

Learning Outcomes within a Server-Virtualization Computing Environment

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Abstract

This paper presents qualitative and quantitative learning outcomes when using virtualization to teach computer and network security concepts. Using the self-determination theory as our lens, we establish the relationship between the components of the self-determination theory— autonomy, relatedness, and competence—and the virtualized instructional environment. The data presented was collected from a higher-education course taught at North Carolina State University in fall 2007.

Background Concepts

The instruction of computer and network security contains, by definition, logistical and/or technical barriers to their effective instruction, and traditional mechanisms and techniques cannot create a learning environment to satisfactorily impart the material to the learner. Information security curriculum traditionally requires students to have physical access to computing resources, and thus forces students to conform to the schedule of lab or school. Furthermore, activities in support of computer security or networking curriculum often require modifications to the operating system to complete the activity. Almost always, these changes must be "undone" after activity completion to reset the operating system for the next student. The need to "reset" often leads activity design to have an element of simulation through statements like, "in a real environment, now we would"

In an effort to overcome these limitations, this study analyzed the learning-outcome connections when leveraging server-virtualization as the foundation of an "isolated" computing learning environment in an actual classroom at North Carolina State University during fall 2007. We intuit that server-virtualization will create "real-time" learning opportunities because students are free to explore along with the learning that comes from authentic mistakes as a result of encouraged experimentation.

We investigated the impact of this learning environment by examining students' perception of autonomy, relatedness, and competency, the three components of the self-determination theory (Ryan and Deci, 2000). Our inspection of learning outcomes is framed from the following research questions:

1. How does a server-virtualization learning environment drive academic performance?
2. What are participants' perceptions of virtualization as a learning environment?
3. How do participants perceive the influence of virtualization on their academic self-efficacy and motivation?

Literature Review

This study explored virtualization as an instruction mechanism, a topic at the intersection of pedagogical theory and computer security discipline. These two areas do not lend themselves to each other by way of natural extension; reflecting this reality, existing, foundational literature is bifurcated into pedagogical or technical perspectives, but never both.

From the technical perspective, several technical publications cite virtualization as a mechanism supporting education in the computer science classroom (Briner et al., 2005; Hu et al., 2004; Ragsdale et al., 2003). A subset of these authors recognizes the inability of students to complete whole exercises because every exercise must be undone before the next student may try (Hu et al., 2004; Ragsdale et al., 2003). Moreover, existing literature recognizes that testbeds supporting network security topics require significant amounts hardware and suggest that virtualization may be the mechanism to overcome this costly requirement (Hu et al., 2004; Ragsdale et al., 2003). These publications, however, do not address with any specificity the learning outcome changes induced in their audience, and, therefore, could not articulate the merits of virtualization from a pedagogical perspective.

Looking through academic education research, there is no pedagogical literature so specific it provides a discourse on the pedagogical techniques and associated merits of computer and network security instruction. However, the research presented herein links virtualization to the self-determination theory through its components: student autonomy, relatedness, and competence (Ryan and Deci, 2000).

The lack of learning-outcomes literature relating server-virtualization environments is a clear indicator of the void in the field, and this publication is the first to apply the self-determination theory model to learning environments powered through server-virtualization. The terms "virtualized" and "virtual" are employed often within literature, but none wield the term to indicate "server-virtualization." In the interest of clarity, "server-virtualization," sometimes called "hardware virtualization," or simply "virtualization" indicates *the simultaneous operation of multiple, completely independent operating systems inside of a single physical computer*.

A high level of understanding of the technical merits of a virtualized environment is critical to understanding why it is being applied to this instructional problem, and it can be best understood from the visual description below. Without virtualization (**Figure 1**), a single physical machine can, by definition, only run one operating system at a time. Multiple students may log-in to this single operating system simultaneously; however, once "user A" begins editing any operating system security or network configurations, these changes affect all other users. This creates the scenario where an operating system has to be "reset" for another student to perform the activity again. Typically, to ensure repeatability of an activity, students must follow the exercise directions exactly and without a mistake or create the potential for an operating system to not return to its "reset" state for the next student. In an effort to not limit students' learning experience at the hand of a technical hang-up, let us consider the virtualization alternative.

Virtualization (**Figure 2**) allows our single physical computer to simultaneously run multiple, totally isolated operating systems, one for each student inside itself. In this way, each student's actions cannot affect or interfere with another student's learning experience; complete operating system independence is the component making our learning environment a completely "isolated" event.

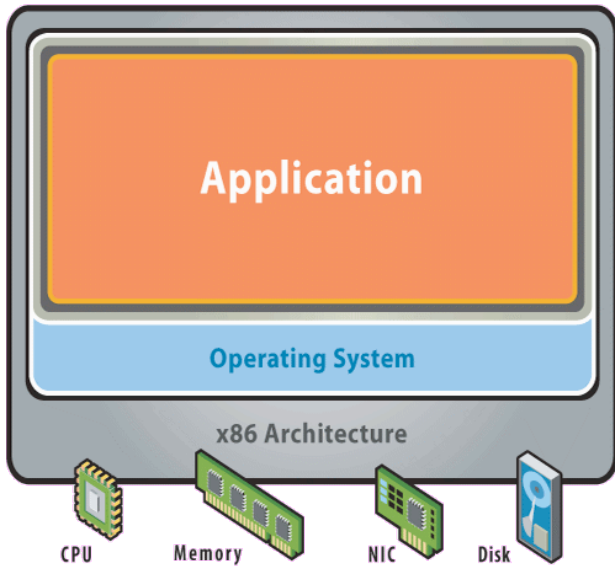


Figure 1. A non-virtualized environment.

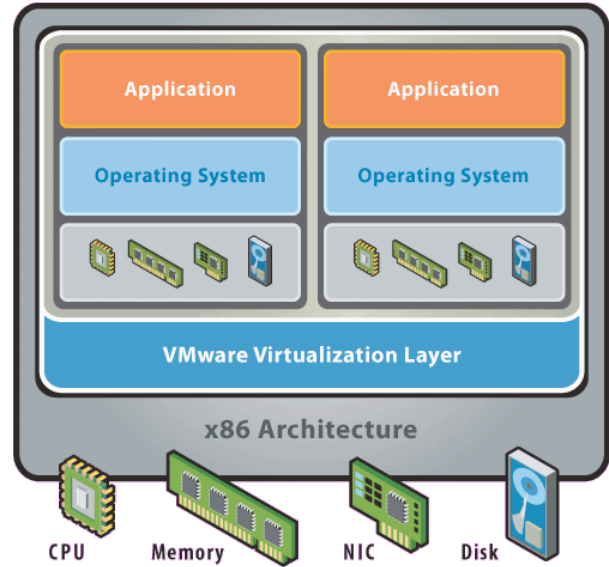


Figure 2. A server-virtualized environment.

Methodology

This study was conducted in a single section of a senior-level Computer Security course (CSC 405) at North Carolina State University taught during the fall 2007 semester; the course description is as follows.

Basic concepts and techniques in information security and management, such as risks and vulnerabilities, applied cryptography, program security, malicious software, authentication, access control, operating systems security, multilevel security, trusted operating systems, database security, inference control, physical security, and system assurance and evaluation. Coverage of high-level concepts, such as confidentiality, integrity, and availability applied to hardware, software, and data.

A pre- and post-content specific, Likert-based survey was developed in collaboration with a doctoral student researcher in curriculum and instruction and was administered on the first and last day of class. Statistical deviation was calculated around these tests to determine correlations between the learning environment and students' perceived learning.

Immediately after the class was completed, students were invited to provide qualitative feedback on their experience through a recorded interview. Two students volunteered for this opportunity. These interviews were later transcribed and coded for themes by two separate readers. Inter-reader reliability was high, as independent readings identified 92% of an overlap of themes.

Findings

Quantitative Results and Implications

Pre- and post-test scores were collected from 36 participants. The pre-test mean score was 40.27 and the post-test mean score was 85.83 (**Table 1**). There was an average gain of 45.56 points from the pre-test to the post-test. This indicates that the students perceived they were more confident and capable on the subject matter, a reflection of autonomy, relatedness, and competency, the three components of self-determinism.

Table 1. Descriptive Statistics

Test Name	n	Mean	Variance	Standard Deviation	Standard Error	Median	Range	Min	Max	Q1	Q3
Pre-Test	36	40.27	739.92	27.20	4.533	30	100	0	100	20	60
Post-Test	36	85.83	213.57	14.61	2.43	90	50	50	100	75	100

Table 2 indicates that there is a significant difference between participants' pre- and post-tests scores. This difference is not due to chance, but may be explained by the server-virtualization learning environment.

Table 2. Paired T-Test Results Between Pre- and Post-Test

Sample Difference	Standard Error	Degrees of Freedom	T-Statistic	P-value
45.5	3.83	35	11.89	<0.001

A correlation was run between participants' post-test scores and final exam grades, and produced an R value= 0.33. To provide an interpretation of this result, participants' post-test scores can explain 33% of final exam grade variation. The post-test measures students' perception of abilities relating to autonomy, competence, and relatedness; therefore, this statistic establishes the correlation link between students' increased self-determinism from the virtualization environment and their overall learning as evaluated from the final exam.

Qualitative Results and Implications

The qualitative portion of this study is interested in the perceived changes regarding autonomy, relatedness, and competency. These three terms are defined as follows: (Ryan and Deci, 2000).

- **Autonomy:** Feeling of control because of the learning environment.
- **Competence:** The nature of the server-virtualization learning environment, participants expressed a feeling of competence.
- **Relatedness:** The learning environment allows participants to feel as if they were learning.

Our two student feedback volunteers have had their names changed; this study will refer to them as Rick and Bob. Our subjects provided feedback, and after being coded independently, sections, which all coders identified, have been reproduced below. The coders identified the statements below as speaking toward autonomy through themes of flexible scheduling, using multiple operating systems, and isolation from other students' mistakes.

Bob: "I prefer the isolated, virtual environment because if it gets screwed, up it can easily be rebuilt."

Bob: "With virtualization, I can do stuff whenever I want to. It's really flexible."

Bob: "I have four different operating systems available to my one computer through the virtual environment, and that's really nice."

Rick: "We can do our security exercises on our systems as well as their systems without interfering with the rest of [North Carolina State University] or the world which is a major concern for some computer scientists."

The coders also identified the following statements from Rick and Bob as fortifying the student perception of competence. Statements supporting competence contain themes of being able to work in an isolated system that allows the student to make mistakes and receive instant feedback.

Rick: "It was nice to see instantaneous results on anything you did."

Rick: "If we were doing this in a real lab, someone would be looking over our shoulders making sure we weren't breaking anything. That sours the experience a little bit, because we're learning from experience, and part of that is making mistakes."

Finally, the coders recognized relatedness themes from our student feedback via statements of appreciation of the virtualization environment being a "real-world" skill.

Rick: "Doing security exercises the other way [not with server-virtualization] would feel fake, and the way we do it now, things can break, and it's more like real life."

Concluding our qualitative findings, students, through their feedback, did show a qualitative increase in autonomy, competence, and relatedness. Reinforcement of each of these learning qualities qualitatively demonstrates how server-virtualization increases self-determination, and, thus increases learning outcomes.

Study Limitations

The sample used in this study does not have an even distribution of males and females. This is not an accurate reflection of the general population, but is a common theme found throughout many computer science courses at the collegiate level. The qualitative portion of this study used a multiple-case study. A consequence of this type of method is that the results cannot be generalized beyond the sample population. The richness and quality of the data collected from the case studies does support our quantitative findings, strengthening the conclusions and stated implications for education. Another limitation is that we do not have a control group to compare against; this would enable our study to also conclusively identify causality in addition to correlation.

Implications for Future Instruction

In conclusion, teaching curriculum within an environment supported by virtualization improves the student experience as shown by positive learning outcomes, such as academic achievement, increased self-efficacy, and an increase in motivation. Therefore, leveraging this technology does not come without its challenges, albeit different challenges. Based on qualitative feedback, a better defined and more effective support mechanism would have decreased frustration and increased student productivity.

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