Automated Authentic Assessment: Applied to an Undergraduate Course in Network and System Administration

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***Abstract*—The traditional pen and paper exam is overwhelmingly the preferred method of assessing students in Norwegian higher education. There is a pressing need to explore alternative approaches that can authentically assess critical competencies needed for solving real-world tasks that professionals typically face in their field. In this paper, we present a solution to address the challenge of applying authentic assessment to a practical course in Network and System Administration (NSA). Furthermore, the solution we propose provides formative feedback to the candidates while a task is being evaluated.**

***Keywords*—Authentic Assessment, Automated feedback, Learning outcomes, Active Learning**

I. Introduction

Whether we are socializing with friends, family members, or simply purchasing goods online, a large portion of the digital services we regularly use heavily depend on underlying IT infrastructure.

For many organizations, deploying, configuring, and maintaining the infrastructure running the critical services we so much rely on, is a challenging endeavor that requires professionals with unique competence and technical skills. Network and system administrators fulfill this crucial role. They are the architects, engineers, and stewards of the interface between the digital world and the real world [9].

Network and System Administration (NSA) is about putting together a networked system of computers, software (workstations, PC's and supercomputers), getting them running and keeping them operation in spite of the activities of users who tend to cause the parts of the system to fail [11].

From a teaching and educational perspective, NSA is challenging for the following reasons.

- **Providing an authentic learning environment:** Acquiring hands-on skills is a crucial part of helping students to understand how NSA concepts are implemented in practice. Students require root/administrative privileges to perform many of the tasks needed, such as installing software, including the operating system, writing or modifying system configuration files, troubleshooting, testing, debugging, etc.
  An authentic learning environment in NSA, demands a numerous amount of preparation and testing to align the practical assignments and projects with the course learning outcome.
- **The need for fair and authentic assessment:** The assessment of learning outcomes is an integral part of the European Credit Transfer and Accumulation System (ECTS). In a white paper [13] published in 2017, the Norwegian Ministry of Education and Research announced that by 2019, it expects higher education institutions to use learning and assessment methods supporting in-depth learning and enabling students to achieve the set learning outcomes. The authors of [16] identified that unfamiliarity with alternative assessment methods and the shortage of digital skills are potential barriers to switching from conventional assessment methods.
  Results from the yearly national student survey show computer science undergraduate student's dissatisfaction with assessment methods practiced at our department. The satisfaction score is slightly lower than the overall national average [19].
  In this paper, we consider authentic assessment as an alternative assessment method.
- **Providing automated and timely quality feedback:** Studies have shown that feedback has a significant positive impact on learning outcomes [12].
  Students in NSA need to acquire troubleshooting skills. They often have to investigate the system logs to understand application misconfiguration and why a service hasn't started. Still, they also would like to know if the assignment or project they completed is correct according to the instructor's requirements. Writing an automated feedback is time consuming, error prone and requires a lot of testing to ensure that the correct feedback is given to the student.
- **The changing roles of NSA:** Traditional NSA skills taught at our department are still in demand, but due to technological advances, NSA is gradually diverging into other directions. Concepts such as DevOps, Microservices, Infrastructure as Code, Continuous Integration - Continuous Deployment (CI/CD), Site Reliability Engineering (SRE) demand additional skillset from NSA. Coping with constant and fast changes in the profession is a challenging endeavor for teachers.

II. RELATED WORK

A. Authentic Learning Environment

Authentic learning is a pedagogical approach that situates learning tasks in the context of real-world situations, thus allowing students to experience the same problem-solving challenges in the curriculum as they typically encounter in their respective professions [5]. Numerous studies have shown authentic learning environments enables students to acquire essential skills that are critical to their careers [5].

An approach to incorporate authentic learning in a network and security course was proposed by [10]. A mobile device based computer network labs was used to help students better understand networking and security fundamentals via hands-on practice and immersive experiences.

The paper [15] presented an authentic learning environment for a secure software development course. Learning modules with hands-on labs based on the recommendations of the Open Web Application Security Project (OWASP) were deployed. The paper reports that students were overwhelmingly favorable to the proposed approach.

A framework of a 3D immersive game designed to educate the networked game device user about the potential security risks is provided by [17].

The authors of [1] presented the capstone course Tech-Launcher that aims to better prepare graduates for the work force. The program is run in collaboration with industry to provide students an authentic project experience.

B. Authentic Assessment

Assessment is a fundamental part of the curricula development that can significantly influence the learning outcome. Studies indicate that authentic assessment has an impact on the quality and depth of learning achieved by the student [20]. The term authentic assessment was first introduced by Grant Wiggins in 1989 [22]. The goal is to provide students with an authentic learning environment that replicates how professionals conduct their work, hence engaging students to demonstrate their competency in a more realistic setting.

An application that permits the students to assess their practical work utilizing scripts was developed and presented in the paper [23]. Students are assigned a set of computer security and network system administration tasks. Upon completion, the student executes the evaluation script from a web interface and then receives an automated assessment.

A portable tool for assessing practical learning outcomes was developed by [14]. Their study focused mainly on how the application could be used within a laboratory environment on a computer networking degree program to improve the quality and timeliness of assessment and feedback.

This paper introduces an innovative approach that combines an automated formative and summative assessment. Furthermore, it presents an authentic learning environment supporting students in obtaining fundamental skills that are crucial to their profession.

III. MOTIVATION AND BACKGROUND

The Department of Computer Science has been offering a course on NSA since 1999. From its inception, NSA has been a core and mandatory part of the Software Engineering undergraduate degree. To appeal to a broader audience, the department decided in 2009 to offer the course as a 10 ECTS credits elective to all the 3rd year students.

In the beginning, the department dedicated 2 lab facilities each containing 15 workstations running Linux. Supporting, securing and maintaining the workstation posed a technical challenge to the department. Another challenge with the physical labs was assessing the work of the students. Although physical workstations gave the sense of real life work situation, the instructor had to manually login to the machines in order to assess the completed tasks. This was often time consuming, prone to error and lacked methods of ensuring the integrity of the delivered work. Students could easily assert that they delivered a working solution and claim foul play.

As the use of virtualization technologies became more widespread, the physical workstations were gradually replaced by virtual machines. The solution we propose utilizes VirtualBox as a virtualization platform .

VirtualBox is a virtualizing software for the x86 computing architecture [21]. In contrast to cloud services, VirtualBox is run locally on the device of the student, thus eliminating the dependency on physical labs or an external cloud service that is prone to outages. The instructor can create an image containing the desired operating system and the necessary software required for the course.

Providing a single image to all the students has the extra benefit of ensuring that every student gets the same environment, thereby avoiding a lot of additional support that usually arises from misconfigurations, different versions of the software, and ambiguous choices. Students can then use the provided image to conduct their weekly assignments at any time or place. The same image is used for the final projects.

Assessment is also simplified as the scripts for assessing and giving feedback is bundled into the same single image. The integrity of the delivered work is assured by taking a SHA 256 hash checksum of the final image that candidates upload to the department's Learning Management System (LMS).

The solution proposed in this paper intends to achieve the following goals.

1) Provide an authentic learning environment and give candidates opportunities to rehearse, practice, look for useful resources, and receive timely quality feedback to improve the quality of performance or product [8].
2) Provide an authentic assessment that is realistic. The tasks performed by the candidates should replicate or simulate the real-world contexts in which professionals are assessed in the workplace [8].
3) Scoring criteria used in authentic assessment must be transparent and be shared explicitly with students to facilitate their learning [8].

TABLE I
COURSE OUTLINE.

Week	Topic
1	Introduction to Linux administration
2	Operating system installation - Disks - Partitions - File System
3	Managing local storage - Redundant Array of Independent Disks (**RAID**) - Logical Volume Manager (**LVM**)
4	Software Installation
5	User Local Accounts Management
6	Centralized Account Management - Lightweight Directory Access Protocol (**LDAP**)
7	**Assessment of Project-1**
8	Manage file permissions and ownership
9	Network Attached Storage - Network File System (**NFS**)
10	Storage Area Network - Internet Small Computer Systems Interface (**iSCSI**)
11	Network Administration - Dynamic Host Configuration Protocol (**DHCP**) - Domain Name System (**DNS**)
12	Introduction to containers
13	Electronic Mail - Simple Mail Transfer Protocol (**SMTP**) - Internet Message Access Protocol (**IMAP**)
14	**Assessment of Project-2**

IV. COURSE DESCRIPTION

NSA is an elective course taught in the 5th semester to 3rd-year Computer Science students. The number of students that sign up for it varied over time, particularly after introducing Operating Systems as a prerequisite, enrollment decreased from circa 100 to approximately 30. The semester lasts for 14 weeks, and the schedule for each week consisted of a combination of 4 hours of lecture and lab. The lecture sessions varied from 1-2 hours, while the rest of the time generally reserved for lab sessions.

The roles and responsibilities of system administrators have evolved over the years; however, many of the core skills demanded are well established. The USENIX Association published job descriptions for System Administrators, including a list of required competencies at different levels or phases in their careers [2]. The course curriculum offered at our department covers a broad range of the skills described in the USENIX publication. Table I shows an overview of the course outline.

Students who desire to pursue further education in NSA are encouraged to enroll in the master's program offered at our University.

A. Providing an Authentic Learning Environment

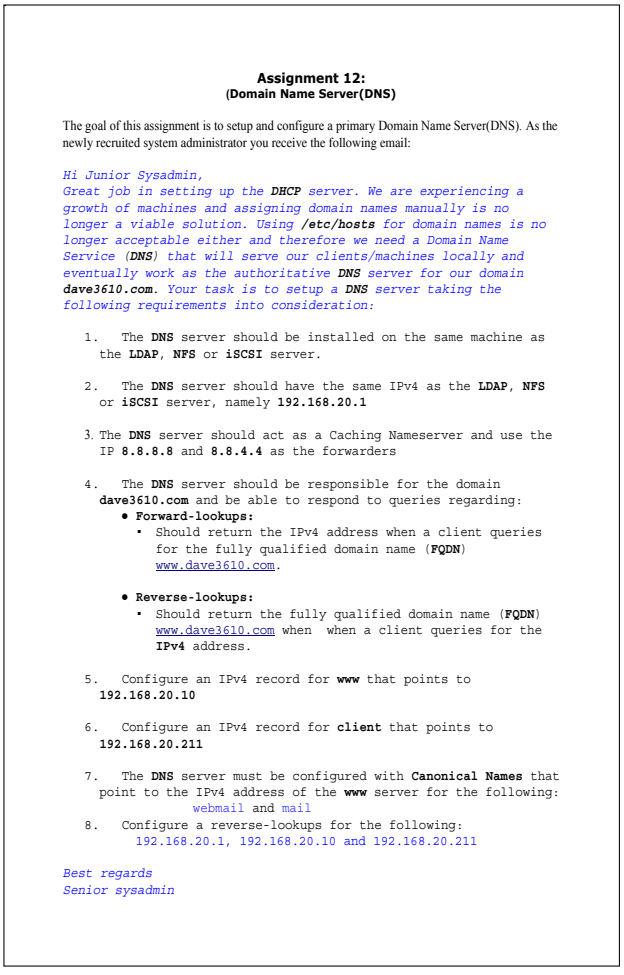
For authentic assessment to be successful, the learning task must resemble the assessment task, only with different underlying goals [3]. Furthermore, students should be permitted to practice with the form of assessment in advance.

System administrators work vigorously behind the scenes to keep the IT infrastructure operating 24/7. They are presumed to possess a plethora of problem solving and technical expertise. Their endeavors are rarely noticed until some digital service we depend on is no longer operational.

Our proposed solution provided the candidates with weekly practical assignments giving them ample opportunities to practice, look for useful resources, and prepare for the final assessment. Also, lectures with interactive demos, links to online resources, and references to the course textbook were provided to assist the candidates in solving the various tasks. Fig. 1 shows an example of a weekly assignment.

Bash scripts similar to the ones used in the final assessment were provided to give automated feedback to the students. Furthermore, the platform and software deployed for both the learning and assessment environments were identical.

Documentation provides a consistent source from which we can repeatedly reproduce our work, reducing the need to memorize the procedure or recurrent mistakes. It is an essential skill needed by system administrators. Candidates are required to document their solutions, and any problems encountered along the way. They are then permitted to use their documentation during the project assessment.



Assignment 12:
(Domain Name Server(DNS)

The goal of this assignment is to setup and configure a primary Domain Name Server(DNS). As the newly recruited system administrator you receive the following email:

Hi Junior Sysadmin,
Great job in setting up the ***DHCP*** *server. We are experiencing a growth of machines and assigning domain names manually is no longer a viable solution. Using* ***/etc/hosts*** *for domain names is no longer acceptable either and therefore we need a Domain Name Service (DNS) that will serve our clients/machines locally and eventually work as the authoritative* ***DNS*** *server for our domain* ***dave3610.com****. Your task is to setup a* ***DNS*** *server taking the following requirements into consideration:*

1. The **DNS** server should be installed on the same machine as the **LDAP**, **NFS** or **iSCSI** server.
2. The **DNS** server should have the same IPv4 as the **LDAP**, **NFS** or **iSCSI** server, namely **192.168.20.1**
3. The **DNS** server should act as a Caching Nameserver and use the IP **8.8.8.8** and **8.8.4.4** as the forwarders
4. The **DNS** server should be responsible for the domain **dave3610.com** and be able to respond to queries regarding:
   - **Forward-lookups:**
     - Should return the IPv4 address when a client queries for the fully qualified domain name (**FQDN**) www.dave3610.com.
   - **Reverse-lookups:**
     - Should return the fully qualified domain name (**FQDN**) www.dave3610.com when when a client queries for the **IPv4** address.
5. Configure an IPv4 record for **www** that points to **192.168.20.10**
6. Configure an IPv4 record for **client** that points to **192.168.20.211**
7. The **DNS** server must be configured with **Canonical Names** that point to the IPv4 address of the **www** server for the following: webmail and mail
8. Configure a reverse-lookups for the following: 192.168.20.1, 192.168.20.10 and 192.168.20.211

Best regards
Senior sysadmin

Fig. 1. An example of a weekly assignment

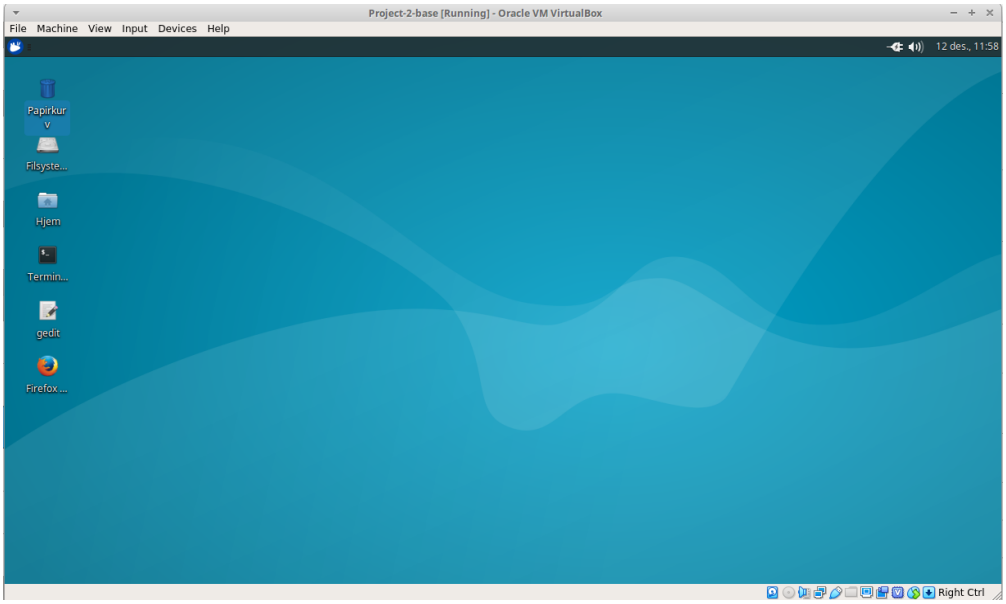


Fig. 2. A minimal desktop environment presented to the student.

V. The Proposed Solution

All the weekly assignments and project tasks are performed on the command line (terminal); hence, the candidates need only a limited number of desktop applications such as a browser to access the department's LMS, an image, and a text editor as depicted in Fig. 2.

The instructor prepared a VirtualBox image containing a Linux Xubuntu core (18.04) virtual machine equipped with the bare minimum software required. This has the extra benefit of producing a small compact image that is easily distributable to the students.

In addition, the following tools were installed on the system to support the proposed assessment solution:

- **a2ps:**
  - a utility that formats and converts file(s) or standard input from the terminal to PostScript.
- **convert:**
  - is used to convert between image formats as well as manipulating image properties such as size, blur, crop, despeckle, dither, draw on, flip, join, re-sample, and much more.
- **expect:**
  - a program that "talks" to other interactive programs according to a script. Following the script, Expect knows what can be expected from a program and what the correct response should be.
- **asciinema:**
  - a free and open source solution for recording terminal sessions and sharing them on the web.
  - the recorded session can be replayed using timing information saved in the asciicast

```
#!/usr/bin/expect -f
# We a set the timeout
set timeout -1
# We set the  variable cand that is read from a file
set cand [exec cat /home/sysadmin/candidate ]

# We set a timestamp of when the test/script was conducted
set dato [exec date +%d-%b-%Y-%T ]
# We creates a new process that executes the asciinema
    program
spawn /snap/bin/asciinema rec -q  -t $cand-$dato
# The input expect is expecting after spawnin the process
expect "$ "
send "/home/sysadmin/project-2/tests/testall.sh $cand\n"
expect "$ "
send "exit\n exit\n"
# Expect is informed to interact with the input
interact
```

Listing 1. An expect script that tests all the tasks and records terminal sessions with Asciinema

```
#!/bin/bash
# The candidate number is written to a file when the
    candidate executes the script.
# Here we are reading the candidate number from that file.
CANDID="`cat /home/sysadmin/candidate`"
# Here we define the task
TASK="permission"
# Here we are executing the script that will produce an
    image.
# The image is then stored under the folder images.
# The script uses several Linux tools to produce the final
    image in a PNG format.
# The final image will be named following the convention
    CandidateNr-TaskName.png.
test-$TASK-Take-Image.sh | a2ps -B -q --media=A4 --borders=
    no -o out1.ps && \\
gs -sDEVICE=png256  -dNOPAUSE -dBATCH -dSAFER -
    dTextAlphaBits=4 -q  -r600 -sOutputFile=images/$CANDID-
    $TASK.png out1.ps

convert -rotate 90 -negate images/$CANDID-$TASK.png images/
    $CANDID-$TASK.png
rm *.ps*
```

Listing 2. A bash script that produce an image from the output of another script

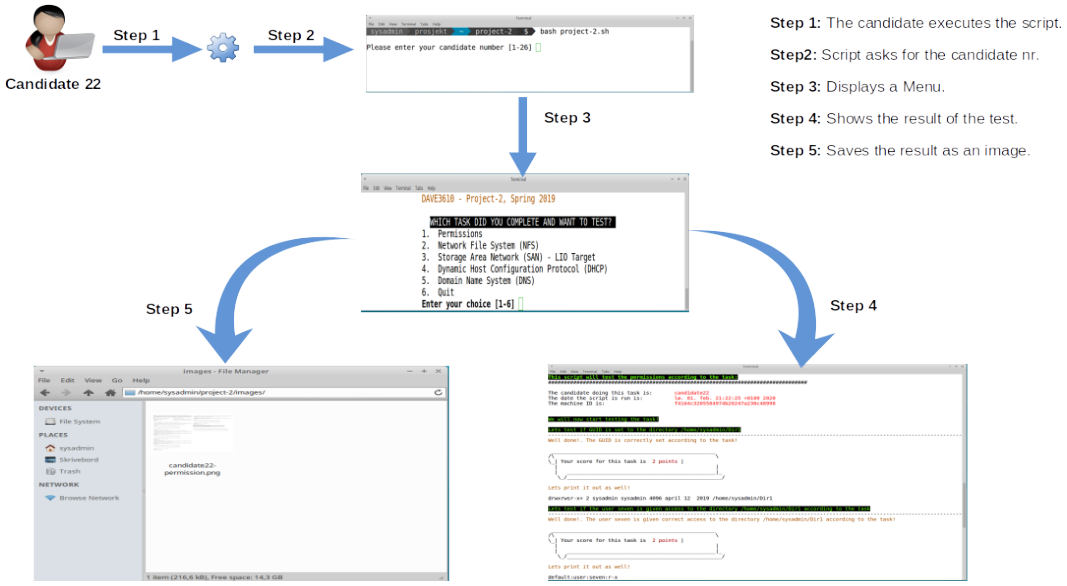


Fig. 3. Architecture of the proposed solution.

VI. Architecture Overview

The assessment methods of NSA has transformed over time from a traditional exam, project reports, and finally to a portfolio with the following deliverable:

- **Two individual projects:** On each project, candidates are required to deliver a virtual machine containing Linux servers with all the services installed and configured according to predefined assessment criteria.

The individual projects are assessed separately in a four hours strictly controlled session. The first is held at midterm, while the second is taken at the end of the semester. Candidates are permitted to use their own devices, documentation, and have access to the internet. Fig. 3 illustrates the overall architecture of the proposed solution. A detailed description of the different steps will be elaborated further in the following section.

A. Automated Authentic Assessment

As mentioned earlier, assessment is cried out in a closely controlled session. Candidates are provided a link where they can download a Linux virtual machine containing the bare minimum software required. The assessment environment is identical to the one provided to the candidates at the start of the semester where they performed the weekly assignments.

When the candidate boot the virtual machine, it is automatically assigned a unique ID that is used in conjunction with the candidate number to identify the project under assessment.

Candidates are then asked to perform practical tasks chosen from a pool of the weekly assignments. An example of practical task is illustrated in Fig. 5.

Once the task is completed, and the candidate is ready to test the setup, they execute a shell script. As depicted in Fig. 3, the script performs several steps. First, it asks the candidate to enter their designated candidate number, then presents a menu where the candidate can select the task to examine.

Depending on the candidate's selection, a separate module gets called that performs the actual assessment. The process is composed of several modules, each containing bash scripts customized for a particular task. Expanding the solution is as simple as adding a new module.

Upon selecting from the displayed options, the script will conduct the necessary inspections and print the results on the screen. It also provides formative feedback to the candidates in the form of scores obtained for the particular task. In the event the assignment is uncompleted, the candidate is informed of the error and encouraged to correct it before proceeding to the next step. The script has a built-in feature that takes a screenshot of the output, adds metadata information to it, and saves the image file adhering to a particular naming convention.

The image is used as a validation of the completed task. It contains the output, including the obtained score, the identity of the candidate performing the task, timestamp capturing when the script executed, and on which machine it ran.

The candidates can execute the script as many times as they desire until they deemed satisfied with the outcome. On each iteration, the previous image is overwritten and a new one produced in its place. Regardless of whether the candidates eventually succeed in solving the task or not, they are required to execute the script and upload the image to the department's LMS.

As a backup and measure against academic dishonesty, candidates must execute a final script before turning off the virtual machine and leaving the premises. The script assesses all the tasks, transfers the results to the Asciinema tool which records the output, and posts it to a private online repository only accessible to the instructor as depicted in Fig. 4. An example of an assessment recorded with Asciinema can be accessed at [4].

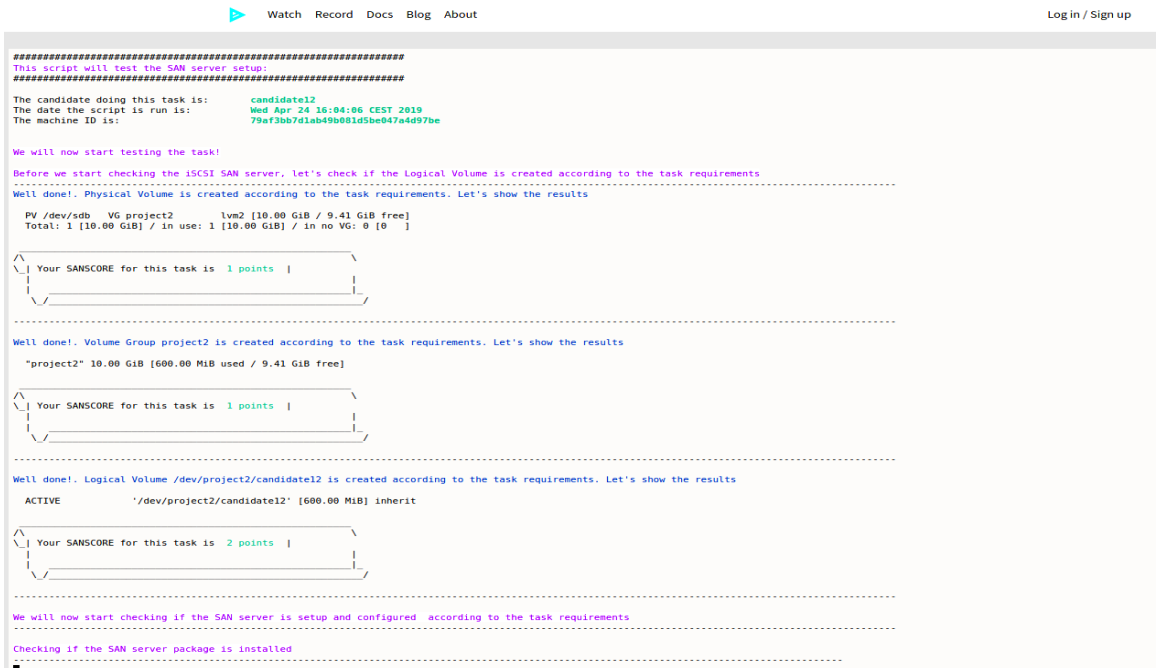


Fig. 4. Results of an actual assessment recorded with Asciinema

B. Transparent Assessment Criteria

There are many positive aspects of authentic assessment, but it requires an enormous amount of time and preparation to put all the building blocks in place successfully.

A core element of authentic assessment is the transparency of the evaluation criteria. To ensure the integrity and impartiality of the assessment method, students should have in advance access to the scoring criteria for what may count as successful completion of the task [8].

Fig. 5 show an example of a scenario with predefined assessment criteria. Having access to the score of each task has the added benefit of enabling candidates to self-evaluate themselves, thus diminishing the need for external interaction. Furthermore, candidates get the opportunity to focus on and prioritize tasks with a maximum return value of invested effort.

By law, students in Norway er entitled to an explanation for the grade they obtained. The reason can be conveyed verbally or in a written report. Regardless of the method adopted, it will demand some time from the instructor.

Before applying the proposed solution, the NSA course had an approximately 1 to 3 students requesting grade clarification. Although this is small and currently manageable, the author preferred to reduce it further. This number dropped to zero after implementing the presented solution. It is the author's understanding that clear criteria, coupled with automated feedback and assessment, contributed to the swift reduction.

The author is convinced that the overall benefits outweigh the amount of time spent on developing proper criteria well aligned with the learning outcome and the assessment method employed.

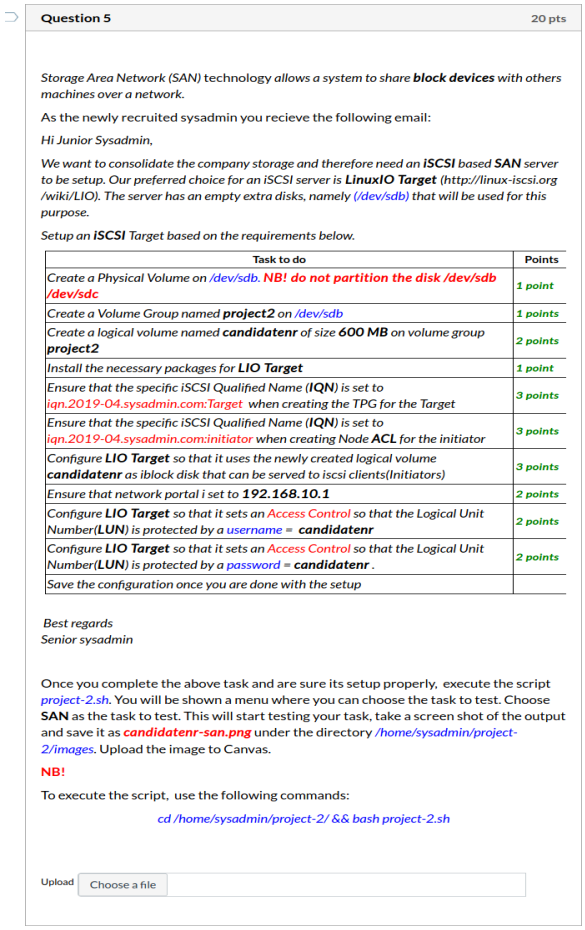


Fig. 5. An example of a scenario with predefined scoring criteria

VII. Method

The data were collected using an anonymous online questionnaire containing both open and closed-ended questions. Table II shows the closed-ended questions, while Table III shows the open-ended questions.

Q1 and **Q2**, are related the the learning environment while **Q3**, **Q4**, **Q5**, and **Q6** are related to the assessment and feedback.

The survey was published on the department's LMS shortly after administering the midterm assessment of the first project and was kept online until the end of the semester.

Candidates could participate at any time during that period, and the author sent reminders periodically urging them to respond. In the end, a total of 25 candidates responded to the survey.

Students' initial exposure to the assessment method was through the first project. An identical assessment method was utilized in the second project; therefore, publishing the survey after administering the first project was necessary, giving the candidates enough time to reflect before responding.

Although thirty students enrolled in the class, only 22 of the students completed the course. The fact that students were required to complete and submit two individual projects to get their final grade was a contributing factor to the decrease. Some of the students that did not complete the course participated in the survey.

Given the fact that the learning environment, assessment, and feedback method stayed the same the whole semester, the author decided to include those responses since the questions posed in the questionnaire were relevant for them as well.

TABLE II
Closed-ended questionnaire

Q1	Assignments were related to the course learning outcomes
Q2	Assignments mirrored real network and system administration scenarios
Q3	Assessment criteria was communicated clearly
Q4	Assessment was related to the course learning outcomes
Q5	Assessment reflected real network and system administration scenarios
Q6	Automated feedback during the assessment helped to improve my work
Q7	This was a worthwhile class and would recommend it to a fellow students

TABLE III
Open-ended survey questions

S1	What parts of the course did you enjoy/like?
S2	What parts of the course would you like to see improved?
S3	Any other suggestions that you would like to recommend?

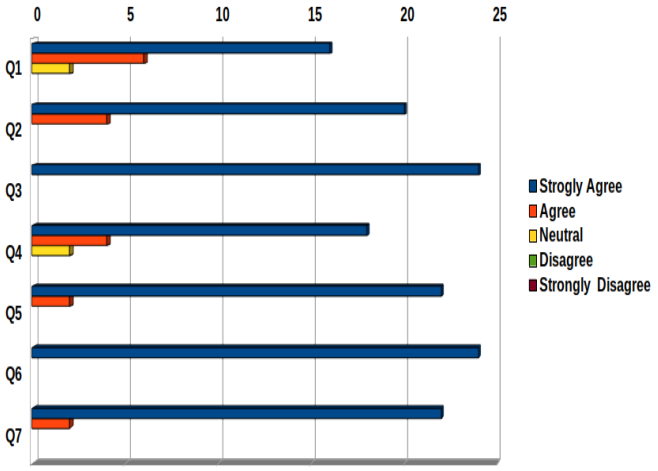


Fig. 6. Feedback from the candidates

VIII. Results

Fig. 6 shows the responses to the closed-ended questionnaire. In the next section we will present some of the responses to open-ended question.

On **Q1** and **Q4**, regarding whether the assignments and assessments were related to the course learning outcomes, 64% and 72% of the candidates responded strongly agree, while 24% and 16% respectively responded agree. In total, a substantial percentage of the candidates deemed the assignments and the assessment methods to be aligned with the learning outcome.

Furthermore, whether assignments and assessments mirrored real network and system administration scenarios, 80% and 88% responded strongly agree. The overwhelmingly positive response to **Q2** and **Q5** indicates that the students see the assignments and assessments as authentic that replicate real-world challenges.

With regards to feedback and whether the assessment criteria were communicated clearly, 100% of the candidates responded strongly agree. The remarkable response on **Q3** and **Q6** is strong evidence of the responder's satisfaction with the transparency of the criteria and the automated formative feedback.

The author acknowledges that the sample size of this study is not large enough to significantly determine and conclude the effect of the proposed solution. However, our results are consistent with similar findings in related research [5], [10] [15], [23], and [14], which reports notable positive impact on authentic tasks, automated timely feedback, and transparent criteria have on students learning.

On the whole, candidates regarded the class as a valuable one that they would recommend to fellow students.

Excerpts from the students' qualitative answers to the survey are presented in the next section.

A. Some qualitative student responses to the survey

"I believe that the basis of assessment reflects situations that could easily be found in the management of networks and systems. Where you have to solve specific tasks within a critical time frame, but have access to documentation and own notes."

"This was a very hands-on course, with unconventional but new and exciting assessment form. In my opinion, the most educational course at the University."

"Excellent documentation, live demos, and automated feedback helped me a lot when working with the assignments. I am also very pleased with the assessment method, which was automated and resembled a realistic situation."

"The positive thing about the course is that you get an insight into how a system administrator works. You get to know the basics of creating users and groups, changing permissions on files, setting up disks and not least installing and configuring packages. Everything from file permissions right up to the more demanding thing like setting up various servers such as DHCP, DNS and client-server based configurations."

IX. Conclusion

In this paper, we presented a solution to address the challenges of applying authentic assessment to a practical course in NSA. The solution also provided formative feedback to the candidates while a task is being evaluated.

Results from the anonymous online survey indicate that overall, students appreciated the automated assessment and feedback and deemed it as an essential enhancement to traditional assessment methods they previously encountered in other courses during their three years bachelor program.

Furthermore, the response from the participating candidates indicates overall satisfaction with the learning environment of the course in terms of weekly assignments that resembled authentic network and system administration conditions.

Although the participants suggested some minor improvements to the course in general, the majority of the responses on the open-ended questions also supported the results obtained in the close-ended survey with regards to an overwhelming satisfaction with the learning environment, assessment method, and automated feedback.

The author recognizes the need for a larger sample size to be able to validate the impact of the proposed solution thoroughly; nevertheless, results from closed-ended questions, coupled with the open-ended responses, suggest that on the whole, candidates responded positively to the proposed solution.

X. Future Work

The proposed solution is composed of several bash scripts customized for the relevant task under assessment. Each can be considered a separate self-contained module that is modifiable without affecting other parts of the system. The architecture is easily extendable and can be applied to cover different scenarios by merely creating a new module. Several courses currently taught at both the bachelor and master level can benefit from the proposed approach. Primarily, Computer Security, Operating Systems, Networking and cloud computing, and Problem-solving with scripting.

Although the presented solution produced successful results, there are some improvements needed to make it more generic that is easily adaptable to various courses. The solution profoundly relies on shell scripts and necessitates an in-depth knowledge of the Bash scripting language. Shell scripts are flexible and allow us to make use of Linux core built-in tools but also have some shortcomings. A common drawback with shell scripts is that they can fail in unanticipated ways and are difficult to troubleshoot or debug. To mitigate this complication, the author aims to explore alternative approaches that reduce or eliminate the dependency on customized bash scripts.

Open-source frameworks such as Chef InSpec [6], Serverspec [18], and Conftest [7] are promising solutions that the author would like to investigate further. Common for these frameworks is they provide generalized building blocks with a plethora of features to conduct many tests, among others the ability to perform a comparison of the current state of a system with the desired state expressed in a human-readable manner. These building blocks would undoubtedly integrate into our proposed solution as many of the tests currently handled by the scripts examine the desired state of services such as LDAP, DNS, DHCP, etc.

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