A Preliminary Validation of Linux System Administration Learning Outcomes

Alessio Gaspar, William Armitage, Naomi Boyer, Gregory Johnson, Cliff Bennett

University of South Florida Polytechnic, 3433 winter lake road, Lakeland, FL 33803. Email – alessio@poly.usf.edu

Polk State College, 999 Avenue H NE, Winter Haven, FL 33881. Email – cbennett@polk.edu

ABSTRACT

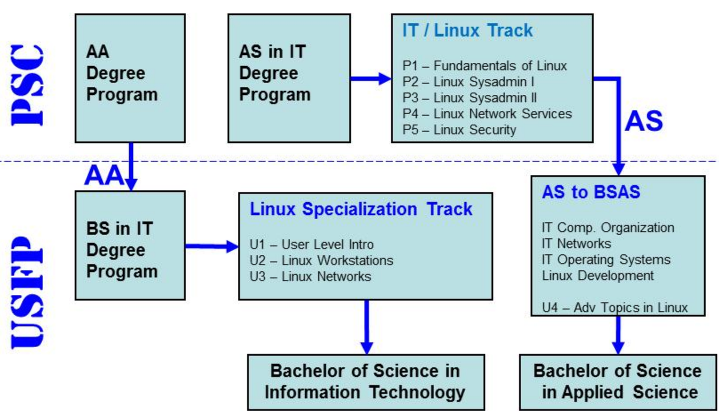
This paper shares our experience in a four-year long NSF-funded project to build an online Linux program as a 2+2 articulation between a state college and a research-intensive university. We present the process used to design and validate a specific list of learning outcomes which served as the foundation of our development efforts. The benefits of a synergy between certification training, higher education, and industry requirements are discussed along with the difficulties in implementing such a model.

1. INTRODUCTION

The nation-wide need for qualified Linux technicians, developers 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, two institutions partnered to build an NSF-funded AS to BSAS (Bachelor of Science in Applied Sciences) program in Information Technology (IT) **[1]**, which is aimed at AS graduates in IT related fields, as an alternative to the BS in IT. This endeavor entails merging certification-based learning outcomes, often taught by state colleges, with advanced topics from the ACM IT model curriculum. To this end, the first and most important goal was to establish learning outcomes that would dictate the pedagogy of contents of the entire program and address both academic and industry needs. The rest of this paper details the process used to design then validate specific learning outcomes for system administrators. Section 2 summarizes our 2+2 online program, section 3 discusses our overarching design objectives, section 4 introduces our learning outcomes, section 5 discusses the results of validating them through our industry-based advisory board.

2. LINUX CURRICULUM OVERVIEW

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



The following Linux courses were developed as part of this project: P1-P5 each incorporated 10 or more lessons created with adaptability to allow all or portions of each lesson to be reused in other courses. U1-U3 took portions of lessons from P1-P5 to create new courses suitable for BS IT students and added U4 as a fourth course to serve as a capstone.

This approach offers two paths to students at both institutions. First, AA students may enroll in the BS in IT to take the Linux Specialization Track which consists of U1-U4, taken as electives. Students not seeking specialization may take just U1 to familiarize themselves with Linux as users or developers. Second, AS students may enroll in the BSAS, skipping U1-U3, taking U4 to prepare them for the latest trends in Linux administration along with several BS IT courses to complete their transition. The next section discusses the design of the modules supporting P1-P5 & U1-U3.

3. DESIGN OBJECTIVES

The partnership on this project provided the opportunity to benefit from Polk State College extensive knowledge of the Linux certification standards, and University of South Florida ACM compliant IT offerings, but also the educational research from the CEReAL group **[4]**.

Given this situation, an obvious approach would have been to develop P1-P5 using only certification expertise, then migrate the modules as-is to form U1-U3 and supplement the BS AS students with core BS IT courses designed to impart the skills expected from model curricula **[3]**.

We felt this approach failed to prepare graduates for higher order thinking skills related to Linux system administration. It relies on the assumption that higher order thinking skills may not be honed through Linux system administration courses. Such assumption is often found in research-intensive universities whose faculty members are, by training, generally unfamiliar with the specifics of the cognitive processes involved in professional system administration. The field is therefore often evaluated based on an "outsider" view which naturally reduces it to its most simplistic characteristics.

Instead, we opted to revisit the manner in which Linux system administration skills are taught in P1-P5 & U1-U3. This view required us to establish learning outcomes satisfying certification-based requirements, while identifying system administration tasks which are both relevant to industry needs and target higher levels of cognition. The next section details the result of this process.

4. DEVELOPING SYSADMIN LEARNING OUTCOMES

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 provides a mechanism for categorizing learning and testing processes to determine the cognitive skills required. While useful, such instruments often need to be adapted to the specifics of the discipline being taught. The computing education research literature frequently illustrated the difficulties in categorizing discipline-specific assessments or learning activities while using a general-purpose taxonomy originally intended for K12 education **[6][7][8][9][10]**.

We identified a list of learning outcomes based on the revised Bloom taxonomy and specifics of Linux system administration work. It spans different levels of required cognitive engagement identified by their "RBT level."

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 in order 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 solution	Analyzing

A few remarks are essential to explain the above learning outcomes;

- RBT is a hierarchy; Featuring a skill at a given level entails featuring all previous levels' skills E.g. "understanding" which is ranked level two is implied by "applying" which is ranked level three.
- Our learning outcomes do not map one-on-one on 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.
- Not all RBT levels are mapped to our learning outcomes. This illustrates the potential gap between this general purpose taxonomy versus the specificities of the disciplines to which it is applied.
- Unlike RBT, our learning outcomes categories are not structured as a hierarchy. Instead, they feature pre-requisite dependencies; SK0 is pre-requisite to other skills. SK3 requires SK1.

From the educational research perspective, taking the revised Bloom taxonomy as a starting point to identify learning outcomes in a specific discipline is a sound endeavor. However, our work still relies implicitly on the assumption that teaching higher order thinking skills would improve our graduates' education and therefore employability. The next section will discuss how we validated this assumption.

5. VALIDATING SYSADMIN LEARNING OUTCOMES

Establishing need for higher order thinking skills

The need to impart higher order thinking skills, alongside with more technical knowledge, to students in the computing disciplines is an endeavor to which almost every university subscribes. However, it is relevant to ground this need in industry-based data, especially when graduates are expected to also compete in the regional hiring market. To this end, our team gathered an advisory committee composed of 11 executives from local companies which rely heavily on Linux technologies and hire accordingly.

The members were surveyed, using surveymonkey.com, to gather background information; e.g. their specific usage of Linux technologies, the number of employees affected by them and other relevant criteria. For the sake of being self-contained, the survey introduced our hypothesis regarding the need for higher order thinking skills. It then defined them by reference to the Revised Bloom Taxonomy **[2]** to ensure both educators and practitioners shared the same vocabulary & concepts.

Question #4 captures respondents' attitude toward the need for higher order thinking skills.

4. Skills for an ideal new hire in Linux system administration:

4c. Please use the below scale to indicate the relative importance of certification-oriented versus high-order thinking skills would be?

Certification-oriented ❒ ❒ ❒ ❒ ❒ ❒ ❒ ❒ ❒ ❒ Thinking Skills

The responses were coded using a value from 1 to 10. Results were then interpreted to determine the potential of the program as a whole in terms of graduates' suitability for our regional hiring market. Section 6 will reviews the conclusions derived from these results.

Establishing the suitability of our Learning Outcomes

Similarly, question #5 was designed to assess whether our learning outcomes were deemed as beneficial to our graduates' employability. To this end, we articulated the question in two parts, asking respondents what percentage of current employees, demonstrated a particular learning outcome; then asked respondents how many employees they would optimally have with the same skill. The question thus allowed us to assess the value attached to each specific skill based on the respondents' expressed need for more employees featuring it. The question was phrased as follows;

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:	0%	10%	25%	50%	75%	90%	100%
SK1 – Following procedures	❒	❒	❒	❒	❒	❒	❒
SK2 – Technical Information Retrieval	❒	❒	❒	❒	❒	❒	❒
SK3 – Designing procedures	❒	❒	❒	❒	❒	❒	❒
SK4 – Evaluating / Validating solutions	❒	❒	❒	❒	❒	❒	❒
SK5 – Troubleshooting	❒	❒	❒	❒	❒	❒	❒

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:

	0%	10%	25%	50%	75%	90%	100%
SK1 – Following procedures	❒	❒	❒	❒	❒	❒	❒
SK2 – Technical Information Retrieval	❒	❒	❒	❒	❒	❒	❒
SK3 – Designing procedures	❒	❒	❒	❒	❒	❒	❒
SK4 – Evaluating / Validating solutions	❒	❒	❒	❒	❒	❒	❒
SK5 – Troubleshooting	❒	❒	❒	❒	❒	❒	❒

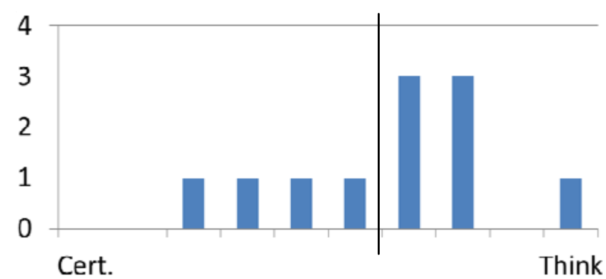
The results were gathered by counting the number of respondents who ranked a given skill at each of the above-listed percentage values. We discuss the results in the next section.

6. OBSERVATIONS & DISCUSSION

This section reviews question #4 to validate the overarching presented hypothesis, and then discusses how each learning outcome is validated in question #5.

Question #4 – Validating need for higher order thinking skills

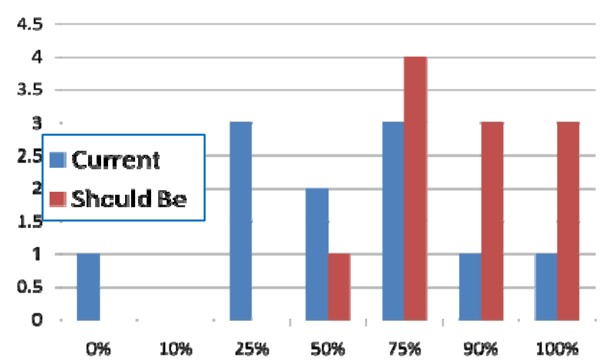
This graph plots the number of respondents for each response value between 1 – certification skills are important, and 10 – thinking skills are important. It reveals that 7 out of 11 respondents prioritized thinking skills over the mean of 5. However, 6 out of 7 responded at levels 7 or 8.



This suggests higher order thinking skills are indeed valued. However, respondents preferred these cognitive skills to support rather than detract from more immediately usable certification-based skills. This actually justifies our initial desire to not only juxtapose certification-only with academic-only courses but instead teach technical skills at a higher cognitive level.

Question #5 – SK1 – Following Procedures

All of the following graphs combine responses to questions 5 and 6 on the same scale; for each percentage value, a number of respondents is plotted as a bar. This blue bar plots the number of respondents who reported this specific percentage of employees already with the skill. The red bar plots the number reporting they would like this percentage of their employees to feature it.

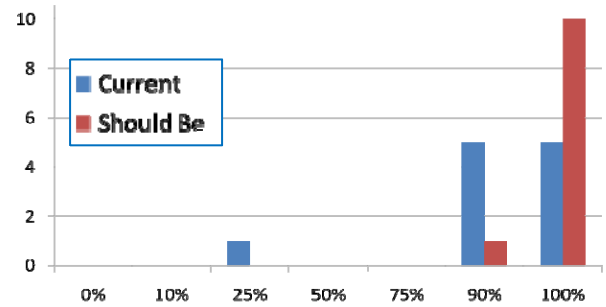


For SK1, only 2 out of 11 respondents indicated that over 90% of their employees were already able to follow procedures. Six respondents indicated still needing 90% of their employees to feature this skill.

Initially, our team thought this learning outcome to be relevant to the daily work of a system administration but also already widespread among Linux professionals. However, this response suggests the skill might not be reliably imparted to students by traditional Linux training thus warranting an explicit focus on teaching it.

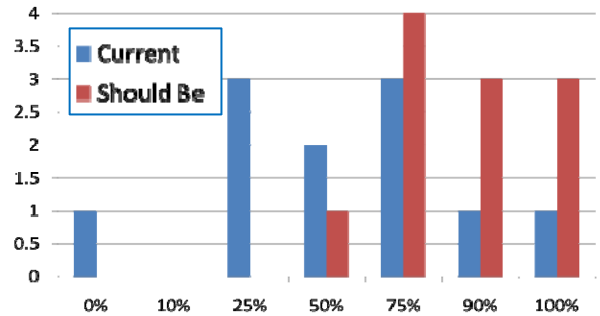
Question #5 – SK2 – Technical Information Retrieval

Responses suggest most of the respondents, i.e. 10 out of 11, estimate to have over 90% of their employee already skilled in technical information retrieval. Even more respondents, 10 out 11, indicate needing 100% employees with this skill. While the move from 90% to 100% might be seen as a small improvement, this response at least suggests SK2 to be an essential skill thus worth explicitly teaching.



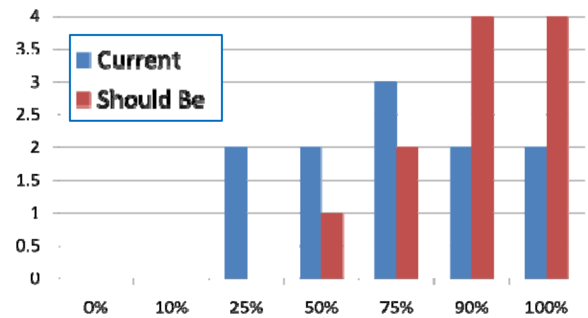
Question #5 – SK3 – Designing Procedures

A significant gap is seen here. While respondents rate their current employees' SK3 skill close to a normal curve, they indicate a significant need for an upgrade of this skill. It is also worth noting that, while all respondents report wishing this skill in over 50% of their employees, the peak is at around 75% - 90% with 7 out of 11 respondents in this range.



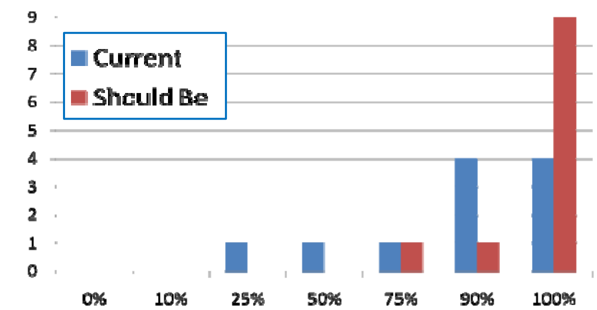
Question #5 – SK4 – Evaluating / Validating Solutions

Again, a significant perception of a need for improvement in evaluation and validating solutions is seen. Notable is that eight of eleven respondents felt that 90 to 100% of their future system administrators should possess this skill.



Question #5 – SK5 – Troubleshooting

Respondents look for a significant upgrade in this most advanced skill in their future hires. Nine of eleven respondents felt that 100% of their future hires should have, or quickly acquire, troubleshooting skills.



7. Conclusion & Future Work

Let us step take a wider perspective on the results provided by this survey in order to establish the limits of what one might infer from our experience. First the positive outcomes;

- Our advisory board validated the need to impart higher order thinking skills to IT graduates destined to work with Linux technologies. The board response to question 4 suggests such skills still need to be related to Linux system administration rather than theoretically abstract.
- The various learning outcomes we have introduced have all been validated through respondent's indication that a larger percentage of employees with these skills would be desirable.

These results allowed our institutions to validate the impact of their joined efforts on the regional hiring market. The next logical step is 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. As such, this study is to be considered preliminary to a much larger one. However, it aims at providing a solid foundation for follow-up studies while drawing the attention of our computing education research community to the potential for discipline-based educational research related to system administration.

8. ACKNOWLEDGMENTS

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