Multi-perspective Survey of the Relevance of the Revised Bloom's Taxonomy to an Introduction to Linux Course

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ABSTRACT

Equipping students with higher-order thinking skills as part of a program in information technology is no trivial aim. Course creation must always have this goal in mind. In particular, learning activities and assessments must be designed to teach, encourage the use of, and assess success in achieving this goal, beyond merely teaching facts, methods and techniques. In this paper, we examine the degree to which we were able to assess higher-order thinking skills in students enrolled in the first course of an online Linux system administration curriculum. To assist other educators contemplating similar efforts, we briefly describe methods used to classify quiz and assignment items using the Revised Bloom Taxonomy (RBT) and discuss results from a survey administered to students who completed the course. Lessons learned throughout the process are described.

Categories and Subject Descriptors

K.3.2 [**Computers and Education]**: Computer and Information Science Education – *computer science education, curriculum, information systems education*.

General Terms

Measurement, Human Factors.

Keywords

Revised Bloom's Taxonomy, Linux system administration, online learning.

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1. INTRODUCTION

The need for qualified Linux technicians and system administrators prompted our two institutions, Polk State College (formerly Polk Community College) and University of South Florida in Lakeland (formerly USF Polytechnic), to collaboratively build an NSF-funded online program in Linux System Administration to prepare advanced technicians with technical, higher order thinking, and problem-solving skills [1]. Linux specialists and educators constructed each course in the curriculum with an emphasis on higher-order thinking skills, as defined in the Revised Bloom's Taxonomy (RBT) [2].

Following the first three offerings of the initial course in the curriculum, we conducted a preliminary assessment of our success in integrating higher order thinking skills. Building on earlier efforts described in a previous paper [**1**], our team used RBT as a standard to assess the assignments and quizzes in the course. Additionally, students in the course completed exit surveys that requested demographic and pedagogical information, and specifically asked students to assess the degree to which the course helped them acquire higher-order thinking skills in Linux Administration.

Since enrollment in these courses was low, the number of students on which this work is based is necessarily low. The authors feel, however, that the information garnered from these surveys reveals worthwhile characteristics that have proven useful in improving the curriculum and may also provide guidance for educators interested in developing higher-order thinking skills as part of an online course.

Section 2 of this paper briefly reviews the Revised Bloom's Taxonomy (RBT) and its history in computing education. Section 3 summarizes efforts (fully described in an earlier paper [**1**]) to classify quiz and assignment items using RBT. Section 4 presents student exit survey results, including student characteristics and implications for the degree of success in imparting higher-order thinking skills in this content area. Section 5 presents our conclusions and advice, while Section 6 describes future work. Sections 7 and 8 provide acknowledgments of support and references from the literature.

2. REVISED BLOOM'S TAXONOMY

2.1 Overview

Bloom's Revised Taxonomy (RBT) represents an update from the initial taxonomy created in 1956 by a team of educators to define, measure, and categorize learning objectives and academic standards [2]. RBT was a necessary update that incorporated new understanding of learning research, cognitive science and pedagogy. In subsequent years since the updates, RBT has become a standard tool of reference for educators or anyone interested in learning in the cognitive domain. The new taxonomy defines six overlapping levels of thinking skills, including:

1. *Remembering,* accounting for the student's ability to recall or retrieve basic information from long term memory,
2. *Understanding,* tasking students with communicating meaning from the presented content by explaining or summarizing,
3. *Applying,* assessing whether the student can use his or her learning in a new way or can complete or implement a procedure,
4. *Analyzing,* requiring 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,
5. *Evaluating,* requiring learners to assess worth or value and justify a recommendation, and
6. *Creating,* assessing students' ability to produce, reassemble, or generate a new product or idea [2].

Levels 1-3 are recognized as lower-order thinking skills, while levels 4-6 are considered higher-order thinking skills.

2.2 Application to Computing Education

Both the original and revised Bloom taxonomies were designed for K-12 education. While they were generalized to higher education, the topics used to illustrate them in defining publications suggest their use in various computing disciplines might require adaptation, e.g. nutrition, Macbeth, mathematics, 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 was focused on the original taxonomy and emphasized its application to programming. For instance, 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 instructors to teach the entire programming skillset in one offering and expect students to start by writing entire programs [4][6][7]. Bloom's taxonomies not only reflect the dependence of higher level cognitive processes on lower-level skills but also suggest a scaffolding approach for teaching the easiest skills to students until they are ready to progress to the more difficult tasks [6]. This pedagogical insight also influenced the creation of improved assessment tools that assign better grades to students able to produce responses that 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 a given assessment is not a trivial task [9] and has led to the development of improved 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 addresses a similar challenge for system administration.

3. ITEM CLASSIFICATION USING RBT

This section summarizes previous work [1] which allowed our team to establish a "RBT profile" of our first Linux track offering.

3.1 Methodology

An interdisciplinary team of four faculty, i.e. two from information technology / one instructional specialist / one education faculty member, examined quiz items and assignments designed for Introduction to Linux System Administration taught at Polk State College. Each assessment item was examined to determine its placement on Bloom's Revised Taxonomy.

Each team member first reviewed each assessment item and assigned an RBT level individually. The team then met as a group to discuss differences in taxonomy categorization and resolved differences through active discussions, research and extensive analysis of the assessment item. A review of the lesson content itself was frequently needed to determine whether it and the assessment item were so closely aligned that students would only require remembering skills to answer, thus warranting the lowest RBT ranking for the item. Group meetings were also used to develop consistent standards as they emerged from the collaborative process.

A stepwise process was gradually defined from team meetings:

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.
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 perceived cognitive demand.
7. Compare researchers' RBT categorizations and note differences. Then determine best RBT level for each disputed assessment item after debate and analysis.

The process was time-intensive but necessary, as the team found that classification decisions were frequently non-trivial, and that significant discussion and debate among assessment team members was needed to classify many items.

Table 1 illustrates some examples of categorization of assessment items found in the course.

Table 1. Sample Classified Assessment Items

RBT Level	Item Text
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?
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.
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. 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.

Table 2. RBT Levels of Quiz vs. Assignment Items

RBT Level	% of Quiz Items	% of Assignment Items
1. Remembering	99% (99)	28.2% (11)
2. Understanding	1% (1)	33.3% (13)
3. Applying	0% (0)	7.7% (3)
4. Analyzing	0% (0)	23.1% (9)
5. Evaluating	0% (0)	5.1% (2)
6. Creating	0% (0)	0% (0)
Could Not Classify	0% (0)	2.6% (1)

3.2 Assessment Distribution in RBT Levels

The classification process revealed significant differences in the RBT level of quiz items versus assignment items. Table 2 shows the distribution across RBT levels of each type of assessment.

The team noted the difficulties in designing computer-graded quiz questions that would require the use of higher-order thinking skills. In fact, *all* quiz items examined were classified as requiring only lower-level thinking skills; indeed, all but one were classified at the lowest level – *remembering*.

Assignment items, in contrast, were constructed as essay or short answer questions, allowing greater opportunities for exercising higher-order skills.

The team found that creating assessment items with high RBT levels was challenging. Beyond the issue of assessment grading (automated or human), our classification experience found many cases in which assignment items attempting to assess higher-order thinking skills were an outcome of a flawed and debatable process in their creation. We came to understand that, where designing assessments demanding higher-level thinking skills is concerned, intent does not easily translate into accomplishment.

4. STUDENT EXIT SURVEY

In each of three recent offerings of the course (all during fall of 2011), students were surveyed at the conclusion of the course. The number of students in each class was 6, 9 and 5, respectively, for a total population of 20 students. The low number of cases limits the depth of analyses that can be performed, but items of interest can still be found in demographics and student reports of learning activities in which they engaged. Students were also asked to rate how well the learning activities supplied in the course helped them develop the higher-order thinking skills as defined in the RBT. Surveys for the three offerings of the course were identical to each other; the survey results were combined into one dataset for analysis.

4.1 Selected Student Demographics

The students in the three offerings of the course were enrolled in an open access community/state college setting in either the AS degree program or high school dual-enrollment students in a Computer Network Engineering Program (Linux concentration). Most enrollees in this course were male; there were two females of twenty students. Sixty-five percent were fulltime students (no outside employment), while five were employed fulltime and two part-time. Seventy percent of students had no IT work experience; the remaining thirty percent were split evenly between students with some IT experience and students with significant (more than five years) IT experience. The mean age of students in the course was 27.1 years, with a range from 16 to 45 years. Students reported a current course load from 1 to 7 courses with the mean being 3.65 courses.

The implication from these results is that the students taking this course vary widely, with minimal homogeneity. The five fulltime employed students were probably able to take the course due to its online delivery mode. Students reported expending a reasonable amount of effort taking this course. The mean number of hours spent each week on the course was 6.8, with a minimum of 4 hours and a maximum of 12.

4.2 Learning Activities

To impart higher-order thinking skills to students in this course, learning activities were made available. Students were surveyed as to their use of each. Learning activities included:

- **Reading assignments**. 90% of students rated this activity “somewhat useful” or “very useful.”
- **Watching videos**. 90% of students rated this activity “somewhat useful” or “very useful.”
- **Discussion forum participation**. 70% of students rated this activity “somewhat useful” or “very useful.”
- **Taking non-graded practice quizzes**. 35% of students rated this activity “somewhat useful” or “very useful.”
- **Working on non-graded practice assignments**. 35% of students also rated this activity “somewhat useful” or “very useful.”

Reading assignments, watching videos and participation in discussions are fairly standard techniques, but the provision of non-graded quizzes and assignments is less typical.

4.3 Development of RBT Skills

The survey used six questions meant to establish the students’ perception on how learning activities supported the development of higher-order thinking skills. These were written with the preamble “Indicate how much the learning activities in this course helped you develop the following skills:”, followed by the RBT skill name (i.e., remembering), and ending with an example of the use of that skill. Students were asked to select among the following options; “No learning activities helped me develop this skill,” “few did,” “somewhat, some did,” and “many did.”

RBT Level 1: *Remembering*. This level, the lowest in Bloom’s hierarchy, is typified by verbs such as “define,” “list,” match,” “quote,” and “recite.” Student responses suggest this skill was well served by the course, as shown in Figure 1.

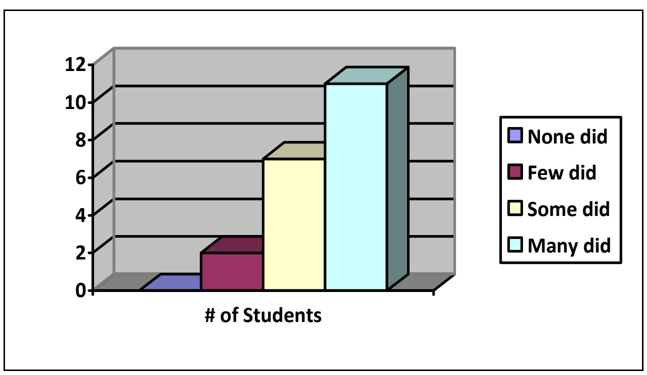

Figure 1. Activities Useful in Developing *Remembering* Skill

RBT Level 2: *Understanding*. This level is typified by verbs such as “discuss,” “interpret,” restate”, and “summarize.” Student responses shown in Figure 2 suggest that this skill was also well served by the course, although perhaps not quite as well as RBT Level 1 (understanding).

RBT Level 3: *Applying*. This level is typified by verbs such as “manipulate,” “demonstrate,” “compute,” and “apply.” Here we begin to see a significant decline in the number of learning activities students found useful in developing this skill. Student responses shown in Figure 3 show a clear shift from “many” activities to “some.”

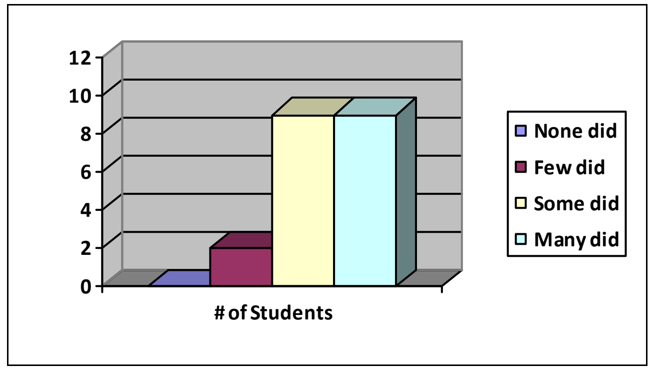

Figure 2. Activities Useful in Developing *Understanding* Skill

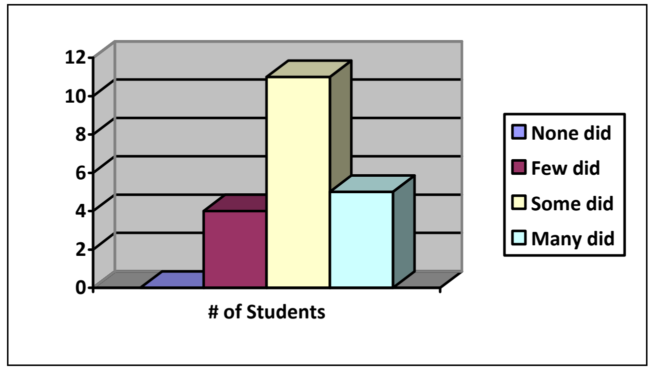

Figure 3. Activities Useful in Developing *Applying* Skill

RBT Level 4: *Analyzing*. This level is typified by verbs such as “contrast,” “differentiate,” “infer,” and “analyze.” Here we see further erosion in the number of learning activities students found useful in developing this skill. We also observe, for the first time, a significant number of students indicating that “no learning activities helped me develop this skill.” This may be due to some activities being inherently low-level on the RBT scale.

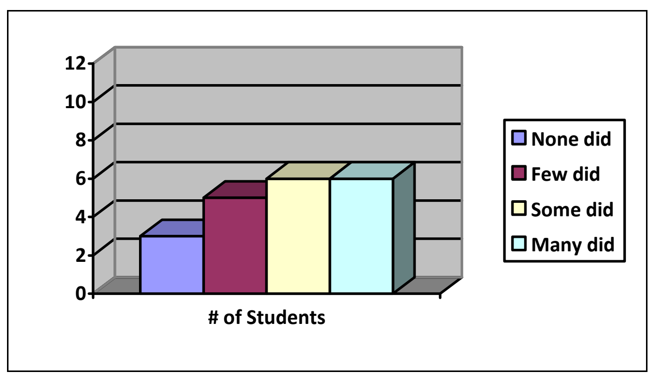

Figure 4. Activities Useful in Developing *Analyzing* Skill

RBT Level 5: *Evaluating*. This level is typified by verbs such as “assess,” “deduce,” “recommend,” and “evaluate.” In Figure 5, we see some “recovery” in the number of learning activities students found useful in developing this skill compared to the previous RBT level. We also see more heterogeneity in student responses; some reporting that no activities helped develop their ability to evaluate, while a larger number indicated many did.

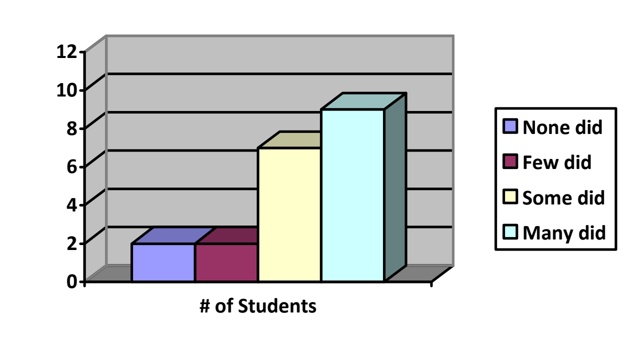

Figure 5. Activities Useful in Developing *Evaluating* Skill

RBT Level 6: *Creating*. This level is typified by verbs such as "construct," "originate," "propose," and "create." In Figure 6, we might see the presence of two groups of students with differing views on creativity, and what activities might prompt it. Nine students indicated none or few activities helped, while ten students felt some or many were of use.

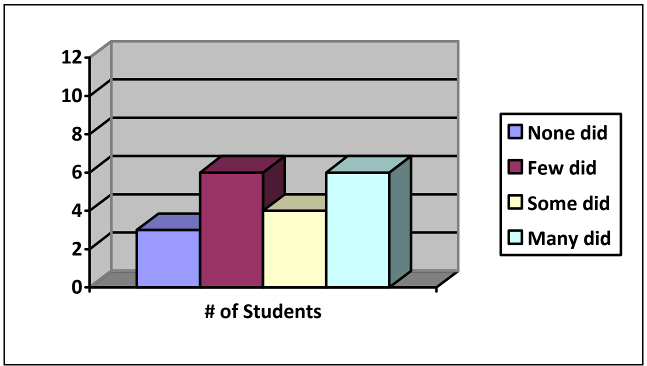

Figure 6. Activities Useful in Developing *Creating* Skill

Comparing RBT Levels. Figure 7 compares RBT levels using the number of students who felt that "some" or "many" learning activities in the course helped develop the skill.

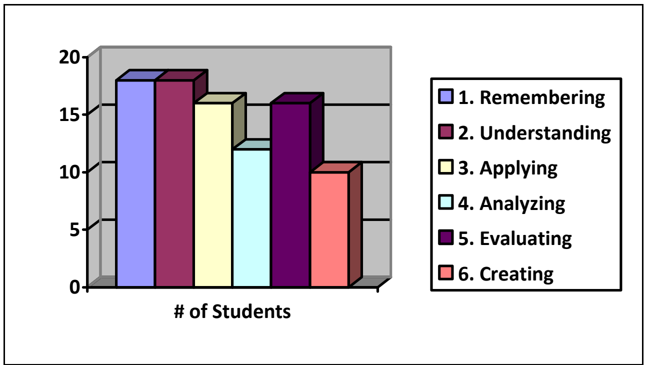

Figure 7. Comparison of RBT Levels

In general, students reported that they found the learning activities in the course useful in developing thinking skills, from a high of 18 of 20 students at the lower end of the RBT scale, to a low of 10 students for *creating*, the highest Bloom level. Within the limitation of the low N of our dataset, and given the natural variance in any group of students, we might cautiously conclude that learning activities provided in the course were successful in their aim of assisting the development of thinking skills, if only in students' estimation.

5. Discussion

Creating a course or program that will yield student graduates possessing higher-order thinking skills, as enumerated in the Revised Bloom's Taxonomy, is achievable, but requires an approach focused on learning activities that will prompt such thinking in a wide range of students. Such activities cannot be mere "add-ons," but must be designed into the structure of the course from the start.

While provision of learning activities and other materials that encourage higher-order thinking can be challenging, measuring the degree to which students possess these skills through quizzes and assignments can be even more difficult. We found that simply rating each quiz and assignment item to its perceived RBT level was a time-consuming and sometimes contentious process. We also found many cases in which a quiz or assignment item that might be seen as an excellent assessment of high-level thinking skills, e.g. a troubleshooting situation, was rendered trivial by a sufficiently analogous example being discussed during lectures. Instructors often evaluate the question "out of context" thus ranking it based on the cognitive processes required to solve it with only elementary knowledge. This view is innapropriate when students might leverage an analogy with a strongly similar problem or simply remember previous discussions.

While our findings suggest a predominance of lower level thinking skills, it is important to keep in mind that the course studied in this work is the *initial* course in the program sequence, and therefore more elementary and less challenging than later courses these students will undertake. We expect that materials and assessment items for the advanced courses will be inherently more adaptable to higher RBT levels.

6. Future Work

The authors plan to extend the work addressed in this paper in multiple ways.

We will continue to gather data from future offerings of this initial course, increasing the number of students in the dataset, and enabling more in-depth analysis.

We will integrate metrics of student performance in the course into the dataset, which will provide us with more data points to judge whether the course is accomplishing its aim of imparting higher-order thinking skills to students. Additional student surveys will also assist with this task.

As data is collected from offerings of more advanced courses in the program sequence, we will assess whether the higher level knowledge addressed in those courses enables more attention to higher-order thinking skills and makes assessment of success in that effort more practical.

We found that computer-graded quiz items were almost uniformly at the lowest RBT level. Consequently, we will explore creative ways to design computer-graded assessment items that rank higher on RBT and encourage higher-order thinking.

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