

CREATING USEFUL TOOLS FOR LEARNING INSECT ANATOMY

VDIL Summer Grant Report

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December 7, 2006

ABSTRACT

Insect anatomy and function is vital to understanding insect taxonomy, evolution, behavior, and ecology, but is often difficult for students to learn. A student's difficulty often escalates to frustration because diagrams offered as learning aids in entomology classroom laboratories are confusing. I will use Maya, Flash, and other software packages to create a more intuitive, user-friendly and interactive 3D computer module to supplement examinations of insect specimens during lab time. The module will cover all major external and internal structures and include animations of vital insect functions. This summer I received a grant from the University of Minnesota Duluth Visualization and Digital Imaging Lab, allowing me to learn the software necessary to complete this project. Special care will be taken to design the module along principles established by educational psychologists who study multimedia learning. Feedback from students will be solicited as the module is designed. The project will conclude with experimental tests of the module's efficacy. If successful, the module will be published on the web and possibly expanded.

An understanding of insect anatomy and physiology is critical to identification, and also aids the answering of questions of insect ecology, behavior, and evolution. Consequently, structure and function are usually taught first in introductory entomology classes. Unfortunately, this material has been notoriously difficult for students to learn because insect bodies are complex, small, and put together in an alien way. Students in entomology classroom laboratories spend hours trying to locate numerous structures and learn their esoteric names. The complicated line diagrams provided to aid this struggle show labels for too many parts at once. They are not clear as to where structures begin and end and fail to convey how parts work, leaving that to be gleaned from dry textual descriptions or not learned at all. Consequently, too often students come away with little understanding upon which to generate hypotheses or else they lose interest in entomology altogether and turn their attentions to another field. Worse yet, many students encounter these line diagrams of insects in general zoology or biology courses, and are so turned off that they never take entomology in the first place.

More effective educational tools would help students master insect anatomy and develop meaningful understanding of how insects function. My goal is to develop a three-dimensional interactive computer-based module to aid undergraduate students in learning insect anatomy and function. I intend it to supplement lab work with insect specimens rather than substitute for direct handling of organisms. To most effectively facilitate learning, I will design the module according to principles established in current educational psychology literature.

The proposed module will cover basic internal and external anatomy, including exoskeletal sclerites, appendages, and major internal organs. Functions such as flight, digestion, and respiration will be included as animations. Once the module's design is completed, the project will conclude with an empirical evaluation of its efficacy. I hypothesize that

students using the module will demonstrate better learning than students using line diagrams in the same lab setting.

METHODS

Phase 1: Gathering Information

During this phase, the bulk of which is already complete, I set out to answer three questions: 1) Are computer models and animations effective learning tools compared with text and diagrams? 2) What makes a tool of this sort effective? 3) Do tools like the one I envision already exist? A summary of results is given here.

Computer-based science education has been a topic of interest and debate for over thirty years (Gerard 1962, Hyatt et al. 1972). More recently, the Internet has sparked myriad digital innovations in biology education and made them more accessible to instructors and students (Baggot-LaVelle 2004, Danforth and Marshall 2002, Syrjakow et al. 2000, Zenger and Walker 2000). At least some instructors consider computer biology modules and simulations most desirable and use them in lectures and labs whenever possible (de Jong and van Joolingen 1998, Key and Nurcombe 2003, McLachlan 2003). Educational psychologists, however, caution against assuming technology's inherent superiority over other learning materials (Lowe 2003, Mayer 1997) and press for more empirical studies to evaluate their performance based on theories of learning. While few studies exist that examine whether these tools actually aid learning in biology (but see Garg et al. 1999) or entomology, some research to that end has been done on similar tools in other fields.

For example, a series of studies at the Georgia Institute of Technology has shown that animations do help computer science students understand algorithms (Stasko et al. 1993, Byrne et al. 1996, Byrne et al. 1999, Kehoe et al. 2001), but not before several redesigns of the animations based on student feedback and cognitive theory.

Although Mayer et al. (2001) and Sweller and Chandler (1994, with Carlson, 2003) advocate the use of computer-based learning aids, both warn against creating redundancy and split-attention effects, which make learning unnecessarily difficult. For example, an animation with accompanying text requires the learner to read and watch at the same time, making the information hard to assimilate, even if the text essentially contains the same information as the animation. While Mayer and Anderson (1991, 1992) champion a multimedia method and show that spoken narration improves understanding of animated material, Craig et al. (2002) suggest that narration alone can be just as effective. Signaling, using tags, colors or lights to emphasize spoken narration makes a module more effective (Mautone and Mayer 2001, Huk 2003a). However, irrelevant sounds and flashy additions can be distracting, and must be reduced to increase coherence of the material and narrative line (Moreno and Mayer 2000, 2002, Mayer 2001). Spatial and temporal contiguity of related elements must be maintained (Mayer and Moreno 2002). Interactivity generally helps student performance on transfer questions, which require learned information to be applied to a new situation. However, students perform similarly on simple retention questions with or without interactivity. (Mayer and Chandler 2001). The learner's background cannot be ignored in these and future studies; learners have different levels of understanding of animations and 3D computer modules due to their own prior knowledge and inherent spatial ability (Huk et al. 2003b,c, Voyer et al. 1995, Calyuga et al. 2000, Mayer 2001).

These studies indicate that, if designed according to how people learn, a computer based module can indeed be an effective learning tool.

Although there are many animations of biological processes and organisms (Baggot-LaVelle 2004), most are related to cell and molecular biology. The few that are of insects come close to the proposed module but each is lacking one or more vital features. For example, Cornell University's "Virtual Beetles" (available at <http://www.explore.cornell.edu/scene.cfm?scene=beetle%20science&stop=BS%20%20Virtual%20Beetles>) are interactive, biologically accurate, three-dimensional, and rotatable around one axis; however they do not include anatomical labels or any other information. Dr. Alexei Sharov of Virginia Tech University has created more than a dozen fairly accurate web animations of insects which can be viewed in Quicktime but simply spin with no interactivity or labels. (<http://www.ento.vt.edu/~sharov/3d/virtual.html>) Recently he has added animated insects that run and fly, and a cockroach with interactive light-up parts. These latter modules are difficult to download as they are created in Virtual Reality Modeling Language (VRML), a format which also requires sophisticated stereoscopic equipment for optimal viewing. Iowa State has an interactive virtual grasshopper with labeled internal anatomy and major systems color-coded (<http://www.ent.iastate.edu/ref/anatomy/ihop/>). It lacks a third dimension, however, and is not much more than an onscreen version of a lab manual with transparent overlays.

Likewise, searches for CD-Rom versions of interactive insect anatomy and physiology learning modules have turned up few relevant results. Moreover, CD-Rom tutorials are often expensive, which discourages instructors from experimenting with them in labs or requiring students to purchase them.

I conclude from work done in Phase 1 that the proposed module, once created and posted online, will be an effective entomological educational tool.

Phase 2: Creating the module

The module will present a detailed three dimensional rendering of a generalized orthopteran insect representing the lubber grasshopper *Romalea*, which is frequently used in introductory labs. The student will use interactive controls to virtually rotate the insect 360 degrees around its dorsal-ventral axis and around its anterior-posterior medial axis. Specific structures will light up on mouse-over, and on mouse click the name of the structure will appear with an optional auditory pronunciation. The student will use controls to electronically remove the exoskeleton piece by piece or all at once, revealing its internal anatomy with similar labeling. To aid in understanding insect function, the module will show accurate animated depictions of respiration, circulation, feeding, digestion, legged locomotion, and flight. I will include optional narrations, and the ability to slow down, stop, or rewind the animation at any point.

To create this module I will use Maya and other 3D modeling software such as Silo and Wings. The VDIL Summer Grant program has provided me the opportunity to learn how to use 3D modeling and animation software. I primarily worked using Maya on the VDIL's computers, and worked through tutorials provided by the lab or purchased with grant funds. Maya is a fantastic program and will suit this project well. Learning the software has helped me sharpen my focus on what the functions of the module should be and what limitations there are. I intend to do most of my modeling in subdivision surfaces and then convert to polygons for final rendering. Animation will consist of one camera that dollies around the insect on the xz plane and also on the yz plane. Both of these animations will be imported into Flash and interactive controls added.

Focus groups of 4-10 undergraduate biology students will be recruited to provide feedback on the modules. Participation in these groups will be voluntary, and will be encouraged by providing food or other reward. After using the module, students will be asked for verbal or written comments about design, content, interactivity, and ease of use. I will conduct focus groups at least three times during the initial design phase of the module, and apply the resulting feedback to redesign with the goal of making the module as student-friendly as possible.

Phase 3: Testing the module

Once the module is complete, it will be tested for its effectiveness as a learning tool in the classroom laboratory setting. UMD's General Biology II, an introductory biology class covering plant and animal diversity, is taught by four graduate teaching assistants in fourteen lab sections. Three of

the TAs have four sections each, and will assign one of two treatments to each section in a randomized complete block design (Ott and Longnecker 2000). Treatment A students will use a typical popular general zoology lab manual, with line diagrams and text, along with an actual insect and dissecting scope to learn basic anatomy and physiology. Treatment B sections will be given similar insects and scopes, but will be provided with the module on laptop computers instead of the lab manual.

Student learning will be assessed immediately following the lab period. Written tests will include questions of retention, for example “name the parts of an insect leg in order from the point of attachment to most distal.” Questions of transfer will also be asked, for example “how might an insect drown?” Tests will be scored blindly and independently by two graders, and where graders disagree on scores they shall discuss until they reach a consensus.

Mean retention scores, transfer scores, and total scores will be compared between the two groups, controlling for TA effects (=block effects) using analysis of variance. I hypothesize that all scores will be higher for the group using the module, indicating that it is a more useful tool for learning.

Instructor permission has been granted to conduct this experiment during arthropod-related labs in General Biology II. If all sections of the courses are used, $n \approx 280$ students, which is sufficient for the study. As human subjects will be necessary, guidance will also be sought from the University of Minnesota Institutional Review Board as to how to proceed.

Phase 4: Publication

Whether the module improves student learning or not, I will seek publication of my experimental results in appropriate journals of national readership, such as *American Biology Teacher*, *Annals of the Entomological Society of America*, *Bioscience*, or *American Entomologist*.

If the module proves to be a superior educational tool, I will make it freely accessible on the Internet. Although the module is intended for use in the classroom laboratory setting in conjunction with real insects, it should also prove useful as a lecture supplement or an individual review tool. Instructors and students will ideally visit a website to download the module free of charge. If the file size becomes too large to make this feasible, I will make CD-Rom versions available to order online at a small cost to cover production price and postage. Promotion of the website will follow.

TIMELINE

This project will span approximately two and a half years from start to finish. Table 1 shows a breakdown of the time allotted to specific aspects of the project.

Sources of funding

Short-term funding of \$2000 was granted by the University of Minnesota Duluth’s Visualization and Digital Imaging Lab. As a grant recipient I spent ten summer term weeks in the imaging lab learning to use sophisticated imaging and animation software, and gave a presentation based on the VDIL experience. A UMD Biology Department Block Grant

Table 1- Project timeline

Month	Task
Sept. 2005- May 2006	Gather and review relevant literature Gain laboratory teaching experience Survey available biological learning tools
June 2006- July 2006	Conduct insect morphology study Survey of available software for module Learn use of appropriate software- VDIL
Aug. 2006	Attend GNSI conference and workshop
Sept. 2006	Begin design phase
Dec. 2006- Feb. 2007	Apply to Institutional Review Board- Human subjects Begin focus group tests Redesign module as needed Present VDIL discussion
March 2007	Test module in classroom setting
April 2007	Assess student learning Perform statistical analysis of data
June 2007- Aug. 2007	Write up findings for publication Upload finished module to web Prepare department seminar
Sept. 2007	Present department seminar
Oct. 2007	Committee meeting #2 Final oral/written examination
Nov. 2007	Submit paper for publication

was awarded to partially cover the expense of attending the 2006 Guild of Natural Science Illustrators Annual Conference and a related 3-D modeling workshop. I have also secured funding for the academic year as a graduate teaching assistant.

Beyond the Master’s project, this module has vast potential for expansion to include more advanced entomological concepts such as identification, evolution of morphological differences between orders, behavior, and ecology. Thus expanded it could prove useful for advanced entomology courses in addition to general biology, zoology, and introductory entomology courses. Funding for long-term expansion of the project could be obtained through a grant from the National Science Foundation’s Division of Undergraduate Education Course, Curriculum, and Laboratory Improvement Program.

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