Bloom's Taxonomy and the Teaching of Introductory Statistics Classes

Ilhan M. Izmirli
George Mason University
iizmirl2@gmu.edu

Susan C. Surina-Chimiak
George Mason University
ssurina1@gmu.edu

Abstract

In this paper our goal is to map the course outcomes of our introductory statistics courses to Bloom's Taxonomy.

The first section is devoted to a brief overview of the Taxonomy. We then discuss how the objectives and the expected outcomes of our introductory statistics courses fulfill some of the university requirements such as critical thinking, quantitative reasoning, scientific reasoning, and use of information technology skills. In the third section we explore how Bloom's Taxonomy applies in this setting and what our role, as educators, should be in the implementation of this taxonomy.

To promote a learner-centered teaching approach, and shift the role of the instructors from givers of information to facilitators of student learning, we must emphasize the role of the learners in our classes. Consequently, in the fourth section, we discuss some learner-based activities that would parallel and complement the educators' efforts in rendering the use of the Taxonomy as beneficial as possible to the learners.

We conclude by mapping our course outcomes to Bloom's taxonomy and thus providing a model that can be used in any introductory statistics course.

1. Bloom's Taxonomy

Since the late 1940s educators have striven to categorize the goals of the educational process in an effort to classify the instructional objectives, aspirations, and assessment, eliciting, in 1956, the formation of a committee of scholars chaired by the American educational psychologist Benjamin Samuel Bloom (1913-1999). The categorization recommended by his committee has come to be known as ***Bloom's Taxonomy*** (Bloom et al. 1956), which, as Bloom himself noted, soon became "one of the most widely cited yet least read books in American education" (Bloom, 1994).

A brief history of this development is given in Bloom et al (1956):

> The idea for this classification system was formed at an informal meeting of college examiners attending the 1948 American Psychological Association Convention in Boston. At this meeting, interest was expressed in a theoretical framework which could be used to facilitate communication among examiners. This group felt that such a framework could do much to promote the exchange of test materials and ideas about testing. In addition, it could be helpful in stimulating research on examining and on the relations between examining and education. After considerable discussion, there was agreement that such a theoretical framework might best be obtained through a system of classifying the goals of the educational process, since educational objectives provide the basis for building curricula and tests and represent the starting point for much of our educational research (Bloom et al 1956, 4).

Bloom's Taxonomy divides educational objectives into three domains, ***cognitive***, ***affective***, and ***psychomotor***, and posits that within each domain, learning at the higher levels is dependent on attaining the relevant knowledge and skills required at the lower levels (Orlich et al. 2004). Although stated at best in a rather oblique and circuitous manner, the expectation is that educators would focus

on all three domains, and thus, pursue a more comprehensive approach to education (Bloom et al. 1956).

The original 1956 book explored only one of the three domains, namely the cognitive one. The second volume that dealt with the affective domain was edited by David Krathwohl and was published in 1964 (Krathwohl, et al. 1964). The committee never published a study that embarked on the psychomotor domain. Later, some work was done on this particular domain by such scholars as Dave (1970), Simpson (1972), and Harrow (1972).

In this paper our main interest is in the cognitive domain. For sake of completeness the other domains will be briefly mentioned. For further details we recommend Wyatt (2001) or Anderson and Sosniak (1994).

1.1 The Cognitive Domain

Proficiency in the ***cognitive domain*** entails knowledge[1] of, comprehension of, and critical thinking about a particular topic. There are six levels in the Taxonomy, from the lowest order to the highest:

(i) Knowledge

- Knowledge of terminology, specific facts
- Knowledge of ways and means of dealing with specifics - conventions, trends and sequences, classifications and categories, criteria, methodology

[1] In order to avoid the common error of misapplying this taxonomy, it must be noted that knowledge is defined rather narrowly

> Knowledge, as defined here, involves the recall of specifics and universals, the recall of methods and processes, or the recall of a pattern, structure, or setting (Bloom et al. 1956, 201).

- Knowledge of the universals and abstractions in a field - principles and generalizations, theories and structures

A typical question: Read the play *Julius Caesar* by Shakespeare. List the characters and describe them

(ii) Comprehension

- Demonstrative understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas
- Extrapolation

A typical question: Read the play *Julius Caesar* by Shakespeare. What was the most significant conflict in the book, and how was it resolved?

(iii) Application

- Solve problems that pertain to new situations by applying acquired knowledge, facts, techniques and rules in a different way

A typical question: Read the play *Julius Caesar* by Shakespeare. Did this book give you any new ideas about yourself? Why?

(iv) Analysis

- Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations
- Analysis of elements
- Analysis of relationships
- Analysis of organizational principles

A typical question: Read the play *Julius Caesar* by Shakespeare. Write a different ending to the play. Tell why you changed it. Provide references to support your statements.

(v) Synthesis

- Compile information in a different way by combining elements in a new pattern or proposing alternative solutions
- Produce a plan, or proposed set of operations
- Derive a set of abstract relations

A typical question: Read the play *Julius Caesar* by Shakespeare. Write a different short play using the same characters.

(vi) Evaluation

- Present and defend opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria
- Make judgments in terms of internal evidence
- Make judgments in terms of external criteria

A typical question: Read the play *Julius Caesar* by Shakespeare. Is the title a good one or a poor one and why?

Here is a table depicting possible wordings of questions aimed at assessing the proficiency of learners at each level:

Table 1 Bloom's Taxonomy: Possible Wording of Questions

Level	Type of Activity or Question	Verbs Used for Outcome
Lowest Level	Knowledge	Define, memorize, repeat, match, record, list, recall, name, relate, collect, label, specify, cite, enumerate, recite, tell, recount
↓	Comprehension	Restate, summarize, differentiate, discuss, describe, recognize, explain, express, identify, locate, repeat, retell, review, translate, paraphrase
↓	Application	Exhibit, solve, manipulate, interview, simulate, apply, employ, use, demonstrate, dramatize, practice, illustrate, operate, calculate, show, experiment
↓	Analysis	Interpret, classify, analyze, arrange, differentiate, group, compose, organize, contrast, examine, scrutinize, survey, categorize, dissect, probe, create an inventory, investigate, question, discover, inquire, distinguish, detect, diagram, chart, inspect
↓	Synthesis	Compose, set up, plan, prepare, propose, imagine, produce, hypothesize, invent, incorporate, develop, generalize, design, originate, formulate, predict, arrange, assemble, construct, create
Highest Level	Evaluation	Judge, assess, decide, measure, appraise, estimate, evaluate, rate, deduce, compare, score, value, predict, revise, choose, conclude, recommend, determine, criticize, test

1.2 The Affective Domain

Affective objectives typically target the awareness and growth in attitudes, emotion, and feelings. There are five levels in the affective domain moving through the lowest order processes to the highest:

(i) **Receiving:** The lowest level; the student passively pays attention. Without this level no learning can occur.

(ii) **Responding:** The student actively participates in the learning process, not only attends to a stimulus; the student also reacts in some way.

(iii) **Valuing:** The student attaches a value to an object, phenomenon, or piece of information.

(iv) **Organizing:** The student can put together different values, information, and ideas and accommodate them within his/her own schema; comparing, relating and elaborating on what has been learned.

(v) **Characterizing:** The student holds a particular value or belief that now exerts influence on his/her behavior so that it becomes a characteristic.

1.3 The Psychomotor Domain

Skills in the psychomotor domain describe the ability to physically manipulate a tool or. As mentioned earlier, Bloom and his colleagues never created subcategories for skills in the psychomotor domain; these were created later. The proposed levels are:

1. **Perception**: The ability to use sensory cues to guide motor activity.

2. **Set**: Readiness to act.

3. **Guided Response**: The early stages in learning a complex skill that includes imitation and trial and error.

4. **Mechanism**: This is the intermediate stage in learning a complex skill. Learned responses have become habitual and the movements can be performed with some confidence and proficiency.

5. **Complex Overt Response**: The skillful performance of motor acts that involve complex movement patterns.

6. **Adaptation**: Skills are well developed and the individual can modify movement patterns to fit special requirements.

7. **Origination**: Creating new movement patterns to fit a particular situation or specific problem.

The Taxonomy faced some criticisms and as a result got modified over the years. As Morshead pointed out on the publication of the second volume, most of the criticisms were centered around the fact that the classification was not a properly constructed taxonomy, as it lacked a systemic rationale of construction (Morshead 1965). Yet some other critiques of cognitive domain part of Bloom's Taxonomy's admitted the existence of these six categories but questioned the validity of a sequential

relationship, considering the three lowest levels as hierarchically ordered, but the three higher levels as parallel (Paul 1993). A revised version of the Taxonomy was given in Anderson, et al. (2000), Anderson and Krathwohl (2001), and Krathwohl (2002).

2. Our Courses

Our introductory level statistics courses are aimed at teaching methods of unbiased collection, organization, analysis, and graphical presentation of data and the use of statistical tests with the goal of

- Interpreting, analyzing, and synthesizing quantitative, statistical, spatial, and graphical data (information) to solve problems encountered in social and natural sciences
- Applying quantitative methods such as data collection, organization, analysis, and interpretation to make informed and effective decisions
- Selecting appropriate methods, procedures, and strategies to critically evaluate and solve statistical problems

Along with developing statistical reasoning of the learners, through carefully planned, designed, and structured assignments that incorporate the use of technology (MINITAB) and data analysis these courses also help them develop the following skills:

(i) Critical Thinking Skills

This is a direct result of our students' having to learn how to

- Identify important questions (problems)
- Analyze, interpret and make judgments about the relevance and quality of data
- Assess whether necessary assumptions are satisfied
- Draw conclusions and make judgments based on evidence gathered
- Communicate the results of their thinking

(ii) Quantitative Reasoning Skills

This follows since in these courses our students are expected to

- Interpret quantitative information (i.e., formulas, graphs, tables, models, and schematics) and draw inferences from them

- Formulate the problem quantitatively and use appropriate statistical methods to solve the problem
- Communicate and present quantitative results effectively

(iii) Scientific Reasoning Skills

This is based on our students' having to demonstrate the ability to develop and test a hypothesis and consequently to develop an awareness of both the power and the limitations of the scientific process.

(iv) Information Technology Skills

This is a direct outcome of our students' having to

- Use technology to locate, access, evaluate, and use information including on-line discussions, tutorials, and YouTube lectures
- Use statistical software to check assumptions, and to analyze data
- Communicate their findings effectively using state-of-the-art information technologies in multiple modalities

3. Bloom's Taxonomy of Cognitive Skills Interpreted for Statistics – What Should Teachers Do?

Blooms Taxonomy can be used by instructors to construct lecture notes as well as to invent test or assignment questions. Here is an interpretation of each cognitive skill in a statistical context. The example questions are aimed for introductory level statistics students, but could be modified to apply to other courses.

(i) **Knowledge:** Questions include "State the definition", "State the theorem", or "Use the specified method."

Examples:

- What is the Central Limit Theorem? The student would have 4 answer choices. They must choose the best answer.
- What does a 95% confidence interval mean? The student would have 4 answer choices. They must choose the best answer.
- Given a small data set, the student is asked to calculate the mean.

(ii) **Comprehension:** Questions ask the student to use definitions or methods to calculate something.

Examples:

- What sample size is needed for the 95% confidence interval to have a margin of error no greater than 0.03? The student would have 4 answer choices. They must choose the best answer.
- Given that the first quartile is also the 25th percentile, calculate the first quartile.
- Given a small data set, the student is asked to pick the five-number summary from the 4 answer choices.

(iii) **Application:** Questions which require the usage of more than one definition, theorem, and/or algorithm.

Examples:

- The summary statistics of a data set are given. The student is asked to test to see if the mean length of Atlantic salmon has increased from 29 inches at a 0.05 significance level.
- Given a data set, the student is asked to use MINITAB to see if it is reasonable to compute the 90% confidence interval (by constructing a boxplot and normal probability plot).

(iv) **Analysis:** These questions can provide a scenario and ask the student to generate a certain type of conclusion.

Examples:

- We are given the mean $\bar{x}$ of a sample of size n and also the fact that the population is normally distributed. If the 95% confidence interval is 22.3 to 25.2 feet, would it be reasonable to believe that the mean is 24.5 feet?
- We are given the mean $\bar{x}$ of a sample of size n and also the fact that the population is normally distributed. We devise a test to see if the population mean has decreased. The p-value is 0.03. Is it reasonable to assume the mean is less than hypothesized mean?

(v) **Synthesis:** Questions are similar to Analysis questions, but the conclusion to be reached by the student is an algorithm for solving the given question. This also includes questions which ask the student to develop their own classification system

Examples:

- Given the following data set, generate a normal probability plot and a boxplot. Is it reasonable to use the t-procedures?

(vi) **Evaluation:** Questions are similar to Synthesis questions, except the student is required to make judgments about which information should be used.

Examples:

- We are given that the population is normally distributed and that the population mean is 25.5cm. The boxplot does not have outliers and the probability plot does not look bad. One has used a t-procedure to test whether the mean has decreased from this hypothesized value. Comment on this person's choice of method, its reliability, etc.

4. Bloom's Taxonomy of Cognitive Skills Interpreted for Statistics – What Should Learners Do?

To derive the maximum benefit from these courses there are certain steps the learners should take. Below is a short list.

1. The learners should take material from the course and apply it to solve problems (***Application***). This is done before and after lectures, while reading the book, and while working on assignments.

(a) Lectures

• Before class the students should review ideas from the previous section and read over the section to be covered

• The students are expected to learn to apply concepts by practicing problems

• The students should ask questions when they have trouble understanding the material

• After the lecture, the students should bolster each technique by trying other examples or homework problems using the same concept

(b) Book/Homework Assignments

The students should

• Work through examples in the text until they understand the steps

• Work on homework problems using methods introduced in the text/class

• If they can't solve the problems at the first attempt, they should wait a day and try the problem again. Only after than should they consult solution manuals or on-line hints.

2. The learners should be able to identify which techniques or tools are needed to solve a problem (***Analysis***). To this end, after fully comprehending a particular technique or tool, the students should list which types of problems use that technique or tool. They should also find identifying features, such as key words or phrases, used in each type of problem to be able to choose the proper tool.

3. The learners should be able to solve problems using multiple tools (***Synthesis***). They should realize that some test, homework, quiz, or project problems would require the use of multiple techniques from different sections of the course. For this purpose, the students should practice breaking down homework or review problems into multiple parts and note the techniques used for each part, and make sure to review and practice difficult techniques that are used in many types of problems.

4. The learners should attempt solving conceptual problems (***Evaluation***). Students should realize that some problems require them to apply concepts in a new way. These problems entail an understanding of the ideas underlying the techniques and tools used to solve problems. For this intent, it is a good practice for students to

• Write down the concept or idea behind each tool or technique

• Connect each new concept to previous concepts used in the course, that is, form a *concept map*: Given a concept C what concepts were needed to explain C and when was C used to explain new concepts?

• Try to understand why the idea is true and what the concept means

• Create their own conceptual problems using the concept

5. Course Outcomes Mapped to Bloom's Taxonomy

Bloom's Taxonomy is a tool for classifying the cognitive demand level of instructional activities or questions. As one moves through the hierarchy from knowledge to evaluation, the activities and questions require increasingly higher-level thinking skills. See list below this table for a summary of Bloom's Taxonomy and examples of verbs corresponding to each cognitive level.

Table 2 Cognitive Demand Level – Based on Bloom's Taxonomy

Course Outcome	Knowledge (Lowest)	Comprehension	Application	Analysis	Synthesis	Evaluation (Highest)
Use appropriate sampling methods for data collection			X			
Organize, summarize, interpret, and present data using graphical and tabular representations				X		
Apply basic concepts of probability in order to assess the likelihood of an event						X
Select and apply the most appropriate statistical test or tests to analyze a data set						X
Demonstrate familiarity with software (MINITAB) to analyze data						X
Determine reasonable inferences and predictions from a set of data to make appropriate and ethical decisions						X

REFERENCES

Anderson, L. W. , D. R. Krathwohl, Peter W. Airasian, Kathleen A. Cruikshank, Richard E. Mayer, Paul R. Pintrich, James Raths, and Merlin C. Wittrock (eds). 2000. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives.* Boston: Allyn and Bacon,

Anderson, Lorin W. and Lauren A. Sosniak, eds. 1994. *Bloom's Taxonomy: A Forty-Year Retrospective*. Chicago National Society for the Study of Education. Chicago: University of Chicago Press.

Anderson, L. W. and Krathwohl, D. A. 2001. *Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives* New York: Longman

Bloom B.S. , Engelhart, M. D., Furst, E. J., Hill, W. H., & Kratwohl D. R. 1956. *Taxonomy of educational objectives: the classification of educational goals; Handbook I: Cognitive Domain.* New York: Longmans, Green.

Bloom, Benjamin S. 1994. *Reflections on the development and use of the Taxonomy.* In Anderson, Lorin W. & Lauren A. Sosniak, eds. (1994), *Bloom's Taxonomy: A Forty-Year Retrospective*. Chicago National Society for the Study of Education. Chicago: University of Chicago Press.

Dave, R.H. 1970. Psychomotor levels. In RJ. Armstrong (Ed.) *Developing and writing educational objectives* (pp. 33-34). Tucson AZ: Educational Innovators Press.

Harrow, A.J. 1972. *A Taxonomy of the Psychomotor Domain.* New York: David McKay Co.

Krathwohl, D. R. 2002. A revision of bloom's Taxonomy: An overview. In *Theory into Practice*, 41 (4), 212-218.

Krathwohl, D. R., B. S. Bloom, and B. B. Masia. 1964. *Taxonomy of educational objectives; the classification of educational goals. Handbook II: The affective domain*. New York: Longman, Green.

Morshead, Richard W. 1965. Taxonomy of Educational Objectives Handbook II: Affective Domain. In *Studies in Philosophy and Education* vol. 4 (1) pp. 164-170

Orlich, et al. 2004. *Teaching Strategies: A Guide to Effective Instruction.* New York: Houghton Mifflin.

Paul, R. 1993. *Critical thinking: What every person needs to survive in a rapidly changing world* (3rd ed). Rohnert Park, California: Sonoma State University Press.

Simpson, E.J. 1972. *The Classification of Educational Objectives in the Psychomotor Domain* Washington DC: Gryphon House.

Wyatt, A. T. 2008. Bloom's taxonomy. Retrieved June 13, 2012, from http://cs1.mcm.edu/~awyatt/csc3315/bloom.htm.