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Short communication

Full-motion videos: Bringing abstract chemical concepts to life in the classroom

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Abstract

A set of full-motion videos utilizing two-dimensional images and representations of three-dimensional chemical structures was made using a software suite, the Molecular Operating Environment (MOE). The videos highlight the drug's structure–activity relationship (SAR) and their corresponding receptor interactions. The full-motion video set was created for use as a supplemental teaching aid for a medicinal chemistry course. The literature describes using full-motion videos in undergraduate courses, such as organic chemistry and biochemistry; however, there is no demonstration of movies being employed in pharmacy chemistry-based courses such as medicinal chemistry. Anecdotal feedback and unsolicited student comments on teaching evaluations from pharmacy students directly indicated increased student understanding and comfort with the course content. Student feedback has motivated the authors to develop a future study to purposefully assess if there is a benefit to using the videos in comparison to static 2D diagrams as a supplement to the medicinal chemistry lectures.

Keywords: Medicinal chemistry; Video; Structure–activity relationships; MOE

Introduction

Full-motion video representations of medicinal chemistry topics, such as drug–receptor complex formation, are not well reported in the literature. Videos have been employed as a supplemental learning tool in organic chemistry and represent an avenue for students to visualize abstract chemistry concepts. Students are required to use their imagination to fully grasp two-dimensional (2D) chemical images of objects that exist in three-dimensional (3D) space, and the nuances of a drug class' structure activity relationship (SAR) can be lost in a 2D image. Model kits are a method to represent chemicals but are intractable when utilized for advanced topics in medicinal chemistry courses. Model kits lack the ability to portray concepts such as drug–receptor complexes or multiphase metabolism due to the size and difficulty of constructing such models as a visual aid for use in the classroom. Through the incorporation of full-motion videos, professors can deliver chemical concepts that students can watch repeatedly while aiding in emphasizing focus on the key aspects important to understanding the lesson. Envisioning abstract chemical concepts requires the ability to visualize spatial orientations from two-dimensional images. Current chemistry teaching methods, such as molecular model kits or 2D images, are inadequate for fully demonstrating complex chemical topics.[1]

Chemical model kits are inadequate for in-class demonstrations of chemical concepts, such as multiphase drug metabolism or drug–receptor complex formation, when both distance and campus cohorts are enrolled in the same course. Creating drug molecules and receptor active sites out of molecular modeling kits is intractably difficult as it would take numerous kits to physically produce models of such capacity, not to mention student confusion related to over abundantly distracting details. In addition, the chemical

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model kits are inadequate as an in-class teaching tool for drug–receptor interactions due to their inability to simply portray specific aspects of drug interactions in a way that is clearly viewed by all students in the class. In the authors' experience, video recordings of lectures often fail to convey the example due to students' difficulties viewing the model. Similarly, students in the back of a large lecture hall may have the same difficulties viewing the model. By employing a full-motion video as a representation of 3D chemical concepts course, professors have the ability to demonstrate complex interactions, such as receptor binding, and the underlying spatial implications of stereochemistry, bioisosteric replacement, SAR, and other concepts on receptor-binding events (bonding interactions, role of steric bulk in receptor selectivity, etc.). The chemical model kit's weaknesses are further compounded when employed in advanced courses, such as Chemical Basis of Drug Action, due to the inability of model kits to portray more complex drug–receptor interactions.

The movies created were used in the Chemical Basis of Drug Action course, informally known as medicinal chemistry, as a supplemental learning tool for further understanding of lecture material. The main focus of this course is to teach students to identify each drug class' pharmacophore, chemical properties, and how the SAR contributes to each drug's particular therapeutic mechanism of action. This course is composed of approximately 110 campus students as well as 65 distance students. An audio-and-visual recording of each lecture is made available to both distance and campus students. The visual components of lecture recordings can be hard to view by the distance students, thus resulting in a potential disadvantage associated with rather small, complexly detailed physical models. Students enter the course with a foundation of organic chemistry. Medicinal chemistry employs the fundamental information from biochemistry and organic chemistry to combine concepts of chirality, steric bulk, and electronic properties with protein structures and function to develop the students' understanding of SAR along with binding affinities of particular drug compounds to their preferred receptor. At the end of the course, students are expected to be able to apply foundational scientific knowledge obtained in the course to a drug's mechanism of action and, ideally, make therapeutic decisions in the best interest of individual patients.

The solidification of chemical concepts, such as the contribution of chirality and electronic properties for drug binding, is required for learning medicinal chemistry principles. The student's ability to manipulate drugs docked in a receptor and meaningfully gain insight into the drug's mechanism of action relies heavily on the student's ability to visualize chemical compounds in a three-dimensional space from two-dimension images.[2] The current teaching aids for chemistry are lacking the ability to portray the chemical structure in a way that prompts student understanding of SAR, ionization, and portraying intra- or inter-molecular interactions, that are crucial to the drug's therapeutic action.[3]

Mastery of the visualization needed to manipulate complex chemical concepts is directly dependent upon one's degree of spatial ability.[4] It has been shown that the higher degree of spatial ability one has, the easier he/she will understand more abstract chemical concepts.[5] High spatial ability has a direct relationship to the capacity of mental manipulation and visualization needed to fully understand chemical theories.[6] Educational techniques need to be adaptable depending on student's degree of spatial ability.

Differences in students' cognitive abilities, as well as their initial understanding of chemistry, will influence the utilization of full-motion videos. Self-identified learners and kinesthetic learners may be more adept at applying three-dimensional visuals to identify concepts.[7] Learners with higher spatial ability prefer techniques involving tasks to decipher a result when the solution is not provided.[7] On the other hand, learners with a lower spatial ability may require a more comprehensive teaching model to cement concepts mentally.[8]

A study done by Balslev et al.[9] found that through the utilization of visual animations students were more inspired to learn as information presented is easier to comprehend. Only slight differences exist in students' understanding of newly introduced chemical topics as compared to viewing two-dimensional images.[10] Higher spatial ability learners will acquire an advanced understanding of material presented as compared to the lower spatial ability learners.[11]

Structural formulas are two-dimensional graphical structures that show the relationship between atoms in a particular compound. As represented in Figure 1, structural formulas employ straight lines to designate atoms in the plane of the page, hashed lines to signify functional groups projecting away from the viewer, and solid wedges indicating the functional group is coming toward the viewer.

Multiple methods to visualize compounds are available for static images and videos. Wire or rod models, displayed in Figure 2A, utilize color-coded vector lines that create angles where atoms are present. The ball-and-stick models, as shown in Figure 2B, utilize balls to represent atoms and cylinders to represent bonds, allowing for an increase in spatial representation as well as atom indication. Space-filling models, represented in Figure 2C, utilize color-coded three-dimensional spheres to represent different atoms. The radius of each particular sphere corresponds to the radius of the represented atom. The space between one sphere and its corresponding sphere is also proportional to the spatial orientation of the distance between the represented atoms.

The wire/rod models have poor spatial representation since the size of an atom and bond lengths are traditionally uniform, with atom identity only represented by an arbitrary color coding that may change from professor to professor. Spatial representation with the ball-and-stick model is still not optimal since heteroatoms are all shown as a uniform size as opposed to showing that fluorine is the size of