Application of Revised Bloom's taxonomy to Engineering education

Introduction

This brief white paper describes the use of Revised Bloom's taxonomy in an engineering education context.

Specifically, this documents the application and adaptation of an educational methodology called Revised Bloom's taxonomy in the delivery of Master's degree programs in Electrical and Computer Engineering.

The results have been quite pleasing. We have applied this methodology to students who did not have adequate proficiency levels or preparation for jobs that require advanced skillsets and were able to impart these in a short time frame.

Bloom's taxonomy and Revised Bloom's taxonomy

Bloom's Taxonomy (wiki : Bloom's taxonomy) was created in 1956 under the leadership of Dr. Benjamin Bloom in order to promote higher forms of thinking in education, such as analyzing and evaluating concepts, processes, procedures, and principles, rather than just remembering facts (rote learning). It is often used in instructional design.

Bloom's classification of cognitive levels has been widely used across K-12 learning, higher education programs and corporate programs.

Most educators in the Western world have adapted revised versions of Bloom's taxonomy. This has been especially widely adopted in K-12 education. However, Revised Bloom's taxonomy has not that often been used in higher education, especially in STEM fields.

One of the tools of revised Bloom's taxonomy is the Two Dimensional Matrix which combines the knowledge dimension with the cognitive dimension. We refer to it hereon as the 2DBT (Two dimensional Bloom's Taxonomy Table). A blank table is shown in Figure 1.

The Knowledge Dimension	The Cognitive Process Dimension					
	1. Remember – retrieve relevant knowledge from long-term memory	2. Understand – Construct meaning from instructional messages, including oral, written, and graphic communication	3. Apply – Carry out or use a procedure in a given situation	4. Analyze – Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose	5. Evaluate – Make judgments based on criteria and standards	6. Create – Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure
A. Factual Knowledge - The basic elements students must know to be acquainted with a discipline or solve problems in the discipline.						
B. Conceptual Knowledge - The interrelationships among the basic elements within a larger structure that enable them to function together.						
C. Procedural Knowledge - How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.						
D. Meta-Cognitive - Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.						

Figure 1: A blank 2DBT table for use by instructors.

Source Ref: A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives, Anderson et al. Publication Date: December 29, 2000 | ISBN-10: 0321084055 | ISBN-13: 978-0321084057

Application of 2DBT

We have specifically applied 2DBT to advanced engineering programs in Electrical and Computer engineering. Most of our courses are applied sciences with specific skill outcomes that can be related to job proficiencies. In other words, we have employer inputs for proficiencies that are mapped to course

learning outcomes. Course learning outcomes are hence defined in actionable, measurable terms such as "Design a …", "Analyze a …", which map exactly or easily to the cognitive levels of Bloom's taxonomy. The knowledge dimension of engineering subjects is also quite amenable to capture for skill oriented fields.

Example classification

An Example job proficiency required would be "Ability to design digital functional units and verify them using the Verilog language".

This would be further broken down into

- Application of (Boolean equations) Mathematical principles to specified functionality
- Develop "(Synthesize/Create") designs and testbenches in the Verilog language
- Apply concepts of device Physics to logic structure
- Evaluate one structure vs the other and choose optimal implementations

Implicit in this, is the procedural knowledge of complex software tools that are used in the process. These proficiencies may be represented in the 2DBT format as shown below in Figure 2.

The Knowledge Dimension	The Cognitive Process Dimension					
	1. Remember – retrieve relevant knowledge from long-term memory	2. Understand – Construct meaning from instructional messages, including oral, written, and graphic communication	3. Apply – Carry out or use a procedure in a given situation	4. Analyze – Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose	5. Evaluate – Make judgments based on criteria and standards	6. Create – Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure
A. Factual Knowledge - The basic elements students must know to be acquainted with a discipline or solve problems in the discipline.						
B. Conceptual Knowledge - The interrelationships among the basic elements within a larger structure that enable them to function together.			✖		✖	✖
C. Procedural Knowledge - How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.			✖		✖	✖
D. Meta-Cognitive - Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.						

Figure 2: 2DBT for an example skill , filled out.

Complexity, a missing element

What is missing though is complexity – for e.g. designing a small adder element is not the same as design an interrupt controller.

In another example, students are asked to search for the largest of a given set of integers. If the sample size is 1000, the problem is simple enough. On the other hand, if the sample size is about 10 Million integers, the user is forced to investigate data structures, Operating system limits, programming language memory usage, swap space, cpu cache size, page fault profile etc. – the same problem suddenly manifests into an inter disciplinary exploration and a search for optimality.

This is not adequately captured by 2DBT in its original form (for various reasons). We have started quantifying complexity in our assignments, projects and assessments as we describe in further publications.

A note on meta-cognitive knowledge

It is often more apt to replace meta-cognitive knowledge with inter-domain/inter-disciplinary knowledge. This is not to underemphasize the importance of self-awareness as originally indicated. We find that most students at advanced engineering levels (senior year/graduate school) could benefit from a broadening of horizons using a more specific inter disciplinary definition.

Benefits of applying 2DBT

This methodology has greatly helped us accomplish the following easily:

1. Map job proficiencies to learning outcomes and reach agreement with hiring managers with ease.
2. Move from an instructor centric model to a student centric model.
    a. Shift the focus to (individual) student achievement of learning objectives – students see for themselves where they are and get motivated to achieve advanced goals.
    b. Student understanding of course objectives is much better.
3. Analyze course contents, activities and assessments using an objective, measurable framework
4. Identify remedial work needed in students and administer it

Further work

At this time, we are experimenting with scaling in deployment, scaling across disciplines and quantifying complexity. These results will be published in the near future.

Conclusion

Revised Bloom's taxonomy, an educational methodology used in K-12 education, can be applied to higher education in engineering (applied sciences) very effectively. It presents a win-win-win situation for hiring managers, instructors and students by enabling an objective focus in student learning outcomes.

About the Author

Srikanth Jadcherla is the Chairman of Seer Akademi. He is a noted technologist, Low power guru, educator and serial entrepreneur. His current research is on smart grids and IoT. His passion is to improve engineering education worldwide. He can be reached at sree@seerakademi.com