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BioSafaris: A rationale for educational software on human biology and health in pre-college as an alternative to dissection

Lynette A. Hart[1], Mary W. Wood[1], David Wiley[2], Bernd Hamann[1], Marco Molinaro[1], Stuart Meyers[1], Frazier T. Stevenson[1] and William A. Storm[3]

[1]University of California, Davis, [2] Stratovan Corporation,
[3]Davis Joint Unified School District, Davis

Corresponding author: Lynette A. Hart
Department of Population Health and Reproduction, School of Veterinary Medicine:
Haring 1024C, University of California, Davis, Davis, CA 95616, USA
Phone: +(1)-530-752-2181, Fax: +(1)-530-752-5845, lahart@ucdavis.edu

Abstract
We present interactive visualization software as an effective alternative to cadaver-based education to teach anatomy. Many laboratories in pre-college biology education still feature dissection of animals and do not reflect the exciting, web-available world. Teachers in focus groups describe that they are constrained by high-stakes testing, contradictory curricular requirements, limited teaching materials, and poorly integrated biology and health educational standards. Students gain insufficient knowledge about their own biology to manage their health care. Our three-dimensional visualization software has been designed, implemented and evaluated by a multi-disciplinary team of educators and computer scientists, and allows a student to explore the human body using the tools of human anatomy, physiology, comparative anatomy, and cellular biology. Our interdisciplinary project team has simplified human datasets of The Visible Human Project (National Library of Medicine). We will prepare a BioSafaris prototype of the digestive and cardiovascular systems. See video: http://www.stratovan.com/biosafaris/ Following funding and production of software, users could investigate essential aspects of human biology, simulate disease, and assess the resulting physiological effects. Technological tools could gather data for graphing and analyses. The eventual goal is to provide high-quality software on the entire human body, giving students an understanding of human biology and health sufficient to develop health literacy.

Keywords: education, dissection, biology, health literacy, software

Introduction

Current biology education laboratories have evolved during the last two centuries from the historical practice of dissection, primarily of human bodies. More detail on this topic is available in a forthcoming book, *Why Dissection? Animal Use in Education* (Hart, Wood, and Hart, 2008). In this paper, we present: 1) a brief review of the historical origins of the use of dissection of humans and animals in medical and biology education up to the present; 2) a summary of current regulatory constraints and the perspectives of students and teachers on biology and health education; and 3) some new options for improving biology and health education for students in pre-college.

Historical origins of dissection in medical and biology education

The practice of dissection of humans arose in a context of medical education, in which anatomical discoveries also were made. As science education was included in basic education for a wider constituency in the 19th century, and laboratories were added for practical experience, it became common practice for students to dissect a variety of animals, as a surrogate for humans.

Ancient instruction in anatomy. Galen systematically gathered and compiled the ancient's knowledge of the human body. This compendium of knowledge was widely disseminated and went through many translations over the centuries. Galen's work was revered and viewed as a completely sufficient source of knowledge, supplanting any need for further scientific exploration. Early medical instruction in Italy featured dissection for medical students solely as an illustration of Galen's writings. When a human body showed discrepancies from the Galen texts, these were regarded as anomalies. Human bodies were typically dissected in the cooler season to delay putrefaction of the body, often in a somewhat jubilant and celebrative setting, with a musical procession leading into the anatomical theater (Klestinec, 2004).

After centuries of scholars relaying Galen's early knowledge, Vesalius took a fresh approach, provocatively throwing over the ancient masters and treating dissection as an opportunity for gaining new knowledge about the human body. His anatomical theater was similar to others of the time in arousing great interest. Unlike earlier professors who stood on an elevated platform and read from ancient texts while a dissector standing below did the cutting to illustrate the readings, Vesalius himself did the dissecting. Studying the human body, he acquired new knowledge while also teaching medical students. His dissections were conducted in a temporary, wooden anatomy theater that was packed with interested onlookers (Magruder, 2007). His famous book, *De Humani Corporis Fabrica Libri Septem,* presented human bodies in lifelike poses and settings, portraying muscles or skeletal structure with detailed accuracy (See Fig. 1; Vesalius, 1543/1964). His artwork resembles current presentations of real plastinated human bodies, as though alive, in exhibits by Gunther von Hagens' BODYWORLDS (Von Hagens and Whalley, 2002).

Contemporary with Vesalius, artists such as Leonardo da Vinci and Michelangelo in the 16th century also dissected human bodies both to learn about them and to draw them more accurately. Both artists and medical scholars were highly motivated to study the human body, even though dissection violated many religious traditions and taboos. The short supply of human bodies led to the dissection of animal bodies, even though these were viewed as a poor substitute.

Gaining access to dead human bodies for dissection was always a challenge. Grave robbers collected freshly buried bodies and sold them for dissection. The bodies of paupers or criminals who had been hanged were routinely supplied to medical schools. Two famous paintings by Rembrandt documented the dissection of two men's bodies following the hanging of the men involved. The earlier of these (See Fig. 2) assured Rembrandt's fame as an artist, and remains one of his best-known works today.

Having one's body dissected was regarded as a fate worse than being executed. Being deprived of a proper burial and having your body publicly dissected and desecrated was a punishment that far exceeded being put to death, and something that violated a variety of religious traditions. Such was the final ignominious end of the villain, Tom Nero (See Fig. 3), whose fictitious life was depicted in a series of vignettes by Hogarth in his engravings, 'The Four Stages of Cruelty.'

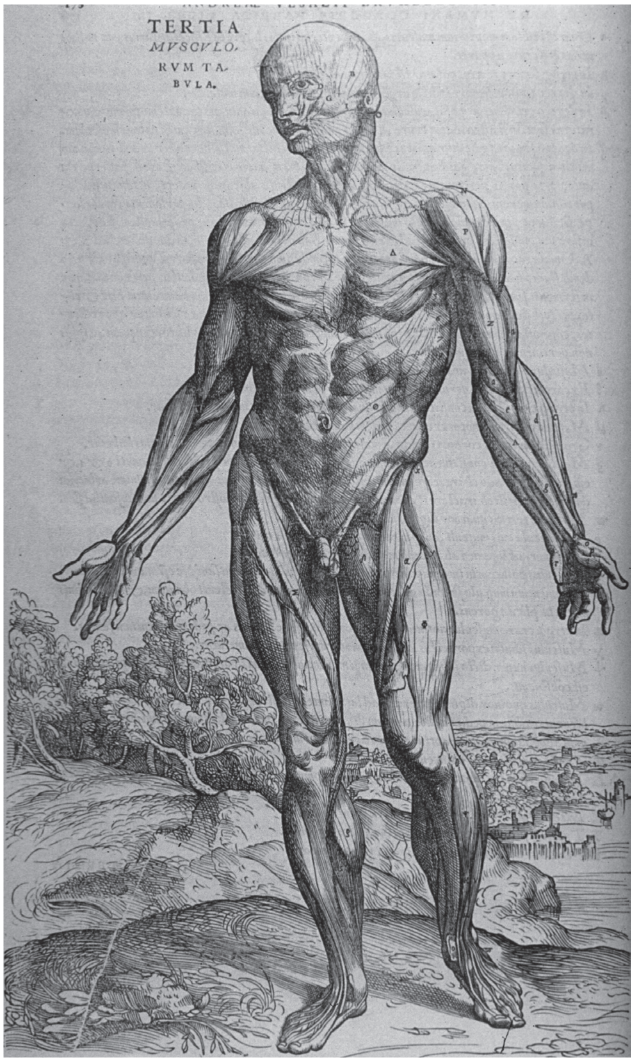

Fig. 1. The lifelike poses presented in *De Humani Corporis Fabrica* by Vesalius(1543/1964) blend anatomy with human emotion and experience. This anatomically-accurate muscular figure exudes vitality, health, and strength. Other figures in his book provoke serious thoughts and emotions, conveying the sadness and grief associated with aging and loss. The practice of dissection thus was set in a context of profound human emotions. The images in Vesalius' book are remarkably similar to the current displays of real, plastinated human bodies in BODY WORLDS (Von Hagens and Whalley, 2002).
(Photo: National Library of Medicine)

Biology education for all children. From the mid-19th century in the United States, in a process reviewed by DeBoer (1991), science became a goal in educating children that was added to the basic disciplines of reading, writing, and arithmetic. Following on the work of Darwin, biology became a new scientific discipline important for all children to study. Along with others, Thomas Huxley (1876/1902) advocated hands-on laboratory experiences in science

Fig. 2. This painting, "The Anatomy Lesson of Dr. Nicolaes Tulp" (1632) solidified Rembrandt's fame as an artist. Although he created other versions of the scene, this oil painting of Dr. Tulp dissecting the arm of the corpse is the well-known one. It shows a dissection with a small group of engaged observers, perhaps contemplating the seriousness of death. The dissection occurred in 1632 following a hanging (Ricketts, 2006). Dissecting the arm prior to opening the abdomen perhaps reflected artistic license, since it would be more typical to hasten opening the abdomen prior to putrefaction of the contents.
(Photo: National Library of Medicine)

education, and emphasized beginning early to teach children biology (Huxley, 1854/1902). In classroom studies of biology, the dissection of small animals became conventional as a method of providing children a view of the inside of a body that had been alive. Only medical students dissected human cadavers, but children from seventh through twelfth grade dissected animals such as small mammals, frogs, and fish---a practice that has continued to the present.

Despite the implications of biology for human health, curricula for health were slower to develop, were more reflective of social problems, and were not integrated within a biological context. Health instruction emerged as a body of coursework separate from general science and biology. Typically health was taught by teachers who had earned a physical education teaching credential, or a health education teaching credential (Varnes et al. 1989) rather than a science education credential. Teachers prepared in physical education often cross-taught health education, and the converse was true for persons who originally studied health and nursing and later were recruited into physical education (Bennett and Peel, 1994). Content suggested for inclusion in health education includes growth and development, mental/emotional health, family life, safety and first aid, consumer health, drug use and abuse, community health management/environmental health, disease prevention and control, and nutrition (English, Sancho, Lloyd-Kolkin, and Hunter, 1990).

Fig. 3. William Hogarth's 1751 engravings on "The Four Stages of Cruelty" have become well-known, especially the first two showing the fictional villain, Tom Nero, torturing small animals, and beating his horse (Jaffe, 2003). In the fourth engraving shown here, Tom has been cut down from the gallows and is being dissected in a gruesome portrayal. The caption on the fourth print describes Tom's unthinkable disgrace in being deprived of a conventional burial.
(Photo: National Library of Medicine)

Current challenges in biology and health education

Educational concerns that were salient in the 1950s-70s, about improving biology curricula and laboratories and including questions about dissection, have been eclipsed by other pressing requirements and controversies. Questions about mainstreaming all children, the economic struggles of schools, the student dropout rates from high schools, the coverage of controversial curricular topics, and the inequality of schools have commanded attention and space in educational journals and newspapers alike. Although other issues have been prominent in educational research and with the public, science education and laboratories are disorganized and ineffective, and require an overhaul, along with improving the professional development to prepare science teachers (Singer, Hilton, and Schweingruber, 2005).

Curricular and testing requirements. Educational standards, laws and regulations, and testing requirements set a guiding framework for science education that has become increasingly constrained in recent years. Combined, they reduce the flexibility available to teachers in organizing their lesson plans. The array of requirements and prohibitions on content can create cross-purposes that interfere with presenting a well-organized curriculum. Particularly onerous are the high-stakes testing requirements and results, since the United States legislation was passed for "No Child Left Behind" (U.S. Department of Education, 2002), that are used as a basis for federal funding, thereby obligating teachers to direct substantial teaching effort specifically toward the mandated testing. "No Child Left Behind" has unleashed a storm of controversy and criticism from professional educators.

Educational standards have been adopted at both the national and state level for all the subject areas and grade levels. The national standards (National Research Council, 1996; National Academies Press, 1996/2007) carry no regulatory authority despite the strong effect of federal funding tied to testing, and in fact, the states retain significant control over the content to be taught. The content of science standards is sometimes influenced by political forces, resulting in contradictory information among states, and requiring specific textbook adjustments to be compatible with the individual state standards. For example, content may differ in various states regarding evolution, intelligent design, and the reproductive system. In many cases, conforming to both the national and state standards would not be possible.

Finally, the importance of biological knowledge and understanding in modern management of health care appears prominent in current events today, but the historical organization of curricula in biology and health impedes students gaining this type of preparation. Biology and health are entirely separate at the pre-college level in terms of educational standards, teacher certification, and coursework. The pre-college study of biology emphasizes structure and function in a context of scientific literacy and process, whereas the study of health pertains to advocating healthful behaviors, without integrating basic biology.

A healthy lifestyle and behavior management to avoid risks are the central emphases in health curricula (HealthTeacher.com, 2008). Healthful behaviors are promoted, such as fitness and nutrition. But, the primary focus is on advocating avoiding harmful or risky behaviors, such as alcohol or drug abuse, and risky sexual behavior: these topics account for significant emphasis in legislation and policy. These requirements for instruction on tobacco, alcohol, and drug abuse are specific for each state (National School Boards Association, 2007). In recent years, promoting emotional development and sexuality education has become a main focus (Carter, 1999). The imperative to provide precautionary information about HIV led to a recent proposal to include such information across the curriculum and effectively link priority health information in 12 core subject areas *without increasing teacher workload* (Pateman, 2003). In some counties and states, health curricula are micro-managed by a list of legislated instructional topics to be taught, such as avoidance of alcohol, tobacco, and drugs, and sexual misbehavior, or a description of procedural requirements such as parental permission and the extent of time allowed for the instruction on specific topics.

<u>Constraints on teachers</u>. As described above, the expectations and requirements for specific content to be taught and tested have been increasing for teachers. Their motivation in becoming teachers is to seek to inspire their students and further their learning. In order to fulfill their professional and personal goals as teachers, they need sufficient classroom time and latitude, combined with effective teaching resources in the biology and health curricula.

Teachers can easily feel impeded in their goals by the limited support and shortage of teaching resources, combined with micro-management of daily schedules. School districts tend not to maintain a supply of equipment and materials for laboratories associated with biology, and budgets have become too limited to purchase what would be needed. Other challenges teachers may face include having multiple course preparations, being drafted to teach subjects for which they may feel insufficiently prepared, and tight scheduling with short periods and quick changes between laboratory preparations. The pressures of limited time and resources make it unlikely that teachers can find time to peruse information on the many resources that could possibly be suitable for use in their classrooms. These pressures reduce the likelihood of teachers collaborating with each other to exchange ideas and acquire or share resources.

Animals appear in classroom throughout the pre-college school years, as pets, and then, later, as specimens for dissection. Most children experience attraction to pets, have known some pets, and may have become personally aware of death through the death of a pet. For children who have kept a pet cat or rat, they may find they are dissecting these same species in seventh grade. Many students have a legal option to decline dissecting and can request an alternative. Dissection of animals has largely been phased out in teaching veterinary and medical students, for whom outstanding software, reusable models and specimens, and other resources are available. The increasing cost of dissection in pre-college classrooms, the lack of suitable materials, and the emotional conflicts for students and teachers contribute to the need for alternatives to dissection.

<u>Current difficulties with science teaching.</u> A major concern is that the quality of instructional and interactive materials is limited and patchy. Children in well-supplied school districts may have informative and interesting laboratory experiences, but those in less-affluent communities may not be

given even a basic preparation in biology. Further, laboratory exercises for the most part seem to be poorly integrated with the instructional material of the curriculum teachers (Singer, Hilton, and Schweingruber, 2005). Effective, accessible, and informative alternatives are needed to offer excellent biology and health instruction to pre-college students.

Software laboratories based on human biology and health

Thousands of teaching resources of various types, related to biology, are available and well-cataloged by NORINA (Norwegian Reference Centre for Laboratory Animal Science and Alternatives, 2007) and AVAR (Association of Veterinarians for Animal Rights, 2007). However, these resources are not precisely developed to complement curricula in grades 7-12, nor are they readily accessible when needed. A few resources that may be suitable for teacher's instructional needs are available on a lending basis to teachers who plan well ahead and order them for delivery at the time when they will be needed (Animalearn, 2007; Humane Society of the United States, 2007a). Most of these resources focus on animal, rather than human, biology, and thus have limited direct usefulness in conveying knowledge related to health.

Dissecting animals. It is already well-documented that students can learn effectively with many different types of activities and materials. Although it promotes excitement and engagement, experiencing dissection does not result in improved learning by students when compared with those using alternative teaching materials, such as software. This subject has been abundantly reiterated and reviewed (Balcombe, 2001; Jukes and Chiuia, 2003; Patronek and Rauch, 2007) and an ongoing summary of these results is available online (Humane Society of the United States, 2007b).

Need for human biology and health software. What is missing in pre-college biology instruction is convenient access to outstanding teaching resources that are interactive and offer opportunities for students to gain experience in scientific observation and methods that includes data collection and analyses. Interactive software is used with veterinary and medical students, but has not been produced specifically to complement instruction at the pre-college level. The national and state science educational standards place instruction on the body systems in the seventh grade curriculum. The general science class offered in seventh grade is the last science class that is the minimum requirement for all students, and for many students a portion of that course is their last formal instruction in biology. Since these classes typically spend only a few weeks of the year on biology and human body systems, they have time for only a few related laboratories. As an initial start, even five to ten outstanding modules on various body systems made freely available on the web would be a substantial contribution for classrooms everywhere.

Focusing on human, rather than animal biology, provides opportunities for more relevant learning. Dealing in a software environment, the human images are readily available. Comparative animal vignettes can be employed as intriguing illustrations that contrast with the human. The software environment can readily support both biology and health literacy, addressing common health problems in a biological context. Obesity, diabetes, and heart disease are topics of high interest that could be presented in an interactive format, with a tool for manipulating health parameters that simulate a disease condition.

BioSafaris Prototype. Today's students are becoming increasingly familiar with modern computer graphics software at an early age, with interactive games being a main reason for this development. Our visualization prototype system uses basic concepts from modern three-dimensional computer graphics and interactive data analysis tools to allow a student to inquire about a body's systems in an inquiry-based fashion. BioSafaris supports a highly intuitive, easy-to-learn user interface to visualize in real time very large three-dimensional data sets. We have assembled a project team that includes expertise in 3-dimensional imaging, animal welfare and alternatives, science classroom teaching, and science education in medical, veterinary, and pre-college contexts. We have downloaded and processed the *Visible Human* images, reducing the 40 gigabytes each for datasets for the man and woman down to 24 megabytes, now usable on conventional computer systems. This size provides adequate resolution to see major internal structures. The resulting images are startlingly realistic portrayals of living body parts, as portrayed on the web video created for this presentation. In this innovative simulation environment, the user can rotate the body, zoom, change transparency and explore the body parts visually by simple mouse movements and left/right mouse clicks and drags. We plan on isolating regions, such as the heart, and storing those images at a higher resolution to permit closer inspection.

We have begun segmenting various regions for the purpose of constructing our interactive educational sequences to create a prototype. We have traced the digestive system throughout the man and have animated a ball to follow the path from mouth and salivary glands, through the esophagus and stomach, and through intestines. A Quicktime demo video illustrates the concept (2.5 min; 45MB): http://www.stratovan.com/biosafaris/

Discussion

Most of the readily available teaching materials for biology and health are of poor quality or otherwise inadequate for the specific curricular needs of pre-college teachers and students. Teachers continue to use the best materials they can access to engage students. They employ dissection as a familiar activity for the classroom. Drawing on the capability today of creating exciting web-based materials, it is possible to produce basic resources of high quality to all classrooms. Providing a framework of five to ten laboratory modules pertaining to the human body systems would address the most essential needs of teachers and students for seventh grade biology instruction and offer enhanced learning opportunities in biology and health to all students.

Delivery on the world-wide web would assure availability to families and people in other informal science education settings, as well as to classrooms. Profiling the visual images in the software increases the appeal of these materials for users in countries around the world, where for many English will be a second language for users. Furthermore, many users in other countries have no budget to purchase materials, yet most of them have access to computers.

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