CK-001

Mitigating Resource Constraints in Web Development Education using Commercial Cloud Services

Zilu Liang† Mario Alberto Chapa-Martell‡

1. Introduction

Web development is an essential component in computer science and information technology education. However, web development has been widely recognized as a challenging subject to teach and was even considered unteachable [1]. One of the main difficulties in teaching web development is that instructors need to prepare, manage and maintain a myriad of IT infrastructure, such as servers, storage, databases and network facilities. However, instructors often face extreme resource constraints. In many cases, they neither have budget available to purchase the equipment and devices, nor have IT support for managing and maintaining the computing resources.

To mitigate resource constraints in web development courses, previous work has attempted to build machines with tailored features in place of using general machines [2]. However, this solution still requires the purchase of on-premise servers and other hardware as well as the human resources to set up and maintain computing resources. Hiring teaching assistants as system administrators indeed reduce the burden of course instructors but will unavoidably trigger extra cost. Another approach is to use private cloud available in the university [3]. However, this option is limited to the universities that have private cloud resources. Also, private cloud limits the access to these resources within the campus and thus may have negative impact on students' learning experience.

In this paper, we provide an experience report of how we leveraged commercial cloud services to mitigate the resource constraints in a hands-on web development course. This is a one-semester course for non-CS major students. All students in the course subscribed to Microsoft Imagine program that allows them to access computing resources in Microsoft Azure cloud free of charge for one year. The Microsoft Azure for Students can be accessed at https://zure.microsoft.com/en-us/free/students. Students also set up their remote version control repositories in Azure DevOps (https://azure.microsoft.com/en-us/services/devops). These benefits eliminate the cost of purchasing on-premise IT infrastructure for the development environment. Students set up computing resources (e.g. web servers, database servers, load balancer, network facilities) using the PaaS (platform-as-a-service) layer in Azure cloud. This strategy benefits both instructors and students. From the perspective of instructors, this significantly reduces the management overhead as the duties of managing and maintaining IT infrastructure is shifted to the cloud service provider. From the perspective of students, configuring computing resources and the subsequent development in cloud allows them to gain hands-on experience in authentic development environment.

† Kyoto Univ of Advanced Science & The Univ of Tokyo
‡ CAC Corporation

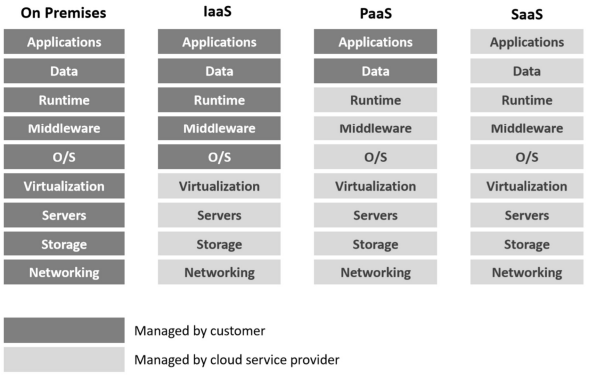

Fig 1 Three layers of cloud services at the infrastructure-, platform-, software-level versus on premise scenario. The role sharing between cloud service provider and customer is also highlighted.

Despite of the wide adoption of cloud in education, this is the first paper that describes how commercial cloud can empower educators to offer web development courses at no cost and in the meanwhile to tremendously reduce management and maintenance overhead without having to rely on IT support in the university. In what follows we describe related work, report our experience in the web development course, and discuss the merits and limitations of our approach to benefit educational institutions and instructors of similar needs.

2. Related Work

2.1 Cloud Computing

Cloud has become the 5th utility, just after water, electricity, gas and telephony, in modern society [4, 5]. Cloud computing enables on-demand access to a shared pool of configurable computing resources that can be rapidly configured and released with minimal management effort [6]. There are three types of cloud: public, private, and hybrid cloud. Examples of public clouds include major cloud services in the market such as Amazon Web Service (AWS), Microsoft Azure, and Google Cloud Platform (GCP). An example of private clouds is the AWS GovCloud that addresses US government needs, which is not accessible by the public. Most public cloud providers offer three layers of services: infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS). Figure 1 illustrates the characteristics of the three layers and the role sharing between cloud service provider and customer. In an IaaS cloud, resources are typically acquired in the form of virtual machines. Customers need to configure and administer their

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virtual servers on their own. In a PaaS cloud, service provider manages the hosting environment. Customers can focus on developing their applications. The downside is that customers have no access to the actual servers on which the applications are running. In SaaS, the entire stack from server to application is handled by the cloud service provider. Previous studies found that the majority of developers mainly consider cloud as a deployment and hosting technology, highlighting the practical importance of the IaaS and PaaS layers [7]. Over the past decades, cloud computing has been widely used in academia to develop systems for research purposes [8-11].

2.2 Cloud for Education

Education has been a major application domain of cloud computing technology [12]. Cloud computing is ideal for education context because it enables easy infrastructure setup and maintenance, and automatic scalability according to the size of the class [7]. Many universities have adopted cloud to optimize resources, to reinforce security and to reduce risks [12, 13]. The IaaS and SaaS are the most commonly used services by universities to reduce the cost of university operation and of course management [3, 14]. Cloud computing also offers benefits for instructors to teach their courses [15, 16]. It has been used to create dynamic and cost-effective learning environment in basic sciences [17, 18], computer science [19-22], information technology [23], and language learning [24, 25]. Cloud host is especially suited for e-learning systems [26-28] and has been proven to be a more efficient solution compared to traditional approach [29, 30]. Cloud computing itself has also been integrated into the curriculum of computer science and IT education [31].

Nowadays major cloud service providers all offer supporting programs to students, such as AWS Educate, Microsoft Imagine, and Google Cloud Education Solutions. In our course we leveraged Microsoft Imagine that allows students to access developer tools for apps and websites at no cost for one year. There are two subscription levels available for Microsoft Imagine: institutional subscription and student subscription. Institutional subscription requires educators to sign up for either a standard or a premium subscription (at a reasonable cost). Educational institutions need to appoint an administrator to set up, assign and manage computing resources as well as managing subscriptions. In contrast, student subscription requires each student to make the subscription and there is no centralized administration by the educational institution. Student subscription does not trigger any cost but will limit the access to some resources available to institutional subscription. In our course we opted for student subscription as it was sufficient to serve our purpose. We will explain how to set up and maintain IT infrastructure and computing resources in Microsoft Imagine and discuss the benefits as well as limitations in the following sections.

3. Setting Up Computing Resources

This web development course was launched in the fall of 2017 as an initiative of project-based learning. It targets non-CS major students from a diverse background. Students are guided to develop web applications that support self-tracking practices within the context of quantified self [8, 9, 27, 32-36]. Details on the design, delivery and outcomes of the course can be found in [37].

We adopted the ASP.NET framework for the development as it is mainstream, cross-platform and is a natural (but not the only) fit in Microsoft Azure cloud. In this course, the design pattern based on ASP.NET MVC framework is illustrated in Figure 2. The implementation of such web applications demands the following tools and computing resources:

1. Internet Information Service (IIS) web server for hosting the web application.
2. Microsoft SQL Server for database development.
3. Microsoft Visual Studio IDE for application development.
4. Microsoft DevOps remote repository for version control.

In what follows we describe how to prepare the required resources at no cost by leveraging the Microsoft Imagine student support.

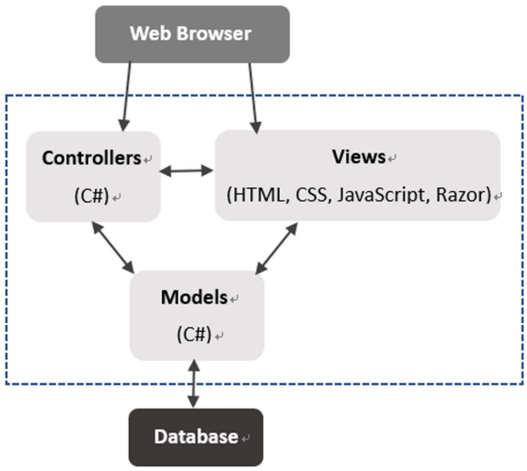

Fig 2 Design pattern based on ASP.NET MVC framework in the course.

3.1 Step 1: Create Microsoft Imagine Profile and Activate Azure Credits

As mentioned earlier, there are two levels of subscriptions in Microsoft Imagine: student subscription and institutional subscription. An institutional subscription does not serve our purpose as it is not free of charge and it still requires centralized resource management (i.e. an administrator should be in charge of resource allocation and maintenance). In contrast, a student subscription not only allows the access to all the resources necessary for this course at no cost but also grant each student the right to manage their own resources. Hence, we opted for student subscription in our course. Note that the instructor needs to make sure that the subscriptions are only used for academic purpose and are not used to developing profitable commercial products.

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A student subscription requires the subscriber to verify his/her student status through a university email account. Verification may take from several hours to a couple of days. Microsoft would send a confirmation email to the subscriber once his/her studentship is verified. This email has a URL that redirects the student to create a profile on Microsoft Imagine. After that, students activated their Azure for Students benefits so that the $100 USD Azure credits will become available. The process is simple and takes only a matter of minutes. No contract or credit card number is required. A full list of resources available under the Azure for Student support can be found on the official website. The benefits of our interest are the 10 web apps with 1GB storage and the 250 GB of SQL Database standard S0 instance with 10 database transaction units. All these resources are free of charge for one year.

We recommend instructors to confirm that all students have successfully activated their Azure for Student. Simply navigate to “cost management” in the Azure Portal and check if an Azure for Student subscription has been added to “My subscription”. Make sure that the status is “active”. Clicking on the subscription, it will show that 100 USD credits valid for 1 year have been granted to the subscriber.

3.2 Step 2: Prepare IDE and Set Up Repository

After activating the Azure for Students, the next step is to prepare the development environment and set up version control for the project. Students downloaded and installed the correct version of the Visual Studio IDE suited for the operating system of their laptops, created a remote repository in DevOps (previously known as Visual Studio Team Service) and set up local repository on their laptops. Students may also opt for

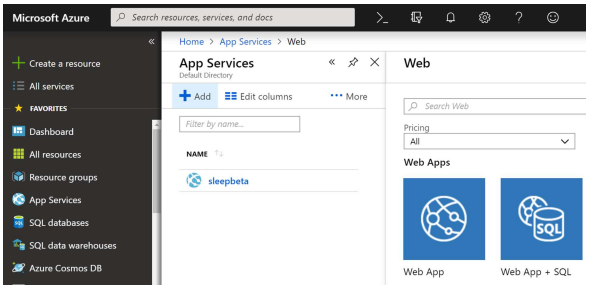

Fig 3　Creating a new App service in Azure Portal.

lightweight C# IDE such as Visual Studio Code or Project Rider to save resources in their laptops. Azure DevOps not only serves as a remote host of Git (like GitHub), but also supports team work throughout a full development cycle (i.e. planning, implementation, testing, building, and releasing). Unlike GitHub, it is possible to set up private repositories for free in Azure DevOps.

3.3 Step 3: Set Up Web Server

In this course, students learned how to develop web applications using the ASP.NET MVC framework, which requires the configuration of a web server and a database server. We use the PaaS layer of Azure cloud that allows us to focus on developing software applications while leaving the configuration and maintenance of servers to the cloud service provider. The cloud platform also balances workload automatically through auto-scaling.

At the PaaS layer, server setup is done automatically when a new app service or a new database is created. The complicated technical details are hidden from the user to increase technological transparency. As is shown in Figure 3, students simply need to navigate to “App Services” in the Azure Portal, create a new web app, and fill in required information (e.g. app name, subscription plan, resource group, operating system). The Azure platform automatically deploys a web server in the cloud and scaffold a blank web app. Figure 4 illustrates the process of configuring a database server. In a similar fashion, students simply need to navigate to “SQL databases”, create a new SQL database, and fill in required information (e.g. database name, subscription, resource group, SQL server, whether to use SQL elastic pool, and pricing tier). The platform automatically deploys a database server and then creates a new database on it. It is also possible to create new servers on the run during the process of publishing a web app to Azure from Visual Studio IDE.

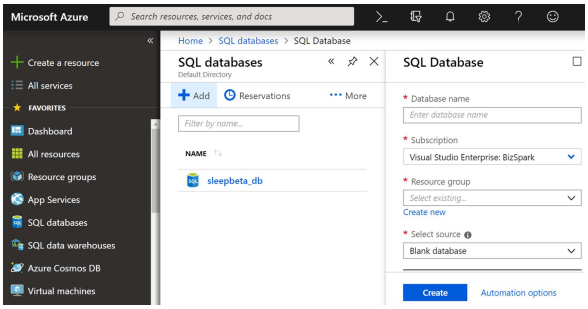

Fig 4　Setting up a new SQL database in Azure Portal.

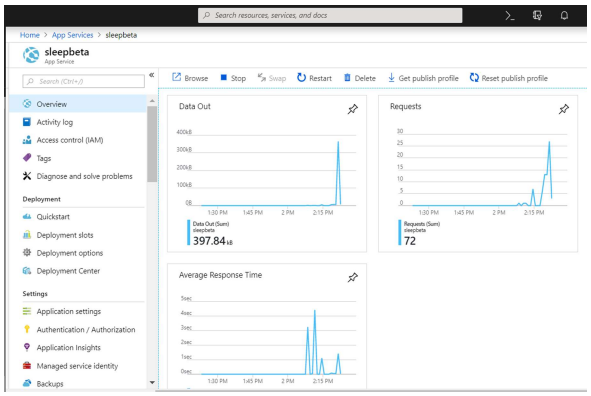

Fig 5　Developers can monitor and reconfigure the app under development in Azure Portal.

3.4 Step 4: Deploy Web App and Database

Once the web service and database are set up, students can publish their apps to Azure cloud. There are three methods to

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publish an app to the cloud: through Visual Studio IDE, through Azure DevOps, and through Azure Portal. The first approach is the simplest yet requires the Visual Studio IDE for windows. Simply right-click on the project and then click “publish” in Visual Studio IDE. If this option is not available, one can manually go through a build and release pipeline on Azure DevOps. Alternatively, it is possible to configure continuous deployment in Azure Portal by specifying a version control repository as the source. The continuous deployment option allows automatic deployment every time a version control commit is pushed to the version control repository. Database deployment is slightly more complicated. The deployment destination needs to be specified by the database connection strings in the configuration file (i.e. web.config). This string can be found on Azure Portal/SQL databases.

4. Managing Computing Resources

Using PaaS in Azure cloud, infrastructure management and maintenance are shifted to the cloud service provider, such as hardware and software update, load balancing, and security. Students could focus on the development of web applications without worrying about the maintenance of their computing resources, and instructors could focus on the planning and delivery of educational contents.

Resources can be monitored and reconfigured in Azure Portal. By clicking on the app, a dashboard will expand where developers can change the configuration of the app and check performance metrics. Figure 5 shows a screenshot of the overview feature in “Web Apps”. It is worth noting that the Azure for Student support is only valid for one year. After one year, students can choose to convert to a pay-as-you-go account or simply cancel the account.

5. Discussions

We have described how Microsoft Imagine program can be leveraged to mitigate the constraints of budget and management overhead in a hands-on web development course. In what follows we discuss the merits and limitations of this approach within the landscape of previous work.

5.1 Merits

Taking advantage of PaaS layer in Microsoft Azure Cloud, we successfully mitigated infrastructure constraints and reduced time required to set up and maintain the IT resources in our web development course. Table 1 summarizes a comparison between our approach and a previous approach described in [2]. The cost of purchasing infrastructure and software was eliminated in our course because Azure for Students grants all resources needed for app development free of charge. The overhead of infrastructure setup was distributed to each student. These tasks include the installation and configuration of operating systems, libraries, application server, http server, database server, load balancer, and applications. The PaaS layer in Azure cloud offers ready-to-use development and execution environment, and thus significantly shortens the setup process. Regardless of their background, students could complete the setup in a matter of minutes. Furthermore, management overhead is minimized as the duties of hardware and software maintenance and update are shifted to the cloud service provider and hence management overhead is minimized. Our experience confirms that commercial cloud can help reduce management overhead in web development courses, which have been validated previously in general programming courses [38].

The solution also introduces two additional benefits. First, it increases the flexibility of learning environment by enabling ubiquitous access to the IT infrastructure and resources. For security reason, it has been a common practice to limit the access to computing resources within the university firewall. Students have to be on campus to work on their development. The cloud-based environment in our course allows students to access their resources from outside the university and thus enables them to work on their project anytime from anywhere. This extra benefit has been reported in other cloud-based hands-on courses [39].

Second, cloud-based resources provide a more authentic learning environment as nowadays most development is carried out in cloud [4, 7, 9, 10, 13, 15, 40]. Setting up and configuring IT infrastructure and resources on cloud and the subsequent development in an authentic environment provides unique learning opportunities for students to gain hands-on experience in cloud computing. In addition to .NET, the PaaS in Microsoft Azure also support a variety of other frameworks such as PHP, Node.js, Python. Instructors can adapt their choices to the needs of their courses.

Table 1. Comparison between our approach and a previous approach in terms of constraints mitigation strategies.

	Our Approach	Previous Approach [2]
Reducing infrastructure cost	Using Microsoft Azure for Students (free)	Building their own machine with on-premise servers
Reducing management overhead (setup)	Letting student set up their resources using PaaS in Azure	Hiring TA administrators to set up resources
Reducing management overhead (maintenance)	Shifting maintenance to cloud service provider	Hiring TA administrators to maintain resources

5.2 Limitations

Our approach also has several limitations. First, resource setup may become a bottleneck in the course flow. Since students have to set up their computing resources, the instructor needs to allocate precious lecture time for students to complete the setup, or else students would not be able to make progress in the following lectures. Second, using Microsoft Imagine may cause authentication problems. The use of Azure Portal and DevOps requires synchronized log-in on all Microsoft related software and platforms such as Hotmail and Skype, which may cause inconvenience to users who log in with different accounts on these platforms. Some students had difficulty in accessing their

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Microsoft Imagine account due to their previous usage of Active Directory. Third, as has been pointed out before, using commercial cloud services may cause conflicts with institutional IT policies. For instance, access to web or database server in Azure may be blocked due to the settings of firewall or Wi-Fi on campus. Last, Microsoft Imagine support for student is valid for only one year. Using resources after the expiration of Microsoft Imagine may trigger considerable cost. Therefore, this approach is not suited for courses spanning over multiple years.

6. Conclusion

This paper has described our experience on how to leverage commercial cloud service to mitigate cost and management overhead of a web development course. In our approach, students signed up for Microsoft Imagine program that grants them free access to Microsoft Azure cloud infrastructure for one year. By requiring students to set up their own computing resources in Azure cloud, we convert the previously time-consuming task for instructors into valuable learning experience in cloud computing for students. The platform-as-a-service (PaaS) layer of Azure cloud allowed us to shift infrastructure management and maintenance overhead to the cloud service provider. This approach enables us to provide a web development course in the cloud environment at no cost and minimal management overhead. We hope this approach can be useful for educational institutions or instructors that aim to offer web development courses at low cost without compromising students' learning experience.

References

[1] K. Treu. To teach the unteachable class: an experimental course in web-based application design. SIGCSE Bull. 34(1), 201-205 (2002).

[2] E. Walker, and L. Browne. Teaching web development with limited resources. In Proceedings of SIGCSE'99, 12-16 (1999)

[3] F. Doelitzscher, A. Sulistio, C. Reich, H. Kuijs, and D. Wolf, "Private cloud for collaboration and e-learning services: from IaaS to SaaS," Computing - Cloud Computing, vol. 91, no. 1, pp. 23-42 (2011).

[4] R. Buyya, C. S. Yeo, S. Venugopal, J. Broberg, and I. Brandic, "Cloud computing and emerging IT platforms: vision, hype, and reality for delivery computing as the 5th utility," Future Generation Computer Systems, vol. 25, no. 6, pp. 599-616 (2009).

[5] M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, R. Katz, A. Konwinski, and e. al, "A view of cloud computing," Communications of the ACM vol. 53, no. 4, pp. 50-58 (2010).

[6] P. Mell, and T. Grance, "The NIST definition of cloud computing. National Institute of Standards and Technology (NIST)," Tech. Rep. 800-145 (2011).

[7] J. Cito, P. Leitner, T. Fritz, and H. C. Gall, "The making of cloud applications: an empirical study on software development for the cloud," In Proc of the 10th Joint Meeting on Foundations of Software Engineering, pp. 393-403 (2015).

[8] Z. Liang, B. Ploderer, W. Liu, Y. Nagata, J. Bailey, L. Kulik, and Y. Li, "SleepExplorer: a visualization tool to make sense of correlations between personal sleep data and contextual factors," in Personal Ubiquitous Comput., vol.20, no.6, pp. 985-1000 (2016).

[9] Z. Liang, B. Ploderer, M. A. Chapa-Martell, and T. Nishimura, "A cloud-based intelligent computing system for contextual exploration on personal sleep-tracking data using association rule mining," Intelligent Computing Systems. Communications in Computer and Information Science (2016).

[10] V. Navale, and P. E. Bourne, "Cloud computing applications for biomedical science: a perspective," PLoS Computational Biology, vol.14, no.6, e1006144 (2018).

[11] J. Bennett, and H. E. Pence, "Managing laboratory data using cloud computing as an organizational tool," Journal of Chemical Education vol. 88, pp. 761-763 (2011).

[12] N. Sultan, "Cloud computing for education: a new dawn?," International Journal of Information Management, vol. 30, no. 2, pp. 109-116 (2010).

[13] M. Mircea, and A. Andreescu, "Using cloud computing in higher education: a strategy to improve agility in the current financial crisis," Communications of the IBIMA (2011).

[14] T. F. Rienzo, and B. Han, "Microsoft or Google web 2.0 tools for course management," Journal of Information Systems Education, vol. 20, pp. 123-127 (2009).

[15] J. A. Gonzalez-Martinez, M. L. Bote-Lorenzo, E. Gomez-Sanchez, and R. Cano-Parra, "Cloud computing and education," Computers and Education, vol. 80, no. C, pp. 132-151 (2015).

[16] R. Saadatdoost, A. Tze, H. Sim, H. Jafarkarimi, J. M. Hee, and L. Saadatdoost, "Cloud computing for teaching practice: a new design," International Journal of Web-based Learning and Teaching Technologies, vol. 9, no. 4, pp. 50-68 (2014).

[17] A. Neal, "Combining Cloud Networks and Course Management Systems for Enhanced Analysis in Teaching Laboratories," Journal of chemical education, vol. 89, pp. 482-486 (2012).

[18] Q. Chris, "Pervasive Science: Using Mobile Devices and the Cloud to Support Science Education," Interactions, vol. 19, pp. 76-80 (2012).

[19] M. Crossniklaus, and D. Maier, "The curriculum forecast for Portland: cloudy with a chance of data," ACM SIGMOD Record, vol. 41, no. 1, pp. 74-77 (2012).

[20] L. M. Vaquero, "EduCloud: PaaS versus IaaS cloud usage for an advanced computer science course," IEEE Transactions on Education, vol. 54, no. 4, pp. 590-598 (2011).

[21] H. E. Schaffer, S. F. Averitt, M. I. Hoit, A. Peeler, E. D. Sills, and M. A. Vouk, "NCSU's virtual computing lab: a cloud computing solution," Computer, vol. 42, no. 7, pp. 94-97 (2009).

[22] R. E. Pike, J. M. Pittman, and D. Hwang, "Cloud-based versus local-based web development education: an experimental study in learning experience," Information Systems Education Journal, vol.15, no.4, pp. 1-17 (2017).

[23] C. F. Wu, and L. P. Huang, "Developing the environment of information technology education using cloud computing infrastructure," American Journal of Applied Sciences, vol. 8, pp. 864-871 (2011).

[24] B. Songbin, and Z. Cuizhen, "A cloud learning environment for foreign language learners," Advances in Information Sciences and Service Sciences., vol. 4, no. 16, pp. 114-122 (2012).

[25] R. A. Calvo, S. T. O'Rourke, J. Jones, K. Yacef, and P. Reimann, "Collaborative writing support tools on the cloud," IEEE Transactions on Learning Technologies, vol. 4, no. 1, pp. 88-97 (2011).

[26] G. Riahi, "E-learning system based on cloud computing: a review," Procedia Computer Science, vol. 62, pp. 352-359 (2015).

[27] Z. Liang, "Empowering globalization of engineering education with open-source e-learning platform and cloud computing technology," in Annual Conference of Japan Society for Engineering Education International Session, Tokyo, Japan, pp. 19-24 (2017).

[28] L. P. Prieto, J. I. Asensio-Perez, J. Munoz-Cristobal, et al, "Enabling teachers to deploy CSCL designs across distributed learning environments," IEEE Transactions on Learning Technologies, vol. 6, no. 4, pp. 324-336 (2013).

[29] T. D. Nguyen, D. T. Nguyen, and T. H. Cao, "Acceptance and use of information system: e-learning based on cloud computing in Vietnam," Lecture Notes in Computer Science, vol. 8407 (2014).

[30] P. Pocatilu, F. Alecu, and M. Vetrici, "Measuring the efficiency of cloud computing for e-learning systems," WSEAS Transactions on Computers, vol. 9, no. 1, pp. 42-51 (2010).

[31] I. Sommerville, "Teaching cloud computing: a software engineering perspective," Journal of Systems and Software, vol. 86, pp. 2330-2332 (2013).

[32] M. Swan, "Sensor mania! The internet of things, wearable computing, objective metrics, and the quantified self 2.0," Journal of Sensors and Actuator Networks, vol. 1, no. 3, pp. 217-253 (2012).

[33] S. Peter, J. Wisit, H. Michael, C. Mark, and D. Scott, "Quantified self and human movement: A review on the clinical impact of

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wearable sensing and feedback for gait analysis and intervention," GAITPOST, vol. 40, pp. 11-19 (2014).
[34] Z. Liang, and M. A. Chapa-Martell, "Framing self-quantification for individual-level preventive health care," in Proc. of HEALTHINF 2015, pp. 336-343 (2015).
[35] Z. Liang, M. A. Chapa-Martell, and T. Nishimura, "Mining hidden correlations between sleep and lifestyle factors from quantified-self data," in Proc of the ACM International Joint Conference on Pervasive and Ubiquitous Computing, pp. 547-552, Germany (2016).
[36] Z. Liang, M. A. Chapa-Martell, and T. Nishimura, "A personalized approach for detecting unusual sleep from time series sleep-tracking data," in In Proceedings of the IEEE International Conference on Health Informatics (ICHI), Chicago, US (2016).
[37] Z. Liang, and M. A. Chapa-Martell, "A top down approach for teaching web development on cloud," in IEEE International Conference on Teaching, Assessment and Learning for Engineering, Wollongong, Australia (2018).
[38] C. Ivica, J. T. Riley, and C. Shubert, "StarHPC - Teaching parallel programming within elastic compute cloud," in The 31st Int Conf. on Information Technology Interfaces, Cavtat, Croatia, pp. 353-356 (2009).
[39] J. Hollingsworth, and D. J. Powell, "Teaching web programming using the Google cloud,"in ACMSE '10, pp.1-5 (2010).
[40] R. Thomas, and B. Han, "Microsoft or Google Web 2.0 Tools for Course Management," Journal of Information Systems Education, vol. 20 (2009).

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