The effect of visualizations on assessment cognitive level

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Visualizations in Assessments

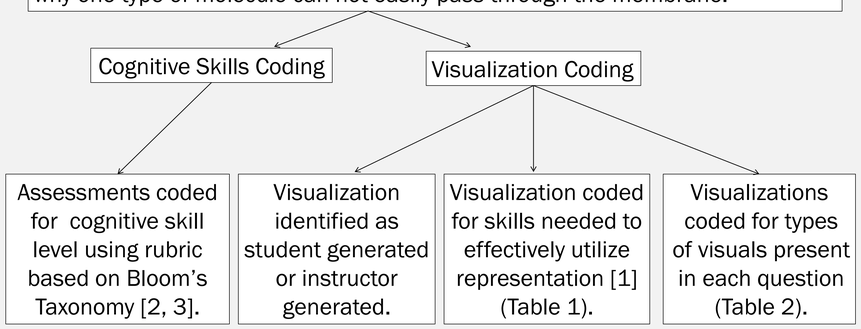
Visual representations are frequently used in science education and can play an important role in developing a learner's understanding of scientific concepts. In order to effectively learn from these representations, learners must become visually literate. The skills required in visual literacy include decoding, interpreting, constructing, translating, evaluating, and spatially manipulating external visualizations [1]. One way to ensure that learners are developing these skills is to provide assessment items that require these skills. This project aims to identify the types of visualizations students must interpret and identify which visual skills are being assessed and at which cognitive level of Bloom's Taxonomy [2].

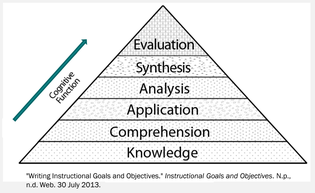
Research Questions

- Do assessment items that include visualizations require higher cognitive skill levels than those without?
- Do the types of visualizations most frequently used on exams differ between Biology 150 and Biology 151?
- Are the visual literacy skills required of students on exams different in Biology 150 than Biology 151?

Cognitive Level and Visualization Coding

Example item: Draw a cell membrane CLEARLY labeling (circle and draw arrow to labeled part) three types of biomolecules, identify and describe why one type of molecule can easily pass through the membrane, and identify and describe why one type of molecule can not easily pass through the membrane.





"Writing Instructional Goals and Objectives." *Instructional Goals and Objectives*. N.p., n.d. Web. 30 July 2013.

Coding of Example Item
- Bloom's Coding: application level
- Student vs. Instructor Generated: student generated
- Skills for Visualization: INT (interpret)
- Type of Visualization: not applicable

Table 2. Coding system to identify type of visualization

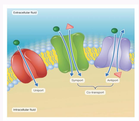
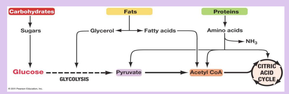
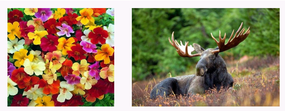
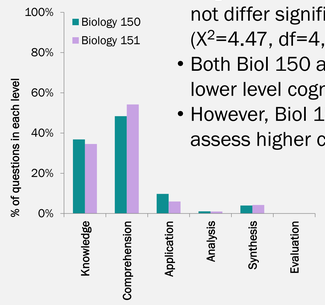
Type of Visual	Example
Graph (GRA)	
Symbolic (SYM)	3' – t c g a t g g c a t t a – 5' 5' – a g c t a c c g t a a t – 3'
Cartoon (CAR, NON)	
Schematic (SCH)	
Photograph (REA)	

Table 1. Coding system to identify visual skills [1]

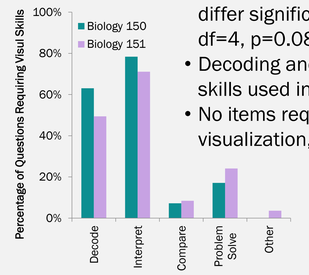
Skills for Visualization	Definition
Decode Symbolic Language (DEC)	Decode and interpret symbols, labels, formulas, and other symbolic language
Interpret (INT)	Concepts, processes, etc. are identified and/or interpreted
Compare/Contrast (COMP)	Concepts, processes, terms, etc. are compared and contrasted
Problem Solving (PROB)	Outcomes/consequences predicted, specific problems solved, information analyzed, and knowledge applied to new concept
Horizontally Translate Concept (HTRAN)	Understanding of concept translated across multiple representations.
Vertically Translate Concept (VTRAN)	Understanding translated through visualizations of increasing or decreasing levels of complexity and structure
Evaluate Power, Limitations, and Quality of Visualization (EVAL)	Effectiveness of concept representation assessed, goals of representation understood, and weaknesses of visualizations identified.
Visualize Orders of Magnitude, Size, and Scale (VIS)	Concept of absolute and relative size of structures, number of structures, etc. is understood.
Spatially Manipulate Representation (MAN)	Location of representation can be transformed, images mentally manipulated, and spatial depth understood.
Other (OTH)	Question requires different skills than those defined.

Results

While there is no difference in the cognitive and visual skills assessed in Biology 150 and Biology 151,

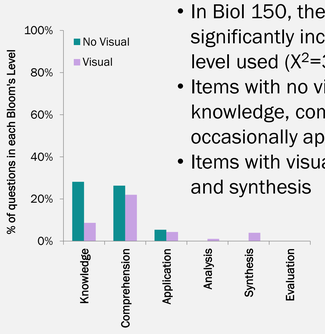


- Cognitive skills assessed in Biol 150 do not differ significantly from Biol 151 (X^2=4.47, df=4, p=0.35)
- Both Biol 150 and 151 assess primarily lower level cognitive skills
- However, Biol 151 has several items that assess higher cognitive skill levels

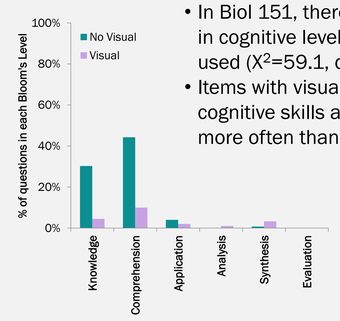


- Visual skills assessed in Biol 150 do not differ significantly from Biol 151 (X^2=8.36, df=4, p=0.08)
- Decoding and interpretation are common skills used in both courses
- No items require translation, evaluation, visualization, or manipulation

in each course, assessment questions with visualizations use higher cognitive levels.

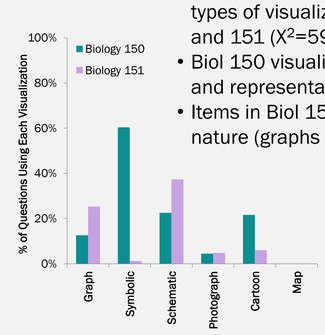


- In Biol 150, the use of a visualization significantly increases the cognitive skill level used (X^2=34.4, df=4, p<0.01)
- Items with no visualizations require only knowledge, comprehension, and occasionally application
- Items with visualizations require analysis and synthesis

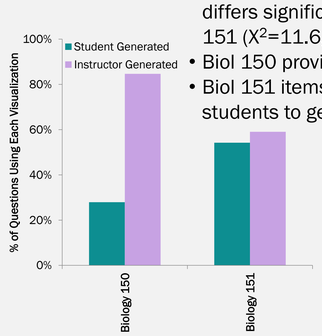


- In Biol 151, there is a significant difference in cognitive level when visualizations are used (X^2=59.1, df=4, p<0.01)
- Items with visualizations access the cognitive skills analysis and synthesis more often than items without

The types of visualizations, along with the way the visualizations were generated, differed between courses.



- There is a significant difference in the types of visualizations used in Biol 150 and 151 (X^2=59.8, df=4, p-value < 0.01).
- Biol 150 visualizations are more symbolic and representative (cartoons and symbols)
- Items in Biol 151 are more empirical in nature (graphs and schematics)



- The way visualizations are generated differs significantly between Biol 150 and 151 (X^2=11.6, df=1, p-value < 0.01)
- Biol 150 provides more visualizations
- Biol 151 items more frequently require students to generate visualizations

*Percentages may not add to 100 due to multiple codes for one visualization.

Conclusions and Findings

- The cognitive skills assessed in introductory biology courses are primarily lower level skills (knowledge and comprehension), which confirms previous studies [3].
- Representations of scientific concepts, processes, and data on assessments varies across introductory level courses and impacts the cognitive skill level that students are using.
- Requiring students to generate visualizations often requires the use of higher level cognitive skills.
- Introductory level biology courses require only limited visual skills to be used on assessments. Many of the visual skills defined were not assessed even once throughout either course.

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References
1. Schönborn, Konrad J., and Trevor R. Anderson. "Bridging the Educational Research-teaching Practice Gap." *Biochemistry and Molecular Biology Education* 38.5 (2010): 347–354. *Wiley Online Library*. Web. 31 May 2013.
2. Bloom, Benjamin Samuel. "Taxonomy of Educational Objectives; the Classification of Educational Goals." (1956): n. pag. Print.
3. Momsen, Jennifer et al."Using Assessments to Investigate and Compare the Nature of Learning in Undergraduate Science Courses." *CBE-Life Sciences Education* 12.2 (2013): 239–249. *www.lifescied.org*. Web. 26 June 2013.