# Applying the Revised Bloom's Taxonomy of the Cognitive Domain to Linux System Administration Assessments

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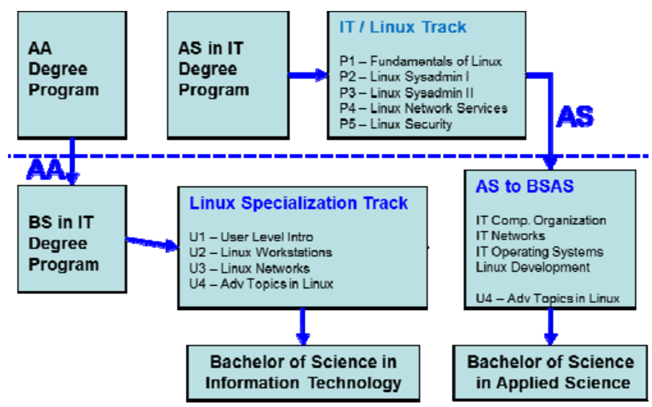
## ABSTRACT

*The Revised Bloom's Taxonomy has been used by educators, regardless of the discipline being taught, to characterize learning outcomes and their assessments. Such efforts help identify the cognitive requirements of a given examination or the expectations of a learning module. Despite having become a de facto standard, the Revised Bloom's Taxonomy is not trivial to apply. Education researchers are often in the best position to understand the subtle differences between taxonomy categories, but they often lack the discipline-specific knowledge to map the taxonomy's categories to assignments or questions. This problem suggests that education research on the application of the revised taxonomy should be multi-disciplinary, involving both education and discipline-based education researchers. This paper summarizes the experience acquired by the CEReAL group – Computing Education Research at Lakeland – as it leveraged the Revised Bloom's Taxonomy to categorize quizzes and assignments used in an Introduction to Linux course. We detail the specifics of the task, discuss the rules which governed our categorization process, and highlight scenarios where the taxonomy did not apply straightforwardly.*

## 1. INTRODUCTION

The need for qualified Linux technicians and system administrators is a driving force for projects enabling Associate of Science (AS) students to further their education by obtaining a Bachelor of Science (BS) degree. To this end, our two institutions partnered to build an NSF-funded, online, AS to BSAS (Bachelor of Science in Applied Sciences) program in Information Technology (IT) [1]. This program is an alternative to the BS in IT for AS graduates in IT related fields.

The following diagram details the structure of the online program: a 2+2 articulation between a state college and a research-intensive university meant to deliver IT graduates with strong Linux skills.




Nine Linux courses were developed as part of this project: P1-P5. Each incorporated 10 lessons created with adaptability to allow them to be reused in other courses. U1-U3 took portions of lessons from P1-P5 to create new courses suitable for BS in IT students and added U4 as capstone.

Articulating such a program requires merging certification-based learning outcomes with advanced topics from the ACM IT model curriculum. With a partnership between a state college and a research-intensive university, it might be tempting to play to each institution's strength and let them handle the learning outcomes at which they already excel. However, this approach fails to prepare our graduates in higher-order thinking skills related to Linux system administration. It relies on the assumption that higher-order thinking skills may not be honed through technical courses. Such an assumption is often found in research-intensive universities whose faculty members are, by training, unfamiliar with the specifics of professional system administration. Instead, we revisited the manner in which Linux system administration skills are taught in P1-P5 and U1-U3 and established learning outcomes satisfying certification-based requirements while identifying system administration tasks that are relevant to industry needs and target higher levels of cognition.

**Paper's Organization**

Section 2 details the educational framework used to establish the kind of learning activity or assessment which would qualify as higher-order thinking. Section 3 of this paper addresses the methodology we used to "tag" each quiz or assignment item with its RBT level. Section 4 describes the results of our effort, including several examples of assessment items tagged with different RBT levels. Section 5 relates specific system administration skills to appropriate RBT levels and discusses difficulties creating assessment items with high RBT levels. Section 6 presents our conclusions and future work.

## 2. BACKGROUND

**Overview of Revised Bloom Taxonomy**

A team of educators reviewed Bloom's Taxonomy (1956) and created an updated categorization system known as Revised Bloom's Taxonomy (RBT) that incorporated advances in cognitive research and learning. The new classification is now a standard tool used by educators to describe, measure, and classify expected learning objectives and academic standards in the cognitive domain that results from instruction [2]**.** RBT contains six overlapping levels of thinking skills that include *remembering*, *understanding*, *applying*, *analyzing*, *evaluatin*g, and *creating*. The first three levels are recognized for lower-order thinking skills, while the last three are considered higher-order thinking skills.

The *remembering* category explores the student's ability to recall or retrieve basic information from long term memory; *understanding* tasks students with communicating meaning from the presented content by explaining or summarizing; *applying* assesses whether the student can use his or her learning in a new way or can complete or implement a procedure; *analyzing* requires students to compare, contrast, and break a concept into its component parts and determine how the parts relate to each other and to the whole; *evaluating* requires learners to assess the worth or value and justify a recommendation, and *creating* explores students' ability to produce, reassemble, or generate a new product or idea [2]**.**

The original Bloom's Taxonomy described various intellectual skills and abilities required of learners. It was expressed as a six-tiered model in a hierarchical manner that required mastery of basic levels before higher levels. The levels were ranked on a scale of increasing complexity from the lowest to the highest with the understanding that higher level skills integrated previous levels. This strict sequence was deemed inadequate and was improved to reflect overlap between levels throughout the taxonomy.

Additionally, RBT advances two taxonomy dimensions—a *Knowledge Dimension* and a *Cognitive Process Dimension.* The two-dimensional approach allows educators to produce strong objectives matched to increasingly complex instruction [3]**.** The focus of our paper is the cognitive domain.

**Review of Computing Education Literature on Applying Bloom's Taxonomy**

Both the original and revised Bloom taxonomies were designed for K-12 education. While they generalized to higher education, the topics used to illustrate them in defining publications suggest that their use in various computing disciplines might require adaptation, e.g. nutrition, Macbeth, addition, parliamentary acts, volcanoes, and report writing [2]**.** Consequently, a significant amount of Computing Education Research literature has been devoted to investigating how these taxonomies apply to computing disciplines. However, most of this research is focused on the original taxonomy and emphasizes application of the taxonomies to programming.

Many studies have been devoted to mapping Bloom levels to programming tasks. The consensus groups Bloom levels in three consecutive pairs, 1-2 / 3-4 / 5-6, which are then used to teach the whole programming skillset [7]**.** Having such a sequential progression in the pedagogy of programming benefits students, especially when compared to the "natural tendency" of programming instructors to teach the entire programming skillset in one offering and expect students to start writing entire programs [4][6][7]. Bloom's taxonomies not only reflect the dependence of higher level cognitive processes on lower-level ones but also suggests a scaffolding approach for teaching the easiest skills to students until they are ready to progress to the harder ones [6]. This pedagogical insight also affected assessment tools with the idea of assigning grades to students which more directly reflect higher level cognitive skills [5].

These studies illustrate the overall relevance of Bloom's taxonomies, however, the literature also warns about the difficulties in applying them. RBT "is a valuable tool which could enable analysis and discussion of programming assessments if it could be interpreted consistently" [11]. Assigning appropriate Bloom levels to given assessment is not a trivial task [9] and has led to the development of faculty training tools [8]. In some situations, ambiguity led investigators to suggest defining a computing education specific taxonomy instead [10]. The consensus is that Bloom's taxonomies are helpful but present a serious challenge when applied to programming. This paper proposes to share our pluri-disciplinary team's experience in applying RBT to system administration.

## 3. METHODOLOGY

Our team of four researchers (two from interdisciplinary/instructional education and two from computing education) examined a series of quiz items and assignments designed for *Introduction to Linux Administration*. We explored each assessment item to determine its placement on Bloom's Revised Taxonomy. The goal was to decide whether assessment items required higher level or lower-order thinking skills from students.

Our initial approach was to review each assessment question independently and assign an RBT level (tag each question), then meet as a group to discuss differences in our taxonomy categorization. We would then resolve our differences through active discussions, research, extensive analysis of the assessment item, and a review of the lesson content to determine whether the content and associated question item were so closely aligned that students would only require remembering skills to answer, thus warranting a low RBT ranking for the question. We tagged quiz items first to gain practice and familiarity before tackling assignments. We also used our group meetings to develop consistent standards as they emerged from the collaborative process.

The steps we followed to tag each assessment item may be summarized as follows:

1. Review each quiz question at least twice independently
2. Identify the main verb associated with the cognitive process the student must employ to answer the quiz question.
3. Assume the intended verb based on the context of the quiz question, if the verb is missing.
4. Select the verb that requires the highest level of cognitive skill if multiple verbs are used in the assessment item.
5. Review RBT and determine the best category that fits the chosen verb for each quiz question.
6. Consult the lesson content that supports the assessment question to determine whether lesson context explicitly contains the expected responses. If content and question are closely matched, then the question is rated at RBT level 1 (remembering) or level 2 (understanding) depending on cognitive demand.
7. Compare researchers' RBT categorizations and note differences. Then determine best RBT level for each disputed assessment item after debate and analysis.

## 4. RESULTS

### Assessments Distribution in RBT Levels

We applied the previously described process to "tag" RBT levels to the various assessments used in the P1 course. P1 introduces students to the topics usually required in an entry-level Linux certification e.g. CompTIA's Linux+. Topics are generally introduced with a focus on terminology, concepts and day-to-day tasks. P1 is organized in 10 online modules, and each features a graded quiz with 10 questions. These questions are either multiple-choice or multiple-answer and are automatically graded by the Learning Management System on which they are deployed, e.g. Moodle. The following table summarizes the distribution of questions among the RBT levels:

| Bloom Level | Remembering | Understanding | Applying | Analyzing | Evaluating | Creating |
|---|---|---|---|---|---|---|
| % quiz questions | 99% (99) | 1% (1) | 0%(0) | 0%(0) | 0%(0) | 0% (0) |

Lower-level RBT results were partially anticipated due to the automatically graded nature of the quizzes and their perceived role as a way to ensure students acquire the elementary knowledge before engaging more difficult activities. Each of the 10 modules also features a variable amount of graded assignments which require students to engage hands-on with their Linux system, report findings or processes used to reach a given goal, and discuss them using online forums with other students. Our team reviewed 39 assignments from the 10 modules. The distribution is as follows:

| Bloom Level | Remembering | Understanding | Applying | Analyzing | Evaluating | Creating | n/a |
|---|---|---|---|---|---|---|---|
| % assignments | 28.21% (11) | 33.33% (13) | 7.69% (3) | 23.08% (9) | 5.13% (2) | 0% (0) | 2.56% (1) |

We used an additional “n/a” level to tag assignments which our team considered incompatible with an RBT level. Assignments which reward students for using Linux in a totally directed manner but do not challenge them to engage in any RBT cognitive processes to complete it were given the n/a designation.

**System Administration Specific Examples for RBT**

Example questions below illustrate the RBT categories used in this study.

| RBT Level | Question | Assignment Or Quiz |
|---|---|---|
| Remembering | Your IP address is 200.45.23.1, and the subnet mask is 255.255.255.0. What do these two sets of numbers tell you about the network and the host? | Quiz |
| Applying | You are employed as an entry level Linux Admin for EZfactory that deploys Windows PCs throughout the company. Recently, Ubuntu 10.043 was added to each system as a virtual OS via Virtualbox. Unfortunately, dozens of employees have expressed frustration when attempting to access mobile devices such as USB drives on their virtual OS. Consequently, your supervisor asked you to create a technical document that details the procedures for mounting / unmounting a USB drive in Virtualbox on a Windows 7 host machine. Additionally, he wants you to use simple language that anyone can understand in your write-up and to include common problems users may encounter while attempting to mount/unmount drives and how these problems may be addressed. | Assessment |
| Evaluating | You are the Linux administrator for a medium-sized firm and are responsible for maintaining four servers and 100 desktop computers and portables. After a stormy meeting in which the CEO demanded a reduction in the IT budget, the Chief Information Officer approached you for a special project.<br><br>He wants you to explore the use of Ubuntu Linux as a standard OS across the company but does not want immediate drastic changes to the core Windows-based configuration. Instead, he wants you to draft a report detailing three options he could explore to introduce Linux to all employees without disrupting their current installations and programs. He specifically wants to know the advantages and disadvantages of each option, the feasibility of a Linux rollout with minimal downtime, and your recommendation for the best choice. | Assignment |

The process of distinguishing examples of certain questions was not easy. We analyzed each task for the RBT level and also determined if the assignment or quiz was asking students to regurgitate content word-for-word. Therefore, while the wording of a question may have represented higher level thinking, if the material was explicitly integrated into the curriculum, then a lower RBT tag was assigned.

## 5. DISCUSSION

What is the relationship of RBT levels of thinking to the day-to-day skills that must be possessed by a competent system administrator? In ongoing work the authors have developed a list of such skills in the form of "learning outcomes" required of a curriculum used to train system administrators. The table below lists those skills, relating them to the highest required thinking level on the RBT scale.

| Learning Outcomes (Skills) | Descriptions | RBT Levels: |
|---|---|---|
| Conceptual & Technical Knowledge | Ability to remember and understand factual knowledge relevant to system administration tools and technologies | Understanding |
| Following Procedures | Ability to apply the procedures presented in a "how to" document or tutorial in order to perform a system administration task successfully | Applying |
| Troubleshooting | Ability to identify abnormal behavior in a computing system, make hypothesis on how to address it, and implement solution | Analyzing |
| Technical Information Retrieval | Ability to use available technical references & resources to find responses to specific system administration questions, including being able to assess the validity & reliability of such sources. | Evaluating |
| Evaluating / Validating Solutions | Ability to review alternative system administration technologies or solutions based on requirements in order to make recommendation on the most suited. | Evaluating |
| Designing Procedures | Ability to write how-to documents, tutorials guiding other system administrators, or users step-by-step through system administration tasks. | Creating |

Not surprisingly, we found that, with few exceptions, computer-graded quiz items require low levels of thinking, typically "remember" or "understand" on the RBT scale. We suggest that this is inherent in the limitations of the grading capability of course management systems today. A multiple-choice question, for example, generally restricts thinking patterns to a *choice between alternatives*, where the distractors (the "wrong" answers) must be sufficiently incorrect to provide an unambiguous response. It is easy to understand, for example, that a computer-graded quiz item is not going be able to successfully assess thinking skills at the "Create" level. Essay and free-form short-answer questions found in assignments can demand higher levels of thinking and, indeed, there were indications of this in our results.

It can be, however, a challenging task to create an assessment item with a high RBT level. Beyond the issue of assessment grading (automated or human), our tagging experience found many cases in which an attempt to create even an *assignment* item requiring higher-level thinking skills was flawed.

## 6. CONCLUSION & FUTURE WORK

This study attempts to merge curriculum development aimed at higher level thinking outcomes with the practical skills required by Linux system administrators. Through a process of triangulated coding of an online Linux system admin course, tasks have been analyzed using RBT to determine the level of "thinking" required by students. This method of assessment, specific to computing education topics, serves as a guide for faculty seeking to extend learning outcomes beyond basic skills and rote tasks.

However, the cycle of curriculum validation and assessment is not complete by merely establishing a process of content analysis. Rather, student learning must be considered to determine whether the content facilitates higher-order thinking. Despite establishing that assignments and quizzes may require different levels of cognitive processing, the performance of students on these tasks relates to whether the supporting content significantly bridges the learner to the learning outcomes. Given the pressure from industry for post-secondary institutions to produce skill-based technicians and "thinking" agents who can problem solve and troubleshoot in creative ways, it is incumbent on higher education to find ways to measure whether successful graduates truly meet this mark.

Therefore, future studies will require that tags identified as part of the process described in this paper, be integrated into the online course management system. As simplistic as this task appears, the tools do not currently exist within most online learning environments that will allow for tagging (categorization) and aggregation of student performance data by rated RBT level. In addition, the process required to manually code quiz and assignment questions in an existing curriculum is tedious. Ideally, learning systems would allow for a coding mechanism to indicate the RBT level assigned to each question, and a weighting factor that would provide additional value in the assessment process to higher-order thinking skills. Our current work has primarily focused on analyzing cognitive processing rather than fully exploring other domains. Investigating the knowledge dimension of the RBT would be of interest for future work. Furthermore, the skill-based learning outcomes previously mentioned in the discussion section require validation to substantiate the scope of the types of skills identified in workplace practice.

## 7. ACKNOWLEDGMENTS

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