Cooperative Studyware Development of Organic Chemistry Module by Experts, Teachers, and Students

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Experts, teachers, and students took active part in a process of organic chemistry studyware development. A unique characteristic of this process was the active involvement of three different groups of people in the authoring process: science educators, chemistry teachers, and chemistry students studying towards an education certificate. The science educators—the experts—advised the team on new methods of presenting the subject matter in an appealing way, using 3D computerized molecular modeling. The in-service chemistry teachers contributed from their rich field experience to constructing the studyware. This mutual development helped maintain the balance between expert requirements and expectations from students on one hand, and the actual student capabilities, as perceived by teachers through constant contact with the students, on the other. Finally, the preservice teachers—the undergraduate chemistry students—were often zealous, enthusiastic, and willing to put in the extra time and effort needed to produce quality studyware, while following the guidelines of the experts and teachers. Feedback on the qualities and shortcomings of the studyware was obtained in two cycles. The first one was done while the studyware was still under development by peers, and the second by individual target students, serving as a beta-site. This double feedback helped improve the studyware, mainly by elaborating on portions that require more detail and explanation. The paper describes the process as well as representative parts of the studyware. The combination of experts, teachers, and students in the development team seems to have the potential to yield studyware that is appropriate for effective science education in general and chemistry teaching in particular.

KEY WORDS: Organic chemistry; studyware; cooperative development; chemistry students.

INTRODUCTION

A major purpose of chemical education is the development of students' reasoning and critical thinking ability, as well as their problem-solving and decision-making capacity. Problem solving in chemistry could be made more meaningful if problems were presented in a way that emphasizes the relations between the problem, the phenomenon, and its microscopic representation (Gabel and Bunce, 1994). Ben-Zvi and Gai (1994) have also suggested that teaching chemical concepts in the nature of matter should emphasize the relations between these concepts and real-world phenomena on both the macro and micro level. Zoller (1993) has indicated that many students do not apply their higher-order cognitive skills due to teachers' inclination to emphasize algorithmic problem-solving abilities and suggested that new teaching methodologies and research-based alternatives are needed to foster meaningful learning.

Other issues that must be addressed in chemistry teaching include experiment hazard and cost (Lunetta and Hofstein, 1989; Smith and Jones, 1989), lack of textbook capabilities to display dynamic processes, and the need for viewing large bodies of knowledge at different complexity levels.
Textbooks create images of chemistry by using words, tables, graphs, and still photos, but they are missing the dynamic element, which is so important in understanding chemical processes and concepts. Modern research in organic chemistry makes extensive use of molecular modeling software packages to visualize and investigate molecular properties in the areas of organic chemistry, biochemistry, and drug industry (Glaser et al., 1992). These computer programs can simulate the molecular structure and 3D spatial interactions, perform energy calculations, and calculate other properties, such as angles and bond lengths. The advantage of computerized molecular modeling over the use of rigid models is the convenience and simplicity of building molecules at any size, in a number of presentations, including ball and stick, space filling, stereo lines, and wireframe. Each atom type can have a precise size and a different color, making the presentation more accurate and understandable. Atom symbols can be added to or removed from the figure at will to enhance the model understanding. Chemical education should not lag far behind in taking advantage of this technology. Indeed, several works have started to take advantages of the use of molecular modeling software (Aduldeka et al., 1991; Campanario et al., 1994). Chapman (1994) has used software for molecular modeling to have students engage in creative molecular design of fullerenes (C₆₀) and other new forms of carbon. A high-tech multimedia application is presented by Whitnell et al. (1994), who use a combination of computer animation, 3D computer graphics, and video to teach a physical chemistry course.

**CHEMISTRY STUDYWARE AUTHORIZING PROCESS**

The development of studyware—advanced CAI—is a complex process that requires careful planning and design. This section applies some elements of the object-process analysis (OPA) method-