Designing Linux System Administration Learning Outcomes – Educational, Industry & Student Perspectives

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ABSTRACT

This paper discusses the design of learning outcomes for a specialization track in Linux system administration offered as a 2+2 articulated program between a Carnegie foundation research intensive University & a state college. We present the process used to design and validate a specific list of learning outcomes which served as the foundation of our development efforts. A discussion of the differences between educational, industry, and student perspectives is provided.

1. INTRODUCTION

The nation-wide need for qualified Linux 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, two institutions of higher education partnered to build an NSF-funded AS to BSAS (Bachelor of Science in Applied Sciences) program in Information Technology (IT) [1], aimed at AS graduates in IT-related fields, as an alternative to the BSIT. Our first goal was to establish learning outcomes which would provide a foundation for the pedagogy of contents of the entire program while successfully addressing educational, industry & student needs.

This paper presents the learning outcomes, LOs, designed for this BSAS in Linux System Administration. Section 2 introduces the educational perspective by basing these LOs on the Revised Bloom Taxonomy (RBT) educational framework [2]. Section 3 validates them from the industry perspective, using results from a survey completed by members of the project's advisory board. Section 4 validates them from the students' perspective using an end-of-semester survey. Section 5 examines the similarities among the various perspectives in order to share the insights gained from this survey-based study.

While the learning outcomes have been designed with the entire program in mind, this study gathered the students' perspective at the end of the introduction semester. We surveyed students during fall 2011 in three offerings of "Linux Fundamentals" which is taught online, using the Moodle learning management system. It is composed of 10 modules featuring PowePoint slides, hands-on demonstration videos, & links to relevant online resources and assignments; i.e. quiz, discussions in forums, hands-on problems. The instructor provided weekly feedback on these assignments and answered questions via emails or forums. Students were immersed in the system administration aspects of Linux from the very start with a focus on terminology & principles underlying each relevant technology in a breadth-first manner. The goal was to increase student competency to an entry-level Linux certification such as CompTIA Linux+.

2. EDUCATION RESEARCH PERSPECTIVE

Learning outcomes are essential in the design of learning activities, assessments, courses and, by extension, entire academic programs. Educational researchers are familiar with frameworks such as the revised Bloom Taxonomy (RBT) of the cognitive domain [2] which helps categorize learning and testing processes based on the required cognitive skills. While useful, such instruments often need to be adapted to the specifics of the discipline being taught. The computing education research literature extensively documented the difficulties in categorizing discipline-specific assessments while using a general-purpose taxonomy such as RBT which was originally K12 oriented [6][7][8][9][10].

In previous work, we identified a list of learning outcomes, based on RBT, but integrating the specifics of Linux system administration tasks [11]. These learning outcomes span different levels of required cognitive engagement identified by their "RBT level" in the following table;

Learning Outcome		Description	RBT Levels
SK0	Conceptual & Technical Knowledge	Ability to remember and understand factual knowledge relevant to system administration tools and technologies	Understanding
SK1	Following Procedures	Ability to apply the procedures presented in a "how to" document or tutorial to perform a system administration task successfully	Applying
SK2	Technical Information Retrieval	Ability to use available technical references & resources to find responses to specific system administration questions. This skill entails being able to assert the validity & reliability of such sources.	Evaluating
SK3	Designing Procedures	Ability to write how-to documents, white papers, tutorials guiding other system administrators or users step-by-step through system administration tasks.	Creating
SK4	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
SK5	Troubleshooting	Ability to identify abnormal behavior in a computing system, make hypothesis on how to address it, and implement solutions	Analyzing

While reading the above table, it is important to keep in mind that RBT is a hierarchy. A skillset at a given level incorporates all previous levels' skills. For instance, an assessment requiring the "applying" level will also require the "understanding" skill. Unlike RBT, our learning outcomes categories are not structured as a hierarchy. Instead, they feature few pre-requisite dependencies besides SK0 being implied by all other skills. Generally speaking, our LOs are not intended to map one-on-one to RBT levels. Several learning outcomes may map to the same RBT level. This reflects our focus on integrating various system administration tasks without merging them solely on their cognitive level.

Also, while we have identified SK3 as being at the "Creating" level in RBT, this LO groups a wide variety of tasks. Preparing a how-to, step-by-step, document is less demanding than preparing a tutorial or writing a white paper. This is especially true if the latter is defined as an expert analysis of the suitability of a given technology. However, these documents are seen differently by different IT professionals. For some, a white paper might be a blog entry specifying the command lines to use for a given task or a vendor's marketing document listing the advantages of a proprietary technology.

3. INDUSTRY PERSPECTIVE

This section provides an industry-based perspective on the above LOs. It is based on review of results from a preliminary survey in order to address data analysis errors from earlier studies [11].

Methodology

In order to gather an industry perspective relevant to our project, our team leveraged the project's advisory board which is composed of 11 executives representing companies heavily relying on Linux technologies in the Polk County / Florida High Tech Corridor. The members were sent a link to an online survey using surveymonkey.com. The survey also gathered background information such as specific usage of Linux technologies, number of employees affected by them...

Questions #5 & #6 were designed to assess whether our LOs were deemed beneficial to our graduates' employability. To this end, we first asked what percentage of current employees demonstrated a particular learning outcome. We then asked what percentage of employees the respondent would desire to have with the same skill. These two questions allowed us to assess the value attached to each specific LO based on the expressed need for *more* employees featuring it. The phrasing was as follows;

Question 5. How things are: If you had trouble with question 4c, this section may help. It is *possible* that your firm may not require that *all* your system administrators have the full range of sysadmin skills, as described in the cover pages to this survey. Below, please roughly estimate the percentage of your ***current*** system administrators who ***do*** possess each of the following system administration skills:

Question 6. How things *should* be: As a follow-on to the last question, please roughly estimate the percentage of your ***future*** system administrators who ***should*** possess each of the following system administration skills:

Each question was followed by a list of the learning outcomes, SK1 to SK5. For each learning outcome the respondents were invited to provide an estimate percentage from the following list; 0%, 10%, 25%, 50%, 75%, 90%, & 100%. The results were gathered by counting the number of respondents who ranked a given skill at each of the above-listed percentage values.

Results & Observations

Questions #5 & #6 allowed us to quantify, for each LO, the total number of respondents who indicated having 75% or more of their employees already possessing the related skillset or indicated wanting to reach such a percentage of employees featuring it. We labeled "Now" the former value and "Target" the latter. The following table lists the number of respondents in each group for each LO;

Learning Outcomes	"Now" above 75%	"Target" above 75%	Delta
SK1	10	11	1
SK2	10	11	1
SK3	5	10	5
SK4	7	10	3
SK5	9	11	2

As would be expected, most respondents indicated a desire for over 75% of their employees to eventually feature each of the skillset associated with our LOs. In order to capture more meaningful information from the responses, we subtracted the "Now" results from the "Target" ones. The resulting values are listed as "Delta" in the above-table.

This difference between the current and desired skillset distributions among employees allows us to identify LOs which yield skills aligned with the most pressing needs felt by these employers. The most significant difference is seen in the SK3 LO, suggesting the strongest need is felt in the ability of our graduates to design procedures. The least significant needs are felt in the SK1 / SK2 LOs, thus suggesting these skillset are readily available in the workforce.

4. STUDENT PERSPECTIVE

This section supplements the previous perspective by investigating how students perceive our LOs in terms of their relevance to their future careers as Linux system administrators.

Methodology

At the end of each of three recent offerings of "Linux Fundamentals" during fall 2011, students were invited to take an anonymous online survey. The number of students in each class was 6, 9 and 5, respectively, for a total population of 20. Among these, 3 took the survey but skipped all questions. Surveys for the three offerings of the course were identical to each other; the survey results were combined into one dataset for analysis. Question #19 prompted the respondents to evaluate the personal relevancy of each LO. The exact phrasing is provided below;

Question 19. Indicate how important you see the following thinking skills for someone working as a Linux system administrator

Responses were provided using a 4-point Likert scale with labels *not very important*, *somewhat important*, *important*, *very important*.

Results & Observations

In order for our observations to be interpreted in their proper context, we start by providing elementary information to characterize our surveyed population. Most respondents were males with only two females in the 20 respondents. The mean age was 27.1 years with a range from 16 to 45 years. While 13 were fulltime students without outside employment, five were fulltime employees and two were part-time employees. While 14 respondents had no IT work experience, the remaining were split evenly between students with some IT experience and students with significant, i.e. more than five years, IT experience. Students reported a current course load from 1 to 7 courses with the mean being 3.65 courses. 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.

The number of respondents who opted for the *not very important* or *somewhat important* responses were summed under the label *low importance*. The remaining respondents were grouped under the *high importance* label. Results are summarized in the table below. We based our percentages on the 17 respondents instead of the whole population including the 3 students who skipped all questions.

Learning Outcomes	Low Importance	High Importance
SK0	5.9%(1/17)	94.1%(16/17)
SK1	23.5%(4)	76.5%(13)
SK2	11.8%(2)	88.2%(15)
SK3	35.3%(6)	64.7%(11)
SK4	23.5%(4)	76.5%(13)
SK5	11.8%(2)	88.2%(15)

SK0 appears to be almost unanimously perceived as important. This result is not surprising but we focused our attention on LOs SK1 to SK4 in order to align our findings with those of section 3. In this subset, both SK2 – finding technical information – and SK5 – troubleshooting – were perceived as most relevant. The least relevant learning outcome was SK4 – evaluating / validation solutions.

5. DISCUSSIONS

While the previous perspectives are interesting on their own, it is even more relevant to identify similarities & differences between them. The following table summarizes the information presented in the previous sections by providing, for each LO, their rank in each of the 3 previously discussed perspectives. The lower the value, the highest the LO's importance in a given perspective. It is worth stressing out that the educational perspective is more specific than the label might suggest in so far that we only used the RBT educational framework to map then rank LOs.

Learning Outcomes		**RBT Perspective**	**Industry Perspective**	**Students Perspective**
SK1	Following Procedures	4	4	2
SK2	Information Retrieval	2	4	1
SK3	Designing Procedures	1	1	3
SK4	Evaluating / Validating Solutions	2	2	2
SK5	Troubleshooting	3	3	1

Looking at the Industry vs. Students perspectives suggests our students might be unaware of employers' needs. SK4 is for instance seen as least relevant by students yet very much so by our advisory board. Similarly, students value SK2 as essential while it is perceived as least relevant by employers. Being aware of this bias is essential in enabling our faculty to further motivate students by addressing, from the get go, misconceptions they might have about the relevance of specific learning activities. This is even further relevant given the fact both the educational & industry perspectives rank SK3 highly relevant. In addition, it is important to understand that the other skills are still relevant but are simply already present in the workforce, which makes them most likely expected from new hires and therefore still relevant to train into. This is most likely the situation with SK2.

The Industry vs. Educational view is also interesting. As already mentioned above, the SK3 LO is perceived as most relevant by both. We hypothesize it is due to the assumption that the related skillset is mostly focused on higher-level documents rather than straightforward instructions or marketing pamphlets. The difference with the students' perspective might stem from a difference in the definition of terms such as "white paper" in the student population. Regardless, an item per item look also suggests that employers are indeed interested in hires featuring higher-level cognitive skills, as ranked by the RBT framework. It would be meaningful to supplement our study by investigating hiring interview protocols used in order to determine whether these same skills, as opposed to technical knowledge, are tested in prospective hires.

Last but not least, the Educational vs. Students view reveals the most significant differences. This suggests our faculty might benefit from educating students on what makes a skillset more or less valuable not only to future employers but also in terms of the cognitive processes it relies upon. This might motivate students to invest more efforts in skillsets such as SK3. One of the authors' personal experience in teaching an introduction to Linux similar to the "Linux Fundamentals" used in this paper is that most students have difficulties expressing solutions in plain English rather than tackling fill in the blank or more technical exercises. The degree of resistance to being asked to learn to express technical opinions, prepare tutorials or simply describe processes to fix a given problem, in plain English leads to feedback in which students express their frustration to be graded on how well they write rather than on their Linux knowledge. Addressing this denial of the need for such skills, and therefore the need for them to be taught & evaluated as part of the student's Linux education, might be the necessary first step in improving our graduates' suitability from both employment & academic perspectives.

6. CONCLUSIONS & FUTURE WORK

This paper built on previous early results aimed at validating the learning outcomes developed for a 2+2, articulated, BSAS in Linux sysadmin program.

Results so far suggest potential misalignments which will need to be addressed in our teaching but have significant potential to impact students' motivation and understanding of the Linux system administrator profile. These aspects will be the explicit focus of future developments of this work.

Similarly, while these results allowed our institutions to validate the impact of their joined efforts on the regional hiring market, the next step might be to generalize this study by surveying nation-wide IT companies which rely on Linux technologies. The generalization will allow both an increase in the statistical significance while providing a more global perspective.

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