Discussion Forum

# Biochemical Visual Literacy with Constructive Alignment: OUTCOMES, ASSESSMENT, AND ACTIVITIES

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Several contributions in BAMBED have highlighted the role of visualization tools and the importance of developing students' visual literacy in biochemistry education. The September 2010 Editorial, for example [1], announced the feature which includes "abstracts" [2] of work published in *Proteopedia*, a web resource with pages that can be edited by all those who register for an account [3]. *Proteopedia* opened the door for educators to develop and share resources that blend text with interactive visual representations of macromolecules, with credit for authorship. A topic review has summarized the underlying cognitive challenges for biochemical visual literacy [4] and, for instance, the learning gains of integrating a user-friendly simulator of protein folding in the educational process have been reported [5]. There are diverse and exciting educational activities published about nurturing the ability of students to visualize molecules. In this forum, we suggest that more focus is needed on the assessment of student learning and we advance "constructive alignment" as a working framework. Beyond considering which visual resources to use in teaching, we argue that biochemical visual literacy requires: (1) The setting of clearly defined outcomes related to the biochemical concepts that involve visual literacy. (2) Adequate assessment tests and programs. (3) Careful consideration on how to integrate visual tools and resources in order to help students achieve the intended learning outcomes.

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## CONSTRUCTIVE ALIGNMENT: CONSIDER ASSESSMENT BEFORE ACTIVITIES

Constructive alignment [6] has to do with designing courses by closely knitting three processes in a certain sequence (Fig. 1): (i) the definition of learning outcomes; (ii) the design of the corresponding assessment programs; (iii) the provision of opportunities for students to achieve the pre-defined outcomes. In higher education, the concept has been applied—albeit often not in this order—every time course requirements specify that learning outcomes must be defined and assessed coherently. The constructive alignment model proclaims that students should be aware, at the beginning of the learning process, what it is they will be required to learn or develop and how that learning will be assessed. Therefore, in defining outcomes which are clear for students, it is inevitable that they are also clear for the instructors.

Since assessment is a key component of learning—in other words "assessment drives learning" [7] or, even better, assessment catalyzes learning [8]—the framework argues that assessments are at least as important as any classroom or online experience and should thus be planned in advance and described to students. This is the opposite to the common practice of giving deep thought to assessments only when testing time is near [9]. Constructive alignment suggests that learning from visual resources may benefit enormously from the catalytic effect of assessments that focus on such resources while being as much as possible coherent with intended outcomes. Below we consider, as an example, constructive alignment applied to visualization and protein structure.

## SETTING OUTCOMES IN VISUALIZATION AND PROTEIN STRUCTURE

It is agreed that biochemistry undergraduate students should "understand" the general principles underlying protein structure—which make proteins look how they look—and how such

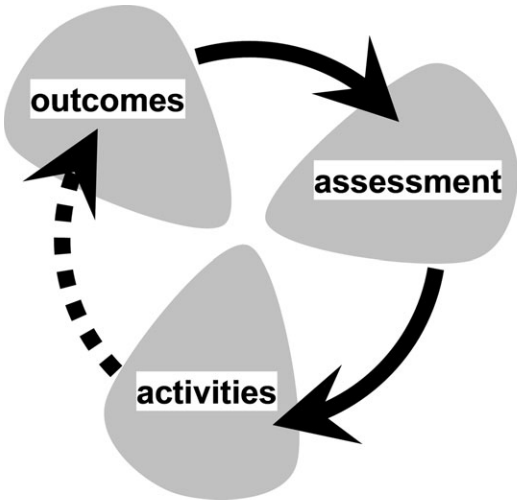


FIG 1 The propeller icon depicting the sequence of design according to the constructive alignment framework.

principles underpin the properties and functions of proteins—which makes proteins do what they do. What students should do, however, to "understand" proteins or how we can find out if they are actually learning is quite a challenge. Indeed, the protein world is as complex as biology itself and the pace of research on protein structure keeps opening new avenues on what syllabi need to cover. In contrast, classes and courses are finite.

Instructors can target student attention on a few proteins and expect them to extend the knowledge and skills to other proteins in future circumstances. This requires students to learn how they can keep learning afterwards on their own. For students, as for any novice in any field, transferring the learning from one protein context to another, in which the protein looks and acts totally different, is an enormous challenge. To help them, teachers must define rigorously and explicitly what they mean by understanding. Once this is done, setting performance indicators becomes straightforward. Programs designed as lists of topics on protein structure should hence be replaced by a list of what it is that students are expected to reach in every topic. For example, "knowing the levels of protein structure," perhaps can become among others, some of the following outcomes: "(1) Listing the four levels of protein structure. (2) Describing the bonding and interactions that underpin the levels of protein structure and, in particular, the most prevalent secondary structures. (3) Predicting which levels of protein structure are affected by physical and chemical challenges in the environment. (4) Identifying the most common motifs of protein structure in 2D and 3D representations and inferring the implications of their presence."

The above reasoning applies similarly to biochemical visual literacy. Understanding the protein structure implies learning from words and (moving or still) models [10]. Learning how proteins fold and work relies extensively on understanding representations, like diagrams, animations, and so forth (sometimes more specifically called "external representations," or ERs [11]). Therefore, misinterpretations of representations can be very harmful for the achievement of visualization-related learning outcomes. The need for such visual literacy increases the level of cognitive complexity for understanding protein structure [4].

Schönborn and Anderson [4] go one step further in defining learning outcomes for students to understand representations, from which we would highlight the following, as applicable to any level of education: (1) Decode the symbolic language of the representation. (2) Interpret and use a representation to solve a problem. (3) Construct a representation to explain a concept or solve a problem. (4) Translate across multiple representations of a concept. As the same authors state, the knowledge and the visual skills about proteins are interdependent objectives and the design of assessments and learning opportunities need to be tackled together.

We will argue that there are three distinct outcomes on visualization to bear in mind when designing classes on protein structure: (1) that students develop knowledge of what science has revealed about the world of proteins: this dimension is probably the one that is covered by every instructor; (2) that students are able to correctly interpret what is represented in visual resources: this is probably a concern for only a fraction of teachers; (3) that students will be able to use visual resources—from static pictures to software displaying 3D models like Jmol—to learn about a certain molecule and, in a more advanced level, to inquire about the connections between the structure and function of a certain molecule. We would argue that in BMB education, visuals are mostly used to illustrate content (item 1 above) but that such "integrated use" (items 2 and 3 above) should be incorporated more widely and consistently.

## VISUALS PROVIDE NEW SCENARIOS FOR ASSESSMENTS

The assessments and class objectives in many science courses are often misaligned. An example on protein structure would be a course that intends to develop students' understanding but does not test students beyond recalling what they have seen in class or in textbooks—a typical question would be "Explain the differences between the secondary and tertiary levels of protein structure." The assessment of biochemical visual literacy demands more than recognition of previously presented materials (such tests have been designated "retention tests"): it should test how well the student can interpret new scenarios, or "transfer tests" [10].

Testing beyond "rote learning" requires "context-rich" questions [12]. A context is a scenario which the student has not met before—in medical disciplines, a context could be for example, the story of a new patient case. This is where visual resources and *Proteopedia* in particular should make a big difference, by providing instructors with access to thousands of scenarios that can be explored in assessments.

For a long time, before the technology existed, instructors were limited to a small number of still book visuals to teach and to prepare tests. Therefore, teaching was inevitably based on a small number of examples—myoglobin, hemoglobin, collagen, and immunoglobulin—and the same examples would be used in formative and summative tests. Current resources—like Jmol [13,14] and, particularly, educational sites that make use of Jmol and are straightforward to use [15]—are extraordinary tools for generating contexts to test students' visual literacy and further objectives related to "understanding" protein structure. The scenarios should be used equally for both summative and formative purposes. Resources deployed on the web are ideal to provide opportunities for students to practice and learn independently. The term "programmatic assessment" has been used to designate programs that use summative tests and formative exercises to maximize learning—the so called "assessment for learning" [16]. Once assessments are constructed routinely with scenarios that students have not encountered before, students will realize that there is actually a need to solve questions which explore the 3D structure of new proteins, and then the odds are that they will learn that better. So we have reached the last element of the constructive alignment cycle: the teaching and learning activities. We have left this part for the end on purpose, since this is exactly what the framework suggests.

## CLOSING REMARKS

The integration of visualization resources with interactive teaching strategies [17] is certainly bound to have positive effects on student learning. Unfortunately, we lack both a valid list of outcomes supported by empirical research to state categorically what is necessary for a student to develop literacy and the assessments to catalyze the process. Faculty development initiatives such as workshops that bring together developers of resources and educators, like the one recently organized under the SEBBM Meeting [18] sponsored by IUBMB, are timely and important in this regard. Inevitably, decisions on learning outcomes and on what to assess are made by teachers at an individual level, and discussion among colleagues is a necessary step to come up with valid assessments and useful outcomes that can mutually catalyze the power of visualization resources. Should we be committed to develop our students in this respect, we should learn how to assess it better. This would be, in our view, a valuable research and development exercise for our community.

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