Using Virtual Laboratories to Teach Mathematical Modeling

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Mathematical modeling encompasses a richness that is not well captured by the prepackaged application topics in textbooks. As the "tendons that connect the muscles of mathematics to the bones of science," modeling requires a connection to the scientific enterprise--a connection that must incorporate observation of scientific experiments, collection of scientific data, and scientific interpretation of modeling results. Unfortunately, real biological experiments conducted in the real world take a significant amount of time and require a combination of good design, technique, and luck. Some innovators have tried to incorporate such experiments into a mathematics course, with varying degrees of success that depend inversely on the richness of the biological and mathematical content. In this talk, we present the BUGBOX virtual laboratories created by the author for the purpose of providing real observational and experimental experiences in a virtual world. The experiments can be conducted quickly and easily using software originally written in Python and converted to Windows executable files. Because of the complete flexibility of virtual world design, the BUGBOX laboratories pose modeling problems without the complication of procedure and measurement problems. BUGBOX-predator is a computerized recreation of a simulated experiment used by C.S. Holling in a landmark 1959 paper to develop models for the effect of prey density on predation rates. The virtual environment includes three different virtual species of predator, providing a simple beginning and the necessary insights to develop more sophisticated models from mechanistic assumptions. BUGBOX-population is an experiment designed to illustrate the phenomena and modeling of stage-structured population growth. Students develop discrete linear growth models for a sequence of four increasingly realistic species of virtual insect; the development requires observation to determine the correct mechanistic assumptions and measurement of parameter values. With a directed approach to analysis of the model, students are led to discover the physical solution features that correspond to the mathematical concepts of eigenvalues and eigenvectors.