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Leveraging AWS Educate Classrooms in Cloud Computing Courses

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Abstract

Cloud computing has become a critical component for many organizations and teaching cloud computing concepts in information technology, information systems, and computer science programs is gaining in popularity. This paper reports the results of leveraging AWS Educate Classroom services to complete hands-on AWS cloud computing labs within cloud computing courses. These labs were completed without additional cost to the students nor the need to provide credit card information. In addition, student experiences with various cloud computing labs are summarized as to their educational benefit, challenge level, and foreseeable usefulness after college.

Keywords: Cloud Computing, AWS Educate.

1. INTRODUCTION

Cloud computing has become one of the primary means by which companies and organizations are fulfilling their technology needs (Srivastava, et al., 2021; Taleb & Mohamed, 2020). Therefore, teaching cloud computing concepts and methods should now be one of the primary foci of computer science, information systems, and information technology programs. Leveraging cloud technologies in education is commonplace through the use of cloud-based systems, such as learning management systems (LMS), office automation tools (such as Microsoft Office 360 and Google docs), and online lab support tools. Teaching how to build these systems is gaining in popularity (Chen, et al., 2012; Pike & Brown, 2019; Wood, 2018). However, finding tools that can be used in the classroom to help students gain hands-on experience creating sophisticated cloud-based systems remains a challenge.

Platforms, such as Microsoft Azure and Amazon Web Services (AWS), often require users to set up billing processes that require a credit card and can present an unknown financial risk to students. Fortunately, Azure and AWS now provide student accounts and resource credits so educators can leverage these platforms in their classroom activities. This can be done without having students provide credit card information and the risk of large unexpected charges when common mistakes in resource allocation are made and cloud resources are not utilized efficiently.

One such option is AWS Educate, which provides students the ability to explore many of the AWS services without cost to the student or the institution. With AWS Educate, students are never required to enter credit card information while leveraging their AWS Educate account, thus eliminating the risk of real charges while logged on through AWS Educate. Before AWS Educate, students would need to provide credit card information and potentially incur costs for using various AWS services. However, AWS Educate provides students with a $100 credit that could

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be applied towards any billable services consumed while exploring AWS technologies. Common billable services include cloud-based storage allocation, compute resources running cloud-based servers, and data transfer services. Even though AWS does provide some free tier services, these services are limited and some AWS costs are unavoidable. If a student consumes all of their AWS Educate credits, then no additional services can be utilized until additional credit is obtained, either through a yearly allocation or through some other student credit offering.

AWS Educate was introduced in 2015, giving educators and students AWS resource credits (Amazon Web Services, 2015). The initial usage of the service was positive but somewhat limited, as educators and students were given few resources on effective learning activities and learners were left to explore the vast services of AWS with no direction.

In 2016 AWS Educate expanded services through cloud career pathways, which provided learning tutorials on specific AWS services. In addition, a job board was added where students could post resumes and AWS skills and organizations could post open cloud technology positions (Amazon Web Services, 2016). The cloud career pathways provided content for educators to leverage in classroom activities and students to focus on self-paced learning labs. However, AWS credit was limited to yearly allocations of up to $200 for educators and $100 for students. This limited the amount of actual AWS activities that could be accomplished during the academic year in multiple classes.

In 2018 Vocareum began a collaboration with AWS Educate and took control of AWS Educate starter account allocations. Vocareum also added Classroom services, which greatly extended educator oversight and student credits for additional learning opportunities (PR Newswire, 2018). AWS Educate Classrooms provided educators with the ability to create a cloud-based classroom environment where students were given classroom-specific AWS credit without having students consume their yearly starter account credits. This created an environment where educators have better control and oversight of student resources for a specific course.

This paper seeks to examine two questions:

1. Can AWS Educate Classrooms be an effective resource in developing an environment to teach cloud computing?
2. Do students using AWS Educate Classrooms find the environment a value in learning cloud computing concepts?

This paper also provides an overview of AWS Educate Classroom and the steps used to integrate the service into cloud computing courses.

2. Literature Review and Study Methodology

From the early 2000s, cloud computing in education has been defined in many ways (Sultan, 2010). These definitions include terms like ubiquitous, on-demand, virtualization, elasticity, resource pooling, and commoditization (Ali, Smith, & Leslie, 2018). In addition, cloud computing is categorized in different service models, such as Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS), and many others (Sareen, 2013). Finally, cloud computing has been classified into different types, such as Private, Public, Hybrid, and Community (Goyal, 2014). Each of these aspects, along with others, contribute to the complexity of studying cloud computing and the difficulties of integrating cloud computing technologies into an education program. For this study, cloud computing will be defined as the creation and definition of Internet-based virtualized services primarily deployed as PaaS and IaaS models in a public environment.

In addition to these complexities, teaching cloud computing offers some additional challenges. The lack of teaching material and textbooks directly addressing cloud computing, the various cloud computing platforms and their continually changing interfaces, and obtaining subscription services for students in an equitable manner are just some of the additional concerns (Ali et al., 2018).

One of the main questions addressed by this study is to answer the challenge of obtaining subscription services for students in an equitable manner. That is, can AWS Educate Classrooms provide a subscription service model for students to allow for an effective resource in teaching cloud computing? Before the release of the AWS Educate Classrooms, AWS Educate put all AWS student credits into a single pool, which then needed to be used for multiple classes throughout the year. This presented a significant problem to educators when their students began their class with little to no AWS credits available to them because they had been used in a previous course.

This study sought to determine if using AWS Educate Classrooms, where additional AWS credits are provided to each student for a particular class, would resolve this challenge. In other words, would the additional AWS credit designated for a specific class provide all students the resources they needed to complete cloud computing lab assignments, regardless of how they had used AWS credit in the past?

This led to the second question for this study. Does AWS Educate Classrooms provide an environment where students can engage in hands-on cloud computing labs that lead to a valuable learning experience?

To address these questions, this study implemented AWS Educate Classrooms in three cloud computing courses. These courses consisted of two sections of a cloud computing course for information technology majors and one special topics course on cloud technologies for information systems and computer science majors. The focus of the labs provided in the courses was to provide students with hands-on experience in developing AWS cloud infrastructure and development skills. At the end of each course, the instructor reviewed student account information to determine if AWS Educate Classroom credits were sufficient to complete all learning activities.

In addition, students were surveyed as to which labs they found most educational, which labs were most challenging, and which labs were most likely to provide skills they would use after entering the workforce (see appendix A for the survey questions used). Each question allowed for an open-ended response and answers were both coded and tallied to score specific labs and to identify common themes. The first and third questions were designed to identify labs that provided a valued learning experience, while the second question was designed to identify labs that provided challenges or limited learning experiences. A total of 64 students participated in the three courses and all responded to the survey. Students had a wide variety of work experience, but most had limited experience using AWS or developing cloud-based technologies.

3. GETTING STARTED WITH AWS EDUCATE CLASSROOM

The first step educators should do is work with their institution to register with AWS Educate as a member institution if they are not already a member. The membership process is free but does require an authorized signatory and central point of contact (CPOC) at the institution to complete and agree to the current terms and conditions. The current membership application process is found at https://www.awseducate.com and takes between five and ten business days to complete. In addition to providing access to AWS Educate Classroom services, AWS Educate membership provides significantly greater AWS credit for educators and students ($200 and $100 respectively) than for non-members ($75 and $30) (AWS Educate, 2021). This step only needs to be completed once and AWS Educate membership does not expire.

The second step is for the educator to register with AWS Educate as an instructor and then request the creation of a classroom. During the classroom request process, educators will first need to select a course template based on the type of activities that will be completed during class. Most often the template will be AWS Cloud Basics. Next, the educator will be required to enter the course number, course name, course information link, start date, and end date. It is recommended the course end dates go until the estimated date when all grading will be complete so educators will still have access to student information if grading goes beyond the last day of class. The end date can also be changed if the course dates change or a student requires an extension to complete assignments after the end of the semester.

In addition to basic course information, educators will need to enter an estimated number of students and request an AWS credit dollar value. The standard credit request is $50 or less and does not require any additional justification. Values greater than $50 may require additional justification, which will include identifying what specific activities and AWS services will be used and their estimated costs. The maximum credit limit is $100 per student and $5000 per classroom (AWS Educate, 2021).

To complete the classroom request process, a student list template file (in the form of an excel spreadsheet) is downloaded and a list of student names and corresponding university email addresses will be added to the file. This list of students is then uploaded and the classroom request is submitted. The initial list of students should be as complete as possible, but additional students can be added after the classroom request is approved for students who add the course later, and students can be removed if they drop the course. The maximum number of students that can be invited to a classroom is 75.

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Classroom requests are typically approved in three to four days, but AWS Educate requests up to six business days to complete the process (AWS Educate, 2021).

Once the classroom request is approved, students will be sent a classroom invite email to the email address provided in the uploaded list of students. The email will give students instructions to log into AWS Educate and create a starter account if they do not already have one. In addition, it will direct them to go to the AWS Educate Classroom. The classroom will initially be in an inactive state and will remain inactive until the educator activates the class. Students will not be able to enter the classroom until the classroom is active.

Once the classroom is active and students are working within the classroom environment, educators will have the ability to view the student's workspace and credit usage. To view a student's specific work, the educator can select their classroom, select the specific student, and select the student's workspace. This will allow the educator to log into the student's workspace as if they were the student. Both the educator and the student can be logged in at the same time, which can be an effective method for remote tutoring. In addition, there is a cost report per student that displays the student credit usage per month per AWS resource.

4. SUMMARY OF AWS LABS

In each of the cloud computing courses, students were given a total of 18 AWS labs focusing on cloud-based infrastructure and cloud development services. Here is a summary of those labs as they were presented to the students:

1. Launch a Linux-based Elastic Cloud Computing (EC2) instance on a default Virtual Private Cloud (VPC) using the default subnet, internet gateway, security group, and routing tables and connect to the instance via Secure Shell (SSH) using a key pair file.
2. Create a new VPC, subnets, internet gateway, routing tables, and security groups using the AWS web interface and launch a Linux EC2 instance on one subnet and a Windows EC2 instance on a second subnet. Connect to the Linux EC2 instance via SSH using a key pair file and connect to the Windows EC2 instance via Remote Desktop Protocol (RDP) using a password derived from a key pair file.
3. Update the Linux EC2 instance created in lab 2 using the update/upgrade Command Line Interface (CLI) commands and then load a stress test application on the instance. Run a baseline analysis to determine CPU, memory, and disk performance. Using the AWS web interface, upgrade the CPU, memory, and EBS volume capacities on the instance and rerun the stress test baseline analysis. Compare the differences.
4. Add a new EBS volume to the Windows EC2 instance created in lab 2. Connect, format, and use the new volume without the need to reboot the server.
5. Add three new EBS volumes to the Windows EC2 instance created in lab 2. Format and configure the new volumes as a RAID 5 array. Break the RAID array by disconnecting one of the EBS volumes via the AWS web interface and demonstrate that the data on the broken array is still accessible.
6. Launch a new Linux EC2 instance using AWS CLI. This requires students to download and install the AWS CLI application and download and save current session key information. Connect to the instance via SSH.
7. Create an AWS Simple Storage Service (S3) bucket and configure the bucket to automatically encrypt all contents using AES-256 encryption.
8. Create an S3 bucket and configure it to host a static website. Upload a simple HTML document to the S3 bucket and demonstrate the website configuration is working by accessing the HTML document via a browser.
9. Create a Windows EC2 instance and configure it as an HTTP server. Configure the security group (firewall) settings to allow port 80 and 443 HTTP requests from all IP address locations but allow port 3389 RDP requests from only the student's local IP address. Test each access type to ensure the firewall configurations are working.
10. Create a new VPC, subnet, internet gateway, routing table, and security group using AWS CLI and launch a Linux EC2 instance in the new cloud environment using AWS CLI. Connect to the Linux EC2 instance via SSH.
11. Create a new VPC, subnet, internet gateway, routing table, and security group, and launch a Linux EC2 instance on the subnet using a YAML file via AWS Cloud Formation Services. Modify the VPC

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by updating the YAML file and updating the cloud configuration stack. This lab focuses on teaching Infrastructure as Code (IaC) concepts. Connect to the Linux EC2 instance via SSH.

12. Create an AWS Lambda (Serverless) function to generate a random number. Create an API gateway service to call the Lambda function and use the API call on a webpage to display a new random number each time the webpage is displayed or refreshed.
13. Create four Linux-based EC2 instances configured as HTTP servers. Load each server with a simple HTTP response program that displays the specific server's local IP address. Create an AWS load balancer that connects all four HTTP servers and demonstrate how the HTTP request to the load balancer distributes requests to each of the four servers. Take one server offline to demonstrate the overall web services remain running.
14. Create a cloud-based database MySQL server and load it with data. Leave the root login to the default userID and password. Back up the server to allow for data recovery in the next lab. Leave the database server running for a week to allow for a simulated (or real) ransomware attack.
15. The educator simulates a ransomware attack (or allows a real attack to occur). Students are to recover the data from their backup and change the default password to prevent future attacks.
16. Create an Ubuntu (Linux) EC2 instance and load a simple Java program to have the server simulate an IoT device. Use AWS IoT Core and Message Queuing Telemetry Transport (MQTT) to message the server and get responses back from it through the AWS MQTT subscription services.
17. Register a Raspberry Pi as an AWS IoT device. The Raspberry Pi has a small breadboard with LEDs connected to the General Purpose IO (GPIO) port. A java program runs on the Raspberry Pi that responds to MQTT messages and turns on and off specific LEDs. Students test the IoT configuration and messaging using the AWS IoT shadow messaging service.
18. Update lab 17 to allow for updates to the IoT device when the Raspberry Pi is offline but will update automatically to the shadow state once the IoT device is back online.

In addition to these directed cloud computing labs, students were given the option to select an exploration lab to research additional cloud technologies offered through AWS Educate. The following is a list of exploration labs that were selected by students:

1. AWS Cloud9 IDE as a multi-language code editor, executer, and debugger.
2. AWS Lex as an AI tool for developing Chatbots responding to voice and text.
3. AWS GameLift to develop multiplayer game environments in the cloud.
4. AWS CodeDeploy and CodeCommit for managing source code.
5. AWS Alexa for developing Alexa skills.
6. AWS Forecast, a machine learning prediction tool.
7. AWS Rekognition, a machine learning image classification tool.
8. AWS Comprehend, a machine learning natural-language processing tool.
9. AWS Sumerian to create browser-based 3D, augmented reality, and virtual reality applications.

5. AWS CREDIT UTILIZATION AND SURVEY RESPONSE RESULTS

At the end of each course, the AWS Educate Classroom credit utilization was evaluated. For students who did not exceed their AWS credit for the course, the average credit usage was $32.54 out of an initial $50 allocation. Four students out of the 64 total students exceeded their AWS credit allocation. In all of these cases, the students had failed to delete large data stores, which then consumed their AWS credit over a five to ten-day period. For students in this situation, AWS Educate Classrooms provides a process for students to request a $20 extension (AWS Educate, 2021). This gave students the ability to complete the remaining course requirements while carefully managing AWS credits with the remaining activities in the course.

In addition, the student survey responses were also evaluated. The response rate was 100% as the survey was a part of a graded end-of-course assignment. Of the 18 AWS labs given to all students, survey results showed students indicated labs focusing on creating AWS infrastructure (VPC, subnets, and EC2 instances), labs creating Lambda functions, and labs working with IoT devices most educational. Of the 64 survey responses, these three groupings of labs were identified as most educational 75% or more of the time. Table 1 displays a summarization of labs indicated by students as most educational.

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AWS Lab	**% Indicated**
VPC/Subnet/EC2 Labs	84.3%
Lambda Labs	76.6%
IoT Labs	75.0%

Table 1. Top 3 labs identified as most educational.

A common sentiment to this first survey question is expressed in this one student's statement: "The first two labs of the course, where we built our own VPCs and Linux servers, were the most educational for me. I have not worked with networking very much and these labs really gave me the knowledge I needed to work on other assignments in the class and outside the class." Based on other survey responses, students felt these labs provided the broadest learning activities with cloud technologies. In addition, these labs opened up additional opportunities outside of the class to leverage cloud technologies in other courses. This was especially true of the computer science majors, who quickly saw the value of being able to develop and test software on EC2 instances as they worked on full-stack development projects. With the combination of multiple servers, serverless API Lambda, and IoT device programming, students felt they could fully explore UI, core, and edge-based software development.

In response to the second survey question, responses indicated students found the labs using CLI and IaC programming to create and manipulate cloud infrastructure and services to be the most challenging. Many students stated they had not used CLI programming extensively before the course and found the "exactness" of CLI commands or YAML file content to be an issue as they worked through the labs. They often had to repeat steps because command parameters were missing a letter or had a typo that miss-created the desired AWS service. Table 2 displays a summarization of labs indicated by students as most challenging.

AWS Lab	**% Indicated**
CLI Labs	73.4%
IaC Labs	65.6%

Table 2. Top 2 most challenging labs

However, several students did note that now having worked with CLI, they could easily see the value CLI provided when writing cloud service creation scripts and that complex services could quickly be created with one or two commands as opposed to several web interface clicks.

In response to the final survey question, students indicated they felt labs relating to EC2 creation and management, and CLI usage were the most likely to be used when they entered the workforce. Table 3 summarizes the indication rate for these two labs.

AWS Lab	**% Indicated**
EC2 Labs	75.0%
CLI Labs	60.9%

Table 3. Top 2 labs teaching skills to be used when entering the workforce.

The comments on the survey suggested students did see the value of being able to create development and test environments as they were needed when exploring various system configuration options. They also saw the value of becoming more confident in utilizing CLI programming to quickly and precisely create and manipulate cloud services.

Of those students that chose to complete an exploration lab, students felt using development tools such as AWS Cloud9 IDE, CodeCommit, and CodeDeploy for developing cloud-based software to likely be beneficial, especially in a software development team. Students also found the machine learning tools to provide a good introduction to what machine learning can be used for but did not find them to be a good tool in learning how to develop their own machine learning models.

6. BENEFITS AND LIMITATIONS

AWS Educate Classrooms provide educators and students the ability to explore many AWS services without direct cost and without the need to enter credit card information. Several AWS services, such as free tier EC2 level instances, can be used at no cost and many other services consume very little AWS credits if they are managed properly. For example, even though free tier EC2 instances do not cost anything to run, the EBS volume needed to store the operating system and local files do cost a small amount for the time the volume is allocated. For instance, the cost of a general-purpose 8GB EBS volume is less than $1 per month. Most students were able to complete all AWS lab work while consuming less than $40 of the $50 they were provided as part of the AWS Educate Classroom credits. However, if a lab assignment required large data storage, such as 1TB or more, then the AWS credit provided would not be sufficient.

AWS Educate Classroom services provide additional AWS credit per student per class beyond what students are given as part of their $100 starter account credit (assuming the student is part of an AWS Educate member institution). This provides the student a clean AWS working environment with additional allocated credit apart from their starter account environment. This is important to educators because they do not need to account for any other AWS activities outside of the classroom environment that might interfere with course assignments.

Although the AWS services provided through AWS Educate is extensive, it is not complete. The complete list of AWS services provided through AWS Educate can be found on a PDF document at https://awseducate-starter-account-services.s3.amazonaws.com/AWS_Educate_Starter_Account_Services_Supported.pdf. The most notable service not supported through AWS Educate is the majority of the Identity & Access Management (IAM) services. IAM is where cloud users are defined, access and policies are created, and various AWS service permissions are granted. Several labs provided to students had to leverage predefined IAM policies that would be a violation of security best practices if deployed outside of the classroom environment. This limitation also impacts the ability of educators to provide hands-on experience with many of the cloud security concepts that should be understood by students.

For educators and students to experience IAM services, learners will need to sign up for an AWS free tier account. The free tier account provides access to many AWS services for little to no cost for 12-months and all AWS services at a potential cost. However, a credit card or other billing service must be set up to utilize this option (AWS, AWS Free Tier FAQs, 2021).

In addition to the limitation of IAM services, activities and labs using Machine Learning can also be limiting. Although AWS Educate provides a Machine Learning environment, the AWS credits provided do not support the training of models with large data sets. According to AWS estimates, a model requiring 20 hours of training and then used for 890,000 batch predictions would cost $97.40 (AWS, Build a Machine Learning Model, 2021). Therefore training and using a single large model would typically cost more than the standard AWS Educate Classroom credit allocation.

7. CONCLUSION AND RECENT CHANGES

Overall, students responded positively in cloud computing courses that leveraged AWS Educate Classroom services for gaining hands-on experience. AWS Educate along with Classroom services offers an isolated environment where students are provided a stable setting with a set AWS credit limit so educators can build cloud technology labs that can have a greater level of predictable outcomes. In addition, students do not need to provide credit card information, nor worry about unexpected expenses when cloud services are not managed correctly.

This suggests that AWS Educate Classroom does provide a qualified “yes” to the two primary questions being considered in this study. It is an effective resource in developing an environment to teach cloud computing for most labs designed to teach cloud computing concepts. It also provides a valued environment for students to experience hands-on lab exercises but is limited to labs that do not require large data sets or compute times. It also does not provide an environment for teaching cloud infrastructure security and policies.

Shortly after the development of this paper, AWS announced the retirement of Classroom services and the addition of AWS Academy Learner Labs. Academy Learner Labs are available as of July 29, 2021, and AWS states they incorporate all the features of Classroom services plus more directed cloud technology labs built into an LMS environment. It is expected that all the benefits of the AWS Educate Classrooms will be available with this next iteration of AWS Educate services.

Future research should look at how the AWS Academy Learner Labs support the cloud computing learning environment. Furthermore, additional research should consider how AWS Academy Learner Labs might support other aspects of cloud computing, such as SaaS and Private or Hybrid cloud environments.

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Appendix A: AWS Lab Survey

Thinking back over the course, which AWS labs did you find most educational (that is the labs that provided understanding and insight into cloud computing)? List each lab you found educational and give a short explanation of why you found the lab educational.

Thinking back over the course, which AWS labs did you find most challenging (that is the labs that required the greatest effort or created the most errors while completing them)? List each lab you found challenging and give a short explanation of why you found the lab challenging.

Thinking back over the course, which AWS labs did you find most likely to provide skills you will use after entering the workforce? List each lab you found most likely to provide you skills after entering the workforce and give a short explanation of why you found the lab most likely to provide skills when entering the workforce.