection versus alternatives. Four invited scholars representing various positions on the issue responded to Balcombe's manuscript. We invite for publication additional comments (of up to 500 words) on Balcombe's target essay or commentators' replies.

Dissection: The Scientific Case for Alternatives¹

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This article presents the scientific argument that learning methods that replace traditional nonhuman animal-consumptive methods in life science education—so-called alternatives to dissection—are pedagogically sound and probably superior to dissection. This article focuses on the pedagogy, a learning method's effectiveness for conveying knowledge.

A basic ethical principle asserts that if we have a choice between two ways of achieving something—one that causes pain, suffering, and death and the other that does not—then ethical conduct dictates using the latter method. Using animals in education presents such a choice. Methods of animal procurement for dissection and other consumptive uses of animals in education frequently involve pain and distress for the animals (e.g., frogs, fetal pigs, cats, dogfish sharks, bony fish, pigeons, turtles), and the majority of animals used in dissections are killed for that use (Balcombe, 2000). Computer simulations, three-dimensional (3-D) models, videotapes, and other alternatives involve little or no deleterious use of animals. If such alternative methods are equivalent to traditional animal-consumptive methods, then ethics requires replacement of the old with the new. This article shows that alternatives present many educational advantages over the use of living or once-living animals, making more forceful the ethical basis for using the alternatives.

Before presenting the scientific evidence favoring alternatives, I want to clarify two points. First, not all students are the same; they are not a homogeneous body of knowledge acquirers. A computer program that works well for Sarah might not work

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¹For the purposes of this article, alternatives are learning methods that replace traditional animal-consumptive methods in life science education.

so well for Claire, who learns best when manipulating 3-D objects. The empirical evidence presented in this article relates to what is effective for most students. Second, different learning methods provide different learning experiences. Dissecting a fetal pig in a dissection tray and on a computer screen are manifestly different experiences. Repeatedly, one hears the empty rhetoric that nothing can replace the experience of using a live (or once-living) animal. This is true, but to what avail? The reverse is just as true: The live animal cannot substitute for the experience of using a computer simulation. The key question is not whether one method is equal to the other but, rather, how well a given method promotes learning.

EMPIRICAL EVIDENCE SUPPORTING ALTERNATIVES

As alternatives have grown in number and diversity, so too have empirical studies examining their efficacy in educational settings. Ten studies have compared traditional animal dissection labs with various alternatives (see Table 1). Balcombe (2000) summarized an additional 20 studies presenting other applications of alternatives in life science education. These studies also provide overall support for alternatives. These studies assess a diversity of alternatives to dissection, including computer programs (5), lectures (2), 3-D models (1), film (1), and slides (1). They also include both high school (5) and university undergraduate (5) students. In 7 of these studies, measurable student learning performance was equivalent between the compared learning methods. In 2 cases (Fowler & Brosius, 1968; McCollum, 1987), students performed better using the alternatives. In only 1 case (Matthews, 1998) was the alternative (MacPig, produced by the now defunct company Intellimation for the Macintosh computer) found to provide inferior learning to the dissection. The design of this study has been criticized elsewhere on grounds that the alternative was deemed too rudimentary for a college-level class (Balcombe, 1998). A conservative conclusion based on these studies is that alternative methods are pedagogically equivalent to traditional animal dissections.

Notwithstanding the teacher's ability, dissection has pedagogical shortcomings. As usually taught in the schools, dissection is weak on both concept learning and problem solving. Yet, the value of concept-driven teaching in the context of solving problems has been demonstrated (Jacobs & Moore, 1998). Generally, dissection is too focused on the acquisition of facts while failing to teach students to conceptualize and synthesize (Rollin, 1981). Almost all students consider memorizing facts and terms "boring," and most of what is learned is forgotten easily (Orlans, 1991). Yet, more terms that are new are introduced in a typical high school biology text than in the first 2 years of a foreign language (Cole, 1990).

An inherent problem of dissection is its destructive (rather than constructive) process, which destroys many of the specimen's structures and their spatial rela-

TABLE 1
Studies Comparing Alternatives to Traditional Animal-Based Learning Methods

<i>Study</i>	<i>Participants</i>	<i>Description</i>
Dewhurst, Hardcastle, Hardcastle, & Stuart, 1994	14 second-year U.K. undergraduates	Six students working independently with a computer program gained equal knowledge, at one fifth of the cost, as did 8 supervised students using freshly killed rats.
Downie & Meadows, 1995	2,913 first-year U.K. biology undergraduates	Cumulative examination results of 308 students who studied model rats were the same as those of 2,605 students who performed rat dissections.
Fowler & Brosius, 1968	456 U.S. high school students	Students who watched films of animal dissections (earthworm, crayfish, frog, perch) demonstrated greater factual knowledge of these animals than did students who performed dissections on them.
Guy & Frisby, 1992	473 U.S. prenursing and premed students	Performance of students doing traditional cadaver demonstration labs was not significantly different from that of students using interactive videodiscs.
Kinzie, Strauss, & Foss, 1993	61 U.S. high school students	An interactive videodisc was at least as effective as actual dissection in promoting student learning of frog anatomy and dissection procedures.
Lieb, 1985	23 U.S. high school students	Posttest scores were equivalent for students who dissected earthworms and those who received a classroom lecture on earthworm anatomy.
Matthews, 1998	20 U.S. biology undergraduates	Eight students who dissected fetal pigs scored significantly higher on an oral test with prosected fetal pigs than did 12 students who studied on a computerized pig (MacPig).
McCollum, 1987	350 U.S. high school biology students	Approximately 175 students taught frog structure, function, and adaptation via lecture performed better on a posttest than did approximately 175 students taught by doing a frog dissection.
Prentice et al., 1977	16 U.S. physician's assistant students	Based on student learning performance, the use of labeled sequential slides of anatomical dissections provided a viable alternative to dissection.
Strauss & Kinzie, 1994	20 U.S. high school students	Two groups of high school students performed equally on a test following either animal dissection or interactive videodisc simulation.

tions, precluding reexamination by the student (Rosse, 1995). Many alternatives, such as computerized dissection simulations, allow the user to repeat, or even reverse, the dissection process an unlimited number of times (Richter, Kramer, Lierse, Maas, & Hohne, 1994).

PEDAGOGICAL ADVANTAGES OF COMPUTERS

In addition to the cultural and economic momentum that computers have going for them in the late 20th century, computer-assisted learning (CAL) is demonstrably advantageous. Almost 20 years ago, Kulik, Kulik, and Cohen (1980) conducted a meta-analysis of 54 published studies of CAL versus traditional teaching in postsecondary classrooms and found that students using CAL performed significantly better (by 3%) on examination scores. By 1996, Kulik had analyzed 250 such studies and reported that gains from CAL generally were enough to move an average student in the 50th percentile to the 64th percentile while working at a 34% faster pace (Beyers, 1996). A meta-analysis of 28 studies by Bosco (1986) of Interactive Videodiscs (a technology now largely replaced by CD-ROMs) rated their efficacy for learning as favorable overall. The Educational Testing Service recently released a report showing that learning improves when technology is used effectively to engage higher order thinking skills (Wenglinsky, 1998).

The reported benefits of CAL in the life sciences include active involvement of students, even in large classes; less time needed to present information and for students to master it (Dewhurst & Jenkinson, 1995; Teyler & Voneida, 1992); self-paced learning that puts students in control of the learning resource (Erickson & Clegg, 1993; Leathard & Dewhurst, 1995; Nosek et al., 1993); and greater cost-effectiveness (Dewhurst & Jenkinson, 1995; Leathard & Dewhurst, 1995). At Kansas State University, faculty members in both veterinary medicine and education found that CAL increased opportunities for active learning, demanded less of teacher resources, decreased live animal use, and improved learner skills in problem solving and information handling.

How students respond to a given learning method has pedagogical significance, because learning tends to improve when students find a given method enjoyable. In their study of 82 U.S. veterinary students, Erickson and Clegg (1993) found that students rated computer-based active learning the highest of 14 learning methods for basic cardiac teaching and electrocardiograph interpretation. Use of computer packages by 20 British biomedical students saved teaching staff both time and money, proved an effective and enjoyable mode of student learning, and significantly reduced animal use (Dewhurst & Jenkinson, 1995). In a study involving 110 U.S. medical students who used both computer demonstrations and companion animal (dog) demonstrations, the students rated the former higher than the latter for

learning cardiovascular physiology (Samsel et al., 1994). Conversely, surveys of student feelings and attitudes toward animal-consumptive learning methods show that concerns and reservations about such use are commonplace, ranging from 30% to 70% of the student body (Balcombe, 1997, 2000).

In reinforcing the value of CAL over cadavers, Holton (2000) quoted Michael J. Ackerman, father of the Visible Human Project: "If a group takes it [the specimen] apart wrong, then the group at the next table better do it right, or nobody gets to see it" (p. 8). Holton suggested an alternative:

But represent the visible humans in three dimensions inside a computer, and the possibilities for learning improve dramatically: organs can be rotated and tilted, highlighted in areas by color, taken apart by layers, compared with textbook or cadaver, then completely reassembled. (p.8)

In addition, computer programs need not rely on static, synthetic data. Not only can random variation be built into the program (Nab, 1989), but some programs (BioPac, 2000; Intellitool, 2000; iWorx, 2000; Pankiewicz, 1995) use data from the students' bodies.

Finally, the argument that dissection benefits students simply because it is a hands-on activity is vacuous and unconvincing. Hands-on activities only are effective for learning if the students' heads are being kept as busy as their hands. Active (vs. passive) learning is a more useful construct for assessing learning value. Active learning is inquiry based (students asking questions, solving problems, and generating hypotheses) and occurs when students engage additional cognitive processes while confronting the information being acquired. It involves learning how to learn rather than merely learning to become knowers. Dissection is weak in these areas. Also, limitless other hands-on learning tools do not require harmful uses of animals: field investigations, student self-study exercises, 3-D models, and dissections of plants or owl pellets. Interactive computer programs also can demand user hand-eye coordination. Balcombe (2000) detailed the hands-on versus active learning issue.

VETERINARY MEDICINE

Several life science disciplines—physiology, pharmacology, medicine, and veterinary medicine—have assessed educational alternatives. Veterinary medicine presents a stringent challenge for the application of alternatives because of its need for student experience with animals. Indeed, if alternatives that do not harm animals can be applied to veterinary training, they probably can be applied anywhere.

Nonanimal surgical training devices are used extensively. Veterinary schools use nonanimal surgical training to hone skills before their application to live animal tissue. Anatomical models are effective in the training of veterinary skills and

techniques. Soft-tissue plastic models of dog abdominal organs developed at the University of Illinois have comparable handling properties and were useful for teaching a range of common surgical procedures (Greenfield, Johnson, Shaeffer, & Hungerford, 1995). Several institutions have used DASIE (Dog Abdominal Surrogate for Instructional Exercises) successfully, developed at the Ontario Veterinary College to reduce animal use in teaching abdominal surgery (Holmberg & Cockshutt, 1994; Holmberg, Cockshutt, & Basher, 1993).

Rigid plastics used to make bone models have been effective for demonstrating and teaching many aspects of bone-related surgical procedures (DeYoung & Richardson, 1987; Johnson & Farmer, 1989; Johnson, Harari, Lincoln, Farmer, & Korvick, 1990). Based on 27 responses to a survey of all 31 veterinary schools in the United States and Canada, Bauer (1993) reported that eight schools (30%) used plastic bones to teach fracture repair. A model of a dog stomach developed and tested at Ohio State University by Smeak, Hill, Beck, Shaffer, and Birchard (1994) had mixed results. Although effective for teaching some procedures, it did not enhance the confidence of students faced with live animal surgery, suggesting that accompanying instruction was necessary.

Additional published studies in the veterinary field support using animal-friendly learning methods instead of traditional animal-consumptive ones. Carpenter et al. (1991) reported no significant differences between the surgical performances of two groups of 3rd-year students—one trained using live animals, the other using cadavers. Unfortunately, the authors did not report the source of their cadavers, but ethical sources are certainly available from companion or stray animals euthanized for medical reasons (see the soon-to-be-released Web site, www.educationalmemorial.org). White, Wheaton, and Greene (1992) reported that seven 4th-year veterinary students in an alternative (animal-friendly) track showed hesitancy in their first live tissue surgery but performed on par with students with a standard laboratory experience.

A study by Pavletic, Schwartz, Berg, and Knapp (1994) compared surgical abilities of 12 graduates from the Tufts University veterinary class of 1990, who had participated in an alternative small animal medical and surgical procedures course with 36 of their counterparts. Their employers rated participants for surgical competency at the time of their hiring and again 12 months later. No significant differences were found on either occasion for any of the measures, which included ability to perform common surgical, medical, and diagnostic procedures; attitudes toward performing orthopedic or soft tissue surgery; confidence in performing procedures; and ability to perform procedures without assistance. This study is especially noteworthy because it assesses the learning experience at the point where its outcome is most important—on-the-job performance.

The previous veterinary studies involved 290 students at all stages of their training, including on-the-job performance at 1 year postgraduation. Collectively, they provide a strong case for the replacement of traditional labs in which healthy

animals are killed. Studies by White et al. (1992) and Pavletic et al. (1994) showed that the initial hesitancy of "alternative track" students when faced with live animal surgery is short-lived and has no lasting effect on surgical performance. The demonstrated validity of alternative-track curricula in veterinary training, combined with growing student dissatisfaction with traditional methods, is fostering progressive changes at North American veterinary schools (Bauer, Glickman, Glickman, Toombs, & Bill, 1992; Bauer, Glickman, Salisbury, Toombs, & Prostedny, 1992; Patronek, 1998). More than half of these 31 schools now have alternative tracks. The newest, Western University of the Health Sciences, whose veterinary program is scheduled to open this year, aims to have a completely nonanimal consumptive curriculum (L. Rasmussen, personal communication, November 28, 1999).

CONCLUSIONS

The ranks are growing of those who recognize the various pedagogical and other benefits of using alternatives. The primary and secondary schools of The Netherlands, Switzerland, Argentina, The Slovak Republic, and Israel no longer carry out animal dissections; they are almost nonexistent in Sweden, England, and Germany. Whether these nations' policy changes were founded in the ethical principle noted at the beginning of this article is unclear. What is clear is that the quality of life science education was not seen to be compromised—and indeed should benefit—by these changes.

The persistence of dissection in life science education is attributable to tradition and inertia, not to any pedagogical imperative typically claimed by its defenders (Pancoast, 1991; Schrock, 1990). Analysis of existing scientific evidence shows that dissection is no better than, and arguably inferior to, a range of alternatives now widely available. That the alternatives also are ethically preferable makes the case all the more clear. Alternatives ought to replace dissections, and the sooner the better.

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