An Architecture for Intelligent e-Learning Platform for Student's Lab Deployment

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Abstract. For better understanding and better learning of new technologies, there is welcome to have some hands-on experiences with these subjects. This helps with knowledge adoption and also increases learning efficiency. In this article, there is analyzed inputs for a proposal of this system and requirements, which should be meet for such system, and also there is identified learning subjects and areas, which could use this tools. This article deals with and describes an architecture, which can help with automation and deployment labs, which can students use for learning and their research. There is described the architecture for a system, which is able to deploy these environment into more cloud type providers and also is open and able to handle more types run-time technologies, especially virtualization (e.g. OpenStack, Kubernetes and more). The architecture describes platform, which consists an portal or a learning web-based tool, which can be used for learning and also for interface of student labs, which can be automatically deployed based on input conditions with automation tools to some public or private cloud services.

Keywords: Learning · Lab deployment · Automation · Private cloud · Public cloud

1 Introduction

The learning of new technologies should not include only theoretical knowledge and learning without touching it. There should be also included some hands-on experience, which increase learning speed and the depth of knowledge. Thanks of this, students are faster in learning and the learning process is faster and more efficient.

The hands-on experience can be delivered via giving students an environment that matches the real environment and students can play with it and try to understand these technologies and contexts.

There are a few challenges, which should be met. For example, how to students will access course resources (theory and practise, thus hands-on environment).

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The deployed lab has to run on some platform and there are basically three option [8] - use some private cloud solution (based on requirements use Infrastructure as a Service on demand solution, e.g. OpenStack [29], VMware [39], Hyper-V [27] or Kubernetes [21,25]), use some public cloud solution (e.g. Microsoft Azure [27], Amazon Web Services [2], Google Cloud Engine [15]) or use some hybrid cloud solution or more solutions together.

2 Problem Definition

The learning process of any learning subject basically includes two phases:

1. Learning the theoretical aspects,
2. Learning the practical aspects and exercises.

Students first learn the basic knowledge they should subsequently demonstrate and deepen within exercises that should help them with the application of acquired knowledge.

To be able to do these exercises, students should have resources, where they can do some basic tasks and get hands-on experiences and also can play with technology if this is possible.

There are a lot of opportunities for hands-on learning and getting resources for these students lab. In general, there can be used any cloud resources environments, which can provide run-time platform for this area. There can be used public provider clouds or there can be used private cloud solutions.

Thanks of virtualization and thanks of abstraction between application and hardware resources, there are possibilities for not taking care about where services will be running and thanks of this, these labs with good architecture layer can be used on more cloud solutions.

Lab environments should meet requests in many areas, which can be required for some specific environment and deployment. It can depend on usage, but generally speaking, areas are:

- availability, which means how will be defined service level agreement of these services,
- accessibility, which means how many students will share the same resources (lab and physical resources)
- performance, which means how much resource will be available for each lab and how many labs will be able to run in each time,
- price, which requests the highest cost effectiveness for such environments and whole implementation,
- and others.

Each from these areas can be different for specific setup, for example the environment for students in school area will be different for students in business area. This research is defining architecture for real deployment of solution for lab deployment, but there should be analysed specific environment setup and its requirements.

2.1 Subjects and Areas

The school and education subject, for which should be able to use this solution are mainly Information Technologies subjects, where for students could be helpful to have hands-on experiences. Between these subjects and technologies belong:

– Desktop and Server Operating Systems (e.g. Linux-based Operating Systems, Windows Server and Client and platforms run on top of these technologies),
– Virtualization Platforms like virtual machines and container virtualization (e.g. VMware virtualization, Hyper-V, Docker and Kubernetes),
– Applications, where is not easily to run and deploy it on standalone machines (e.g. databases, application based on backend and frontend layers, large enterprise systems and platforms),
– and many others.

2.2 Cloud Computing Solution

The designed environment could be able to run on Private and also Public Cloud Computing solutions [8]. Each Cloud Computing solution brings specific advantages and disadvantages, so there is needed to choose this one, which will meet requirements and run will be the most suitable.

On Fig. 1, there are shown basic Cloud Computing solution types, which can be used for implantation of this system.

This figure also shows a third type, hybrid cloud solution, which can be used and it means that solution is using both, private and public cloud solutions, and thanks for that can optimize benefits of both solutions.

The background of such a solution should be virtualization - mainly Infrastructure as a Service (IaaS) solution, but there could be possible to use also another Cloud Computing solutions, such Platform as a Service (PaaS) and Software as a Service (SaaS), but this paper is mainly concerned with the Infrastructure as a Service solution.

2.3 Cloud Based Educational Companies and Institutions

On the market, there is a lot of companies and institutions, which are delivering some e-Learning services, which also includes providing student's labs, where they can learn.

But on the other hand, these solutions are not publicly available and therefore there is no generic architecture that describes the possibilities and uses and the best practises.

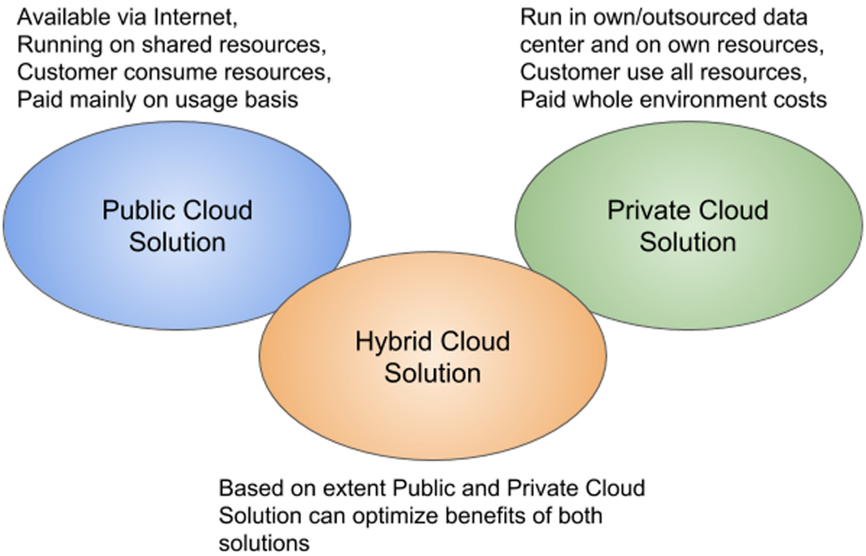

Fig. 1. Basic Cloud Computing solution and their main benefits.

3 Related Works

A lot of research works is based on some learning platform usage, which can be used in learning or analysed cloud computing usage in learning areas.

Alabbadi [1] analyses the usage of cloud computing services in learning and defines the Complete Cloud Computing Formation Model for cloud computing usage analysis. The similar analysis are Babu [4] and Sanchez [32] with Agent Based Cloud Computing Architecture.

Dahdouh [9] examines how to interconnect more e-learning and cloud computing platforms and also describes architecture of e-learning system based on Spark and Hadoop [10].

Thomas [37] analyses a potential of cloud computing usage in learning and his advantages and disadvantages.

Between another similar studies, which are considers to cloud computing usage in e-learning and education, but on regular basis, belong also An [3], Dong [12], Fernandez [13], Gonzalez-Martinez [16], Horalek [17], Juan [20], Mikulecky [28], Siddiqui [34], Sommerville [35].

Barak [5] and Stantchev [36] examine this area more in behaviour aspects and Boja [7] and Maresova [24] examines economics aspects of cloud computing usage in learning and education.

Another studies are focused to another cloud computing usage in school or scientific area. For example Horalek [18] describes model for cloud computing usage in scientific calculations. Also Tuncay [38] analyses an effective usage of cloud computing in educational institutions. Xu [40] defines an architecture of virtual laboratory for network security education.

Some studies helps with cloud computing usage optimization. Kumar [22] analyses workload prediction with using the neural networks. Komarek [23], Pavlik [31] and also Sebastio [33] study availability and performance of cloud services.

Ghobaei-Arani [14] examines how to effectively use cloud data centers for virtual machines and resource efficiency is also addressed by Zhu [41]. Bartuskova [6] describes a framework for resource management.

4 System Inputs and Requirements

The architecture of the solution should effectively serve the purpose, which is mainly student learning. Because of this, students should be able to use it any time and also should be able to rebuild and/or skip the environment to any state of course.

Some of main requirements has been introduced in Problem Definition section (availability, accessibility, performance and price), but anyway, based on specific requirement, some of these can be changed, modified or omitted entirely.

From the requirement, there are implicated system inputs for particular usage of this architecture. There should be included and considered above all:

- how many user will be active (have deployed lab), inactive (be able to deploy lab) or how many labs can each user deploy,
- how will be setup time to live of deployed labs and if will be deleted after some period,
- how user accounts will be handled, if there will be some local user management solution or some integration to another user management solution,
- how user will connect to the environment, if there is needed some VPN, another external portal or is public Internet available,
- if there will be used private or public cloud solution and if public, which provider will be chosen for deployment,
- which virtualization platform will be used for control plane (this means learning application) and if virtual machines or containers,
- which virtualization platform will be used for data plane (virtual user environments) and if virtual machines or containers,
- how much will be used automation for deployment and which configuration will be on user side,
- for which education subject will be the lab environment and his possibilities used and how,
- if there will be used only one type of deployment and used for whole subject topic or will be possible switching between e.g. lessons,
- and possibly much more other, based on implementation and specific requirements.

5 System Architecture

The architecture of entire system is based on some components, which are interconnected and mainly there are used open-source tools and software.

Figure 2 shows basic architecture concept, which consists parts of a system for deployment of student environments and these components are important for successful implementation and working setup of this architecture.

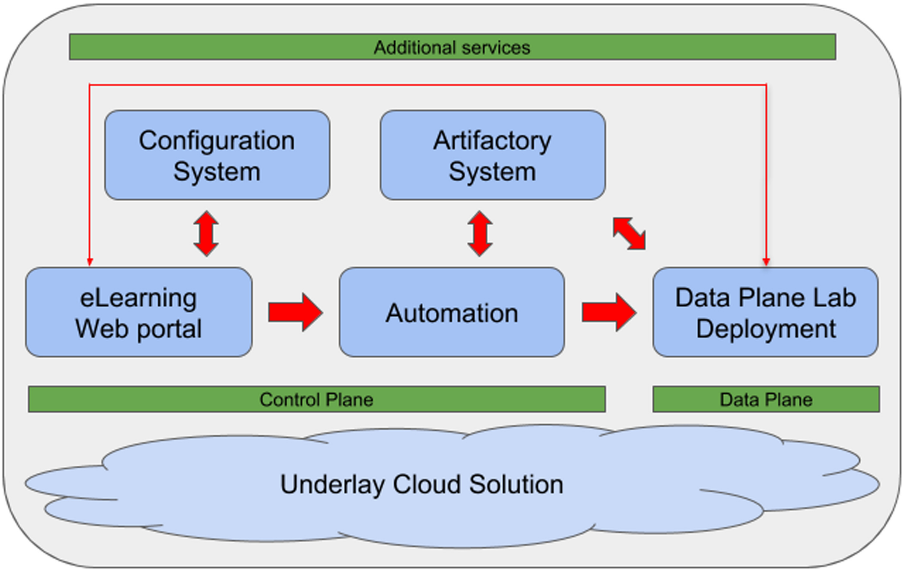

Fig. 2. Basic lab deployment system architecture.

5.1 Components

The whole system consists a few components, which each act like subsystem of this solution and have its own meaning.

These components are split to 2 parts:

1. Control plane, which takes care of the whole platform,
2. Data plane, where run student deployed labs.

The both part are running on top of some cloud solution. Both part can share the same cloud solution but also cannot and for example control plane can run on public cloud solution and data plan on private cloud solution. Also there is possible to run data plane on public and private cloud solution and there can be implemented some logic for choosing, where each lab will run

e-Learning Web Portal. The main component of the solution for students is e-Learning Web portal, where courses are available for student and students use it for learning process. This is mainly web page, where are located learning materials and resources, exam and practical exercises, which student should complete via their deployed labs.

This portal can be used also some existing e-Learning solution, where can be implemented some trigger for building lab or labs can be deployed separately without connection to e-Learning system.

Configuration System. The configuration system consists store of configuration and also data for e-Learning Web portal. The part of configuration system should be also some user management system, which will used for user authentication, authorization and also for quotas store for management of used and available resources. Also some billing solution could be part of the configuration system.

Automation. The automation subsystem is one of main important parts of this solution. It helps with automatizing of deployments and routines in whole environment.

This subsystem is mainly built on automation server system and also predefined procedures, which are done during deployment.

The most suitable tools for these purposes is software called Jenkins [19]. Jenkins is automation software for continuous delivery of software. In Jenkins, there are written pipelines, which are consists procedures which are done during student lab deployment.

Data Plane Lab Deployment. This part of solution means all deployed student labs. These labs may consist virtual machines with installed application and/or with specific configuration, containers, which run specific application.

In some specific situation, there can be run virtual machines with nested virtualization, where can run another virtual machines or containers.

Additional Services. The part of solution can be external or internal services, which can help with management and run of the environment. Between these services, there can belong:

- Monitoring solution,
- external e-Learning System,
- external user management solution,
- external accounting and billing system,
- supporting web services non-directly related to e-Learning,
- and a lot of others.

Between additional services can belong also integration parts with another external systems.

5.2 User Deployment Workflow

When user is starting learning and requesting any new lab deployment, there should be a few steps, which should be done before and after lab will be successfully deployed. The workflow of this action should be:

1. Student logins to e-Learning system with provided credentials,
2. e-Learning system validate user credential, system authorization, permissions and current deployed resources,
3. Student is using e-Learning system, if there is needed some lab, student will start request for resources,
4. System is validating available resources and user resource quota, current state and predefined Cloud Computing solutions and rules and after this, lab deployment will start,
5. System start deployment, build pipeline run for this based on request and current state of system,
6. System run pipeline for user lab deployment via predefined deployment workflow,
7. After lab is successfully deployed, inform user via predefined notification and also provide credential and information how to login to deployed lab.

This is basic workflow for student lab deployment, but there can be differences and also another steps, which can come with local requirements and implementation.

5.3 Another Workflows and Functions

There is also needed to have some another workflows for management whole cluster to be able to manage whole environment successfully. This system is not only about student lab deployment, but also management current deployed labs and also their life cycle.

Between these workflows and functions should belong:

- Regular check for current usage of labs and comparing student resource validity,
- Based on requirements, upgrade current labs to the newest versions (optionally with current student state),
- Process and pipeline for destroying deployed labs with expired time to live or deactivated users and resource cleanup and optimization,
- Resource validation and possibility for migration to another Cloud Computing solution, if enabled,
- Upgrading artifact stored contents based on upstream updates (e.g. new packages, new operating system images, docker images),
- Automatically triggered test deployments, which will ensure, that there will be possible to deploy labs in each time and for preventing non-working state,
- Regular monitoring of the whole environment and all interconnected components,

- Data synchronization of with another e-Learning systems or management systems if needed (e.g. users, classes),
- and some specific others.

Thanks to automation, there should be prepared pipelines, which will be trigger by scheduled triggers and will start based on configuration. But this is not only about system implementation, but also about processes for specific implementation.

6 Proof of Concept Lab Deployment System

To be sure, this infrastructure is working and is possible to implement it, there were implemented and tested proof of concept setup with basic and small configuration.

For testing purposes, there were created basic web portal and with basic form for creation of student lab. This lab has two alternatives: 3 and 6 virtual machines based on Ubuntu 18.04.2 LTS (Bionic Beaver) with installed and configured basic Kubernetes cluster.

Th configuration system stored some service, like basic user management subsystem and also store of available lab configurations.

Artifact system stored Ubuntu images and also some repositories in Gerrit code software, where has been store pipeline configuration for Jenkins automation server. For Linux repositories has been used upstream repositories, but also could be used some package management server like a part of artifact system.

Jenkins has been used like automation system with a written pipeline, which received trigger from e-Learning Web portal with configuration, start pipeline run, which deployed student lab.

Deployed labs has been installed to OpenStack based cloud, where also has been running virtual machines with rest of infrastructure (control plane).

After this first phase, there were second phase, which consists verification on some public cloud solution. There were chosen Amazon Web Services cloud, which provides Amazon Elastic Compute Cloud (EC2) solution for virtual machines. Because there has been needed some changes in written deploy pipeline, this pipeline has been extended with additional parameters, which are related for deployment to AWS cloud.

7 Conclusion

This paper describes architecture of system, which can be used like support for the learning of technical subjects mainly. This architecture contains web interface, which is for user interaction, automation subsystem, which serves for lab deployment automation, core subsystem, which is managing user and system requests and also opened virtualization subsystem, which can be used like private or public cloud solution.

This architecture concept can be used in large usage variants and thanks of this, can be modified on specific environment requirements and possibilities, because there are a lot of variants for usage and also technical and non-technical requirements for learning and possibilities of the particular institution, school or university.

The whole architecture is possible to built on open source technologies so this can be possible for next development and the architecture in opened for another extensions and specifics.

The main benefit of this architecture is in the openness for future development and there are possibilities to change and/or modify it for needs of the specific organisation, which can be some educational institution or also some software company, which wants to deliver labs for their employees. And between another benefits belong the openness for underlay virtualization platforms, which can be on premise cloud solution or some public cloud solutions.

The architecture also provides and recommends the usage of highest layers of virtualization (e.g. container virtualization), but there is possible to use more traditional type of virtualization (virtual machines based virtualization).

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References

1. Alabbadi, M.M.: Cloud computing for education and learning: education and Learning as a Service (ELaaS). In: 14th International Conference on Interactive Collaborative Learning, ICL 2011–11th International Conference Virtual University, pp. 589–594 (2011)
2. Amazon Web Services offers reliable, scalable, and inexpensive cloud computing services. https://aws.amazon.com/. Accessed 30 Jan 2019
3. An, W., Huang, L.: E-learning exploration based on cloud computing. In: Measurement Technology and Engineering Researches in Industry, PTS 1–3, Applied Mechanics and Materials, vol. 333–335, pp. 2226–2230 (2013)
4. Babu, S.R., Kulkarni, K.G., Sekaran, K.C.: A generic agent based cloud computing architecture for e-learning. Adv. Intell. Syst. Comput. **248**, 523–533 (2014). https://doi.org/10.1007/978-3-319-03107-1_58
5. Barak, M.: Science teacher education in the twenty-first century: a pedagogical framework for technology-integrated social constructivism. Res. Sci. Educ. **47**(2), 283–303 (2017). https://doi.org/10.1007/s11165-015-9501-y
6. Bartuskova, A., Krejcar, O., Selamat, A., Kuca, K.: Framework for managing of learning resources for specific knowledge areas. In: 13th International Conference on Intelligent Software Methodologies, Tools, and Techniques (SoMeT 2014), Frontiers in Artificial Intelligence and Applications, vol. 265, pp. 565–576 (2014)
7. Boja, C., Pocatilu, P., Toma, C.: The economics of cloud computing on educational services. In: 3rd World Conference on Learning, Teaching and Educational Leadership (WCLTA 2012), Procedia Social and Behavioral Sciences, vol. 93, pp. 1050–1054 (2013)

8. Buyya, R., Vecchiola, C., Selvi, S.T.: Mastering Cloud Computing, 3rd edn. McGraw Hill, New York (2013)
9. Dahdouh, K., Dakak, A., Oughdir, L.: Integration of the cloud environment in e-learning systems. Trans. Mach. Learn. Artif. Intell. **5**(4) (2017)
10. Dahdouh, K., Dakkak, A., Oughdir, L., Ibriz, A.: Large-scale e-learning recommender system based on Spark and Hadoop. J. Big Data **6**(1), 2 (2019). https://doi.org/10.1186/s40537-019-0169-4
11. Doelitzscher, F., Sulistio, A., Reich, C., Kuijs, H., Wolf, D.: Private cloud for collaboration and e-Learning services: from IaaS to SaaS. Computing (Vienna/New York), **91**(1), 23–42 (2011). https://doi.org/10.1007/s00607-010-0106-z
12. Dong, B., Zheng, Q., Yang, J., Li, H., Qiao, M.: An e-learning ecosystem based on cloud computing infrastructure. In: 9th IEEE International Conference on Advanced Learning Technologies (ICALT 2009), pp. 125–127 (2009)
13. Fernandez, A., Peralta, D., Herrera, F., Benítez, J.M.: An overview of e-learning in cloud computing. In: Uden, L., Corchado Rodríguez, E., De Paz Santana, J., De la Prieta, F. (eds.) Workshop on Learning Technology for Education in Cloud (LTEC 2012). Advances in Intelligent Systems and Computing, vol. 173, pp. 35–46. Springer, Heidelberg. https://doi.org/10.1007/978-3-642-30859-8_4 (2012)
14. Ghobaei-Arani, M., Rahmanian, A.A., Shamsi, M., Rasouli-Kenari, A.: A learning-based approach for virtual machine placement in cloud data centers. Int. J. Commun. Syst. **31**(8), e3537 (2018)
15. Google Cloud Engine. https://cloud.google.com/compute/. Accessed 30 Jan 2019
16. Gonzalez-Martinez, J.A., Bote-Lorenzo, M.L., Gómez-Sánchez, E., Cano-Parra, R.: Cloud computing and education: a state-of-the-art survey. Comput. Educ. **80**, 132–151 (2015)
17. Horalek, J., Cimler, R., Sobeslav, V.: Virtualization solutions for higher education purposes. In: 25th International Conference RADIOELEKTRONIKA 2015, pp. 383–388. IEEE (2015)
18. Horalek, J., Soběslav, V.: Analysis and solution model of distributed computing in scientific calculations. In: Younas, M., Awan, I., Holubova, I. (eds.) MobiWIS 2017. LNCS, vol. 10486, pp. 314–324. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-65515-4_26
19. Jenkins. https://jenkins.io/. Accessed 30 Jan 2019
20. Juan, Y., Yi-xiang, S.: The initial idea of new learning society which based on cloud computing. Mod. Educ. Technol. **20**(1), 14–17 (2010)
21. Kubernetes - Production-Grade Container Orchestration. https://www.kubernetes.io/. Accessed 30 Jan 2019
22. Kumar, J., Singh, A.K.: Workload prediction in cloud using artificial neural network and adaptive differential evolution. Future Gener. Comput. Syst. **81**, 41–52 (2018)
23. Komarek, A., Pavlik, J., Soběslav, V.: high level models for IaaS cloud architectures. In: Barbucha, D., Nguyen, N.T., Batubara, J. (eds.) New Trends in Intelligent Information and Database Systems. SCI, vol. 598, pp. 209–218. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-16211-9_22
24. Maresova, P., Sobeslav, V.: Effective evaluation of cloud computing investment - application of cost benefit method analysis. E M Ekonomie Manage. **2**(20), 134–145 (2017)
25. Mercl, L., Pavlik, J.: The comparison of container orchestrators. In: Yang, X.-S., Sherratt, S., Dey, N., Joshi, A. (eds.) Third International Congress on Information and Communication Technology. AISC, vol. 797, pp. 677–685. Springer, Singapore (2019). https://doi.org/10.1007/978-981-13-1165-9_62

26. El Mhouti, A., Erradi, M., Nasseh, A.: Using cloud computing services in e-learning process: benefits and challenges. Educ. Inf. Technol. **23**(2), 893–909 (2018). https://doi.org/10.1007/s10639-017-9642-x
27. Microsoft - official website. https://microsoft.com. Accessed 30 Jan 2019
28. Mikulecky, P., Mercl, L.: Clouds for smart learning environments. In: 12th International Scientific Conference on Distance Learning in Applied Informatics Conference Proceedings (DIVAI 2018), pp. 473–480 (2019)
29. OpenStack. https://www.openstack.org/. Accessed 30 Jan 2019
30. Komarek, A., Pavlik, J., Sobeslav, V.: Performance analysis of cloud computing infrastructure. In: Younas, M., Awan, I., Holubova, I. (eds.) MobiWIS 2017. LNCS, vol. 10486, pp. 303–313. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-65515-4_25
31. Pavlik, J., Sobeslav, V., Komarek, A.: Measurement of cloud computing services availability. In: Vinh, P.C., Vassev, E., Hinchey, M. (eds.) ICTCC 2014. LNICST, vol. 144, pp. 191–201. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-15392-6_19
32. Sánchez, M., Aguilar, J., Cordero, J., Valdiviezo-Díaz, P., Barba-Guamán, L., Chamba-Eras, L.: Cloud computing in smart educational environments: application in learning analytics as service. New Advances in Information Systems and Technologies. AISC, vol. 444, pp. 993–1002. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-31232-3_94
33. Sebastio, S., Ghosh, R., Mukherjee, T.: An availability analysis approach for deployment configurations of containers. IEEE Trans. Serv. Comput. **PP**, 1 (2018)
34. Siddiqui, S.T., Alam, S., Khan, Z.A., Gupta, A.: Cloud-based e-learning: using cloud computing platform for an effective e-learning. In: Tiwari, S., Trivedi, M.C., Mishra, K.K., Misra, A.K., Kumar, K.K. (eds.) Smart Innovations in Communication and Computational Sciences. AISC, vol. 851, pp. 335–346. Springer, Singapore (2019). https://doi.org/10.1007/978-981-13-2414-7_31
35. Sommerville, I.: Teaching cloud computing: a software engineering perspective. J. Syst. Softw. **9**(86), 2330–2332 (2013)
36. Stantchev, V., Colomo-Palacios, R., Soto-Acosta, P., Misra, S.: Learning management systems and cloud file hosting services: a study on students' acceptance. Comput. Hum. Behav. **31**(1), 612–619 (2014)
37. Thomas, P.Y.: Cloud computing a potential paradigm for practicing the scholarship of teaching and learning. Electron. Libr. **29**(2), 214–224 (2011)
38. Tuncay, E.: Effective use of cloud computing in educational institutions. Procedia Soc. Behav. Sci. **2**, 938–942 (2010)
39. VMware - official site. https://www.vmware.com/. Accessed 30 Jan 2019
40. Xu, L., Huang, D., Tsai, W.-T.: Cloud-based virtual laboratory for network security education. IEEE Trans. Educ. **57**(3), 145–150 (2014)
41. Zhu, Q., Agrawal, G.: Resource provisioning with budget constraints for adaptive applications in cloud environments. IEEE Trans. Serv. Comput. **5**(4), 497–511 (2012)
42. Zurita, G., Baloian, N., Frez, J.: Using the cloud to develop applications supporting geo-collaborative situated learning. Future Gener. Comput. Syst. - Int. J. Grid Comput. Sci. **34**, 124–137 (2014)