Development of Learning Modules to Enhance Students' Higher-Order Cognitive Skills

Patricia Montano and Alison Crowe
Department of Biology, University of Washington, Seattle, WA 98195

ABSTRACT

It is commonly accepted that memorization and recall (knowledge-level skills) are lower order cognitive skills that require only a minimum level of understanding, whereas the application of knowledge and critical thinking (application, analysis, synthesis & evaluation-level skills) are higher order cognitive skills that require deep conceptual understanding[1]. In our Biology department we have begun introducing students to Bloom's taxonomy[2] during the introductory series to help students recognize the different levels of thinking they will need to master to succeed in the curriculum. To aid students in identifying the levels that are most challenging for them, we are piloting a program that provides students with their individual "Bloom's score" after each exam. The Bloom's score indicates how well they performed on questions requiring different levels of Bloom's. We created the Bloom's-based Learning Activities for Students (BLASt)[3], a complementary student-directed tool designed to specifically strengthen study skills at each level of Bloom's. However, we found that students were not able to use this chart effectively without further instruction. We have therefore developed a 1-hour workshop to give students practice in developing application and analysis levels of thinking.

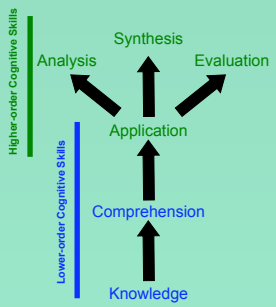

Fig. 1. Bloom's Taxonomy of Cognitive Domains[3]

"Bloom" Exam → Determine the highest level of Bloom's taxonomy needed to successfully answer each question on the exam

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Calculate "Bloom's Distribution" For Exam →

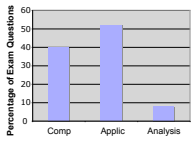

Fig. 2. Bloom's Distribution for an Introductory Biology Exam. The exam was scored for the level of Bloom's required to successfully complete each question. Next, the Bloom's distribution was calculated by determining the percentage of questions on the exam that required each level of Bloom's.

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Students Take Exam

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Ask Students to Self-Report Scores for Each Question

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Calculate Individual Student & Average Class Performance for Each Level of Bloom's →

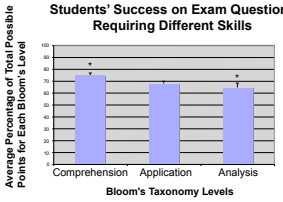

Fig.3. Students' Performance on an Introductory Biology Exam. Students self-reported the points they earned for each question on a biology exam (n=79). We determined the level of Bloom's required to successfully answer each question ("Bloomed" the exam). Next, we calculated the average percentage of possible points that students earned for each level of Bloom's. Error bars indicate standard error. Asterisks indicate statistically significant differences (p=0.01) based on a one-way analysis of variance (ANOVA)

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Students Receive Their Individual Bloom's Scores

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← All Students Receive BLASt To Help Guide Their Learning Strategies

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Encourage Students to Attend Learning Skills Workshop Designed to Teach Them How to Think at the Higher Levels of Bloom's →

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Long-term goal:
Track student progress longitudinally to ascertain whether participation in the Bloom's workshop enhances student performance on future exams

Bloom's level	Individual activities	Group activities
Knowledge (LOCS)	• Practice labeling diagrams • List characteristics • Identify biological objects or components from flash cards • Quiz yourself with flash cards • Take a self-made quiz on vocabulary • Draw, classify, select, or match items • Write out the textbook definitions	• Check a drawing that another student labeled • Create lists of concepts and processes that your peers can match • Place flash cards in a bag and take turns selecting one for which you must define a term • Do the above activities and have peers check your answers
Comprehension (LOCS)	• Describe a biological process in your own words without copying it from a book or another source • Provide examples of a process • Write a sentence using the word • Give examples of a process	• Discuss content with peers • Take turns quizzing each other about definitions and have your peers check your answer
Application (LOCS/HOCS)	• Review each process you have learned and then ask yourself: What would happen if you increase or decrease a component in the system or what would happen if you alter the activity of a component in the system? • If possible, graph a biological process and create scenarios that change the shape or slope of the graph	• Practice writing out answers to old exam questions on the board and have your peers check to make sure you don't have too much or too little information in your answer • Take turns teaching your peers a biological process while the group critiques the content
Analysis (HOCS)	• Analyze and interpret data in primary literature or a textbook without reading the author's interpretation and then compare the authors' interpretation with your own • Analyze a situation and then identify the assumptions and principles of the argument • Compare and contrast two ideas or concepts • Create a map of the main concepts by defining the relationships of the concepts using one- or two-way arrows	• Work together to analyze and interpret data in primary literature or a textbook without reading the author's interpretation and defend your analysis to your peers • Work together to identify all of the concepts in a paper or textbook chapter, create individual maps linking the concepts together with arrows and words that relate the concepts, and then grade each other's concept maps
Synthesis (HOCS)	• Generate a hypothesis or design an experiment based on information you are studying • Create a model based on a given data set • Create summary sheets that show how facts and concepts relate to each other • Create questions at each level of Bloom's Taxonomy as a practice test and then take the test	• Each student puts forward a hypothesis about biological process and designs an experiment to test it. Peers critique the hypotheses and experiments • Create a new model/summary sheet/concept map that integrates each group member's ideas.
Evaluation (HOCS)	• Provide a written assessment of the strengths and weaknesses of your peers' work or understanding of a given concept based on previously determined criteria	• Provide a verbal assessment of the strengths and weaknesses of your peers' work or understanding of a given concept based on previously described criteria and have your peers critique your assessment

[1] Students can use the individual and/or group study activities described in this table to practice their ability to think at each level of Bloom's Taxonomy.

Table 1. Bloom's-based Learning Activities for Students (BLASt)
LOCS = lower-order cognitive skills; HOCS = higher-order cognitive skills

Learning Skills Workshop: "Thinking Like a Scientist"

Skill Activity #1:
Read a textbook passage and think of exam-type questions related to the passage
1) Students read a passage from text
2) Instructor discusses example questions with students
3) Students read a new passage
4) Students work in groups to create new questions
5) Groups share questions

Purpose: Encourage students to make connections between what they are reading and what they are discussing in class; teach students to move beyond comprehending a text and begin to ask themselves how they can use the information in a new way

Skill Activity #2:
Convert recall questions into questions requiring application/analysis level skills.
1) Instructor illustrates process for students
2) Students work in groups to convert 5 recall questions into problem-solving questions
3) Groups share questions and discuss why questions are more challenging

Purpose: Teach students that there are different types of exam questions that require different types of thinking; Teach students to ask themselves application-level questions when they are studying e.g. "what would happen if this process was blocked at this point" or "what effect would increasing component A have on component B"

Skill Activity #3
Provide an example of an application-level question from the class exam
1) Show students different possible answers to the question
2) Illustrate for students the reasoning required to successfully answer the question

Purpose: Give students practice answering a problem-solving question

References

[1]U Zoller. Are lecture and learning compatible? Maybe for LOCS: Unlikely for HOCS. J Chem. Educ. 70: 195-197 (1993).

[2]BS Bloom (ed.), MD Engelhart, EJ Furst, WH Hill, DR Krathwohl.Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: Cognitive Domain (David McKay, New York 1956).

[3]AJ Crowe, C Dirks, MP Wenderoth. Biology in Bloom: Implementing Bloom's Taxonomy to Enhance Student Learning in Biology. CBE Life Sciences Education 7: 368-381 (2008).

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