AN ANALYSIS OF STUDENTS’ PERSPECTIVES IN USING VIRTUAL LABS IN AN UNDERGRADUATE IT COURSE

Nada Alharbie, Rukshan I. Athauda, Simon
The University of Newcastle, Australia
University Drive, Callaghan, NSW 2308, Australia
Nada.Alharbie@uon.edu.au, Rukshan.Athauda@newcastle.edu.au, Simon@newcastle.edu.au

ABSTRACT
Access to computing laboratory facilities is an integral part in teaching/learning environments in higher education today. However, usage model of traditional computer laboratories has many limitations. The use of virtualised computing laboratories, enabled by cloud and virtualization technologies, aims to overcome many of these limitations. However, the use of virtualised labs in higher education institutions is still in its infancy and many questions remain unanswered. In this paper, we outline a pilot implementation of a virtual lab environment using Cloud technologies in an undergraduate IT course. We evaluate the student experience from a number of perspectives through quantitative and qualitative survey responses. Our results are show positive response and attitudes to the use of such technologies by students and also gain some useful insights.

KEY WORDS
Virtual labs, Cloud Computing, Learning Environments

1. Introduction
Access to computer laboratory facilities is an integral aspect of learning environments in higher education. This is especially true in computing education where expensive software and hardware configurations are created and maintained for student learning [8, 15]. Traditionally, educational institutions invest large amounts of resources to develop and maintain dedicated educational laboratories, which are used by students for learning activities during tutorial/lab sessions and at other times when they are available. The provision and use of these laboratories gives rise to a number of issues.

- Physical access: Access to laboratories in university environments is limited by their physical location.
- Extended lab hours: Access to laboratories is limited by their opening hours, as a consequence of which educational institutions sometimes feel obliged to open computer laboratories for extended hours. This is costly, and creates potential social issues such as students needing to travel to and from campus after hours.

- Inconvenience and inflexibility to students: With many students juggling work, studies and personal life, they find it difficult to spend extended hours in university computer labs undertaking assessments and other learning activities. This is especially true with distance education programs where students visit the campus seldom or never.
- Emulating lab resources on personal computers: To mitigate these issues, those students with adequate computing resources such as personal laptops and desktops download software (sometimes trial versions) and try to configure their own computers to avoid or work around the constraints imposed by the physical laboratories. This is not ideal. Software licensing issues and inadequate hardware resources are common in such situations, providing less than optimal performance from individually configured systems. More often than not, the students’ attempts at configuration are cumbersome, time-consuming, trial-and-error processes which occupy valuable time that students should ideally be spending on the subject matter of the courses they are studying. This is exacerbated by the fact that the university’s IT staff can provide little or no support for students’ personal computers, and that different courses require different types and versions of software tools and packages.

- Lack of resources and flexibility for academics: Academics themselves are sometimes unable to obtain the resources (e.g. hardware) needed to teach certain computing subjects. As a consequence they are likely to change the design of the course, with a possible negative impact on the overall teaching quality [5].
- Lack of flexibility in online offerings: Many educational institutions find themselves unable to offer certain programs in distance or online modes. One of the main impediments is the inability to offer facilities such as complex laboratory facilities to students in distance-mode programs [7].

Cloud computing technologies are revolutionising the IT industry and its delivery models. Cloud computing and related virtualisation technologies enable remote on-demand access to computing resources in ‘the cloud’ (i.e. remote data centres). In many areas of work, cloud computing is seen as an opportunity, and ways are being found to take advantage of that opportunity. Education is one of those areas, and ways are being sought for...
educational institutions to use cloud computing for teaching, learning, and research purposes.

Educational institutions can create virtual laboratory facilities to provide remote access to computing resources for students in teaching and learning environments. Virtual labs enable students and academics alike to remotely access computer laboratory facilities at any time of the day or week, and can cost less to manage and maintain than traditional physical computing laboratories. Virtual lab environments can address the issues listed above and provide students with a more flexible, convenient and enriching learning experience. A number of publications in literature support this view.

Vaquero [15] observes that “…this will save students from the frustration of having to install software in every machine they use, which suffers limitations such as licensing and variation in machine versions…”. Li [10] states that “IT related learning institutions can significantly benefit from the following as a result of incorporating virtualization and cloud computing within their IT infrastructure: reduction of hardware acquisition costs, maintenance costs, increased accessibility of laboratory resources and increased development of new laboratories”. Chenyang [5] notes that “…the virtual labs reduce the need; hence the cost of hiring administrators for the labs, besides making the labs more available to students. They also offer flexibility in design of practical assignments, as well as a more engaged and open laboratory and learning environment”. A number of other authors explain how they have used virtual labs in computing education [2, 9, 14, 20].

Notwithstanding these reports on the use of virtualised labs for teaching and learning purposes, the use of virtualised labs is still in its infancy. Many institutions are beginning to pilot these technologies. Many questions yet remain to be explored and answered. For instance, how does the use of virtual labs impact on students in distance or blended learning environments? What do students, academics, and IT support staff feel about the use of virtualised labs? How can courses, teaching/learning activities and academic programs adopt or be designed to take advantage of virtualised lab environments? What tools and models are best suited to developing and deploying virtual lab environments?

In this paper, we analyse the students’ perspective on the use of virtualised labs in an undergraduate IT course. The results are encouraging and positive for the use of virtual labs. They also provide some insights in the use of virtual environments in blended learning environments.

This paper is organised as follows: Section 2 discusses related work. In section 3, a conceptual model of the virtual lab environment is presented with a discussion of the pilot implementation. Section 4 presents the results and analysis of students’ quantitative and qualitative feedback. Section 5 concludes the paper.

2. Related Work

Cloud computing is a term used quite frequently in IT industry and research in recent times. It generally refers to the model of computing whereby computing resources, typically available in remote data centres, are allocated and used by various consumers (i.e. individuals or organisations) to meet their computing requirements. Web mail (such as gmail) is a form of cloud computing service: Google hosts the email service in its own data centres, from where it is accessed by consumers.

With cloud computing, virtualisation technologies permit the on-demand customisation and configuration of the required computing resources at various levels with minimal interaction from the service provider. This permits organisations to host their own IT services on the cloud; for example, an organisation can host its payroll application in a remote data centre and access it via the network.

Cloud computing provides three service models and four deployment models. Below we outline the definitions from the (US) National Institute of Standards and Technology.

Cloud computing is “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [11].

The three service models for Cloud Computing are Software as a Service, Platform as a Service, and Infrastructure as a Service.

- In Software as a Service (SaaS), “the capability provided to the consumer is to use the provider’s applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings” [11].

- In Platform as a Service (PaaS), “the capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment” [11].

- In Infrastructure as a Service (IaaS), “the capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources.”
resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components” [11].

Cloud Computing has four deployment models.

- Private cloud: In a private cloud, “the cloud infrastructure is used exclusively by a single organisation. It may be owned, managed, and operated by the organisation, a third party, or some combination of them, and it may exist on or off the organisation’s premises” [11].

- Community cloud: In the community cloud, “the cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organisations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises” [11].

- Public cloud. “The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organisation, or some combination of them. It exists on the premises of the cloud provider” [11]. Public cloud providers include Amazon [1], Google[6], and others.

- Hybrid cloud. “The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds)” [11].

In the literature we can find a number of reports on the use of different deployment models – private, public and hybrid clouds – to facilitate virtual lab environments. We observe two main approaches to using cloud computing and virtual labs in education. First, many academics have introduced virtual labs to computing-related courses that require complex configurations and hardware resources for teaching and learning purposes. Virtual labs implemented with virtualisation technologies have provided a flexible, unrestricted approach to developing course materials for teaching and learning purposes that traditionally require extensive computing resources and facilities. Second, the IT support departments of universities and community colleges have taken up virtualisation to provide computing labs (in addition to traditional physical labs) to provide students and academics with flexible access to resources for teaching, learning and research purposes.

Tomov [8] reports on the use of a public cloud provider (Amazon) to implement virtual labs in teaching database related courses, and discusses a Cloud Vendor Selection model for selecting appropriate cloud providers. Vaquero [15] evaluates students’ perceptions (mainly on ease of use and usefulness) following assignments based on PaaS and IaaS models in an advanced network course using public cloud providers: Google App Engine[6] for the PaaS assessment task and Amazon [1] for the IaaS assessment task. Ivica et al. [9] explain the configuration and tools that they used to deploy VMs for teaching a parallel programming course using Amazon’s Cloud infrastructure. Wang et al. [20] and Caminero et al. [4] both use virtual lab spaces to provide students with a sand-boxed secure environment for learning in networking courses. Wang et al. [20] use a private cloud implemented using VMWare virtualisation platform [17], while Caminero et al. [4] use a hybrid cloud in the VirtualBox virtualisation environment [16]: they begin with a private cloud, but as resources are exhausted, they switch to a public Amazon EC2 cloud. Yuan et al. [22] use a private cloud to present a resource-intensive IP-telephony course, thus avoiding the use of expensive laboratory equipment. Peng et al. [12] present a cloud computing course which creates complex virtual data centre environments for student learning.

Schaffer et al. [13] present a Virtual Computing Lab (VCL), which provides VMs on demand for academics and students university-wide at North Carolina State University (servicing over 30,000 students and a dozen or so campuses). The code developed to implement VCL is converted into an open-source project for further development. This is probably the most mature organisation-wide implementation of virtual computing laboratories. VCL was also deployed in a pilot introductory computer technology course at Wake Tech Community College, where student and instructor perceptions were collected and evaluated [3]. Anderson et al. [2], used the Xen virtualisation environment [21] to create a virtual lab for teaching and learning activities in the Information Assurance program at Iowa State University.

3. Conceptual Model and Pilot

The Virtual Lab used in our course was configured on a private cloud implementation using VMWare’s vSphere virtualisation platform [19]. The pilot database course selected for the trial did not require a complex sandboxed environment such as mentioned in [4, 20 and others]. Rather access to a pre-configured VM for each student with all necessary software installed which can be remotely accessed was deployed. Since this virtual lab was deployed to a single pilot course – not to an entire organisation-wide deployment, a complex management layer for provisioning and controlling VMs such as in
VCL implementation [13] was deemed un-necessary. The major aim of the pilot virtual lab deployment was to provide an opportunity to students to experience a virtual lab environment and analyse students’ perspectives on the use of virtual labs. Figure 1 shows a high-level conceptual model of the virtual lab.

The private cloud environment was implemented on a single physical server, whose specifications are given in Table 1. On the physical server we installed the VMWare ESXi, which provides a virtualisation layer to manage the physical hosts and to create and deploy virtual machines. The VMWare vCenter Server 5.0 was used to create and manage the data centre (which can include multiple hosts). This software also facilitates features such as the creation and deployment of VM templates. The administrator uses the VMWare vSphere Client 5.0 to interact with the virtualised environment, and the student VMs are hosted on the ESXi host.

The pilot course was an advanced database course in the undergraduate IT program at the University of Newcastle, Australia. There were 33 students enrolled in the course. The virtual lab was accessible to students for the final seven weeks in semester 1, 2012. Each student was given access to his/her own VM configured with all the software required for learning activities in the course. Students were given administrator access to further configure and install any additional approved software. The students access the virtual lab via Remote Desktop from either within or outside the campus network using a pre-assigned IP address. The VMs were available 24 hours a day for student access throughout the trial period. Table 2 shows the configuration of the lab VM used in the virtual lab.

The virtual labs were deployed as a supplementary resource to the traditional physical labs. At the end of the semester, students were invited to fill in a survey whose results were analysed.

Table 2: VM Specifications

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Windows 7 Professional (x64)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>1 vCPU</td>
</tr>
<tr>
<td>Memory</td>
<td>2 GB</td>
</tr>
<tr>
<td>Disk space</td>
<td>40GB</td>
</tr>
<tr>
<td>Software (pre-installed)</td>
<td>Microsoft Office 2012 (incl. Visio)</td>
</tr>
<tr>
<td></td>
<td>Microsoft SQL Server 2008 R2</td>
</tr>
<tr>
<td></td>
<td>Microsoft Visual Studio 2008</td>
</tr>
<tr>
<td></td>
<td>Firefox</td>
</tr>
</tbody>
</table>

The survey was divided into four sections:
(i) Assistance in learning;
(ii) Accessibility and ease of use;
(iii) Virtual lab vs. physical labs; and
(iv) Overall experience.

The survey, designed to assess the respondents’ satisfaction with the virtual lab, consisted of 25 questions. Quantitative data was provided by closed questions using a 5-point Likert scale. Qualitative data came from open-ended questions that allow the participants to give their own views, and that are intended to help the researchers understand the reasons behind the quantitative findings. Through this survey, the researchers were able to evaluate the students’ perspectives on the use of virtual cloud computing labs. The results of the survey are analysed and presented in the next section.

4. Results and Discussion

The survey had a response rate of 36% (12 students from 33 enrolled students). Survey results for each section of the survey are analysed and presented below.

4.1 Assistance in Learning

The pilot course consisted of laboratory based tutorials, assignments consisting of laboratory exercises and group work. Each section of the survey addressed these three areas of the course. Table 3 shows the collated responses to the survey’s closed questions regarding Assistance in Learning.
Of the students who answered the survey, 58% say that virtual labs helped in completing their tutorial work, and 92% would like to use virtual labs in future tutorial work; 83% responded that virtual labs helped with their assignments, 92% responded that they would like to use virtual labs for future assignments. On the other hand, only 42% felt that virtual labs helped them in their group work, and only 66% would like to use virtual labs in future group work.

This section of the survey included three open-ended questions, which are listed below with some excerpts from student responses.

“When do you prefer to use virtual labs to do university work?”
- “Late in the afternoon or night”
- “always - they save up a lot of time.”
- “Mainly when i don’t have the programs installed on my own computer.”
- “when i need to code or develop something i need to set up lots of things including application and other environmental conditions, but the virtual lab lets me do the assignments right away without any other annoying setting and installing. Setting and installing(maybe downloading application as well) are highly time consuming process and it also wastes time for the assignments.”

“Whenever I’m actually in a lab class.”

“Mainly during tutorials, virtual labs simplify things and allow me to do my work from home. I find that i prefer to socialise while i am at university, but having access to the virtual lab helps me do my work in my own time without cutting into my social life.”

“Only to meet with groups, wother than the virtual lab is good to use”

“When unique or expensive software is required. During groupwork”

“When doing group work with group members”

“When I am on campus?”

“When do you prefer to use your home computer and not virtual labs to do university work?”
- “When I have the software available”
- “When speed is necessary. Virtual machines have input delay and act sluggish sometimes. Generally, i will use virtual labs when i don’t have programs available to me, or when i need to access something from multiple locations i will save to my VM. But for coding or just doing basic documents i will use my home machine.”
- “almost never, because it is far to old to handle most of the stuff that we have to do.”
- “When doing tutorial and assignment work that I have access to the appropriate software to complete.”

From the student responses it is clear that most students use virtual labs from home when the traditional lab is unavailable. This provides flexibility, convenience and improved access. They prefer the convenience of having all necessary software pre-installed and configured so they do not waste time in configuring their computers. Also, sometimes it is convenient as their home computers may not have the necessary software and hardware resources. However, it can also be said that students with adequate hardware and software resources may opt to use their own computers, which have better performance than VMs. Most students use on-campus labs during tutorials or when on campus, and find the on-campus labs particularly useful for group work.

### 4.2 Accessibility and Ease of Use

A primary benefit of using Virtual Labs is the accessibility of laboratory facilities at any time, remotely from a client computer with Internet access. Table 2 shows the closed questions and collated student responses for accessibility and ease of use.
The virtual lab was easy to use

<table>
<thead>
<tr>
<th>Question</th>
<th>Response rate</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Agree 58% Agree 42% Neutral 0% Disagree 0% Strongly Disagree 0%</td>
<td>4.58</td>
</tr>
</tbody>
</table>

The virtual lab was available to you when you needed it

<table>
<thead>
<tr>
<th>Question</th>
<th>Response rate</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Agree 50% Agree 42% Neutral 8% Disagree 0% Strongly Disagree 0%</td>
<td>4.42</td>
</tr>
</tbody>
</table>

The virtual lab was easier to use than on-campus labs

<table>
<thead>
<tr>
<th>Question</th>
<th>Response rate</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Agree 17% Agree 17% Neutral 67% Disagree 0% Strongly Disagree 0%</td>
<td>3.50</td>
</tr>
</tbody>
</table>

It was easier to use the virtual lab than to reconfigure your home computer to do your university work

<table>
<thead>
<tr>
<th>Question</th>
<th>Response rate</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Agree 45% Agree 18% Neutral 27% Disagree 9% Strongly Disagree 0%</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Virtual labs lived up to your expectations

<table>
<thead>
<tr>
<th>Question</th>
<th>Response rate</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Agree 27% Agree 73% Neutral 0% Disagree 0% Strongly Disagree 0%</td>
<td>4.27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Response rate</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Agree 50% Agree 42% Neutral 0% Disagree 0% Strongly Disagree 0%</td>
<td>4.42</td>
</tr>
</tbody>
</table>

The following open-ended question was posed in the survey with regard to accessibility and ease of use:

“Do you have any observations with regard to the accessibility and ease of use of virtual labs?”

Following are some excerpts of student responses:

- “Can be a little bit annoying if you’re using a roaming wireless connection. Drops in and out.”
- “The advantage with the virtual labs is that you have 24 hour access. For example, I would have been able to use them in the middle of the night at the AIC if necessary.”
- “Dynamically re-assigning IP addresses caused a lot of problems with people being unable to access their VM’s online during the weekend to work on assignment. Otherwise they have been stable and easy to use.”
- “I thought the virtual labs were easy to use and access.”
- “I hope the virtual lab server is upgraded with better performance.”
- “I feel laggy and delayed sometimes (even connection from on-campus accommodation it might be network problem. But there was no disconnection problem”

It can be safely concluded that the students who filled the survey found the virtual lab easy to use (58% strongly agree and 42% agree) and found it available when required (50% strongly agree and 42% agree). All respondents agreed that the virtual lab lived up to their expectations (27% strongly agree and 73% agree). A reliable internet connection is essential for accessing the virtual lab. Also the use of IP addresses for the Remote Desktop connection resulted in a need to inform re-assigned IP addresses after a server restart. This could have been avoided if a web access to VMs were configured, avoiding the use of IP addresses altogether.

4.3 Virtual labs vs. Physical labs

When using virtual labs for on-campus students, one of the critical questions that come to mind is the usefulness and relevance of physical lab spaces. Do we still need them? What role do physical labs play if virtual labs are available? Are virtual labs complementary to physical lab space?

Figure 2 depicts responses to the following closed questions:

- You would rather use virtual labs than visit the actual (i.e. physical) lab to do your university work
- The virtual lab was easier to use than on-campus labs

A majority of the student were neutral on the question of using the virtual labs rather than the physical labs. Furthermore, 33% of students also had neutral views concerning the ease of using the virtual labs as compared to the physical labs, and 8% of the students felt that the on-campus labs were easier to use than the virtual labs.

The open-ended comments indicate that students prefer to use both physical labs and virtual labs and view them as complementary. This was an interesting insight gained. They do not see the virtual lab as a replacement for the physical lab. This statement is affirmed by the following student comments:

- “I would hope the term virtual lab does not mean students would no longer have labs to attend. I go to
4.4 Overall Evaluation of Virtual Labs

The collated responses to closed questions focusing on overall evaluation of virtual labs are presented in Table 5.

Table 5: Survey results for ‘Overall Evaluation’ closed questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Response rate</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>The virtual labs enhance the quality of studying Information Technology</td>
<td>Strongly Agree 50% Agree 33% Neutral 8% Disagree 8% Strongly Disagree 0%</td>
<td>4.25</td>
</tr>
<tr>
<td>The virtual labs were important to your learning in the course</td>
<td>Strongly Agree 8% Agree 42% Neutral 33% Disagree 17% Strongly Disagree 0%</td>
<td>3.42</td>
</tr>
<tr>
<td>You would like to use virtual labs in the future</td>
<td>Strongly Agree 50% Agree 33% Neutral 17% Disagree 0% Strongly Disagree 0%</td>
<td>4.33</td>
</tr>
<tr>
<td>You would like to have virtual labs in other courses</td>
<td>Strongly Agree 50% Agree 17% Neutral 33% Disagree 0% Strongly Disagree 0%</td>
<td>4.17</td>
</tr>
<tr>
<td>You are highly satisfied with virtual labs</td>
<td>Strongly Agree 50% Agree 42% Neutral 8% Disagree 0% Strongly Disagree 0%</td>
<td>4.42</td>
</tr>
</tbody>
</table>

This section of the survey included open-ended questions regarding the overall evaluation of virtual labs. Two of these are listed below, with some student responses.

“What are the strengths of using virtual labs?”
- “Some programs are hard to obtain due licensing and so on. In this case, they are very useful.”
- “Ability to access software from anywhere that I need for an assignment/uni work without the need to use MSDN to download software needed.”
- “Being able to co-ordinate work over multiple computers. Having easy access to necessary programs without reconfiguring your home PC. Easy to use, simple to navigate. Very good for doing assignments.”
- “Software consistency and mobile data access”

“What are the weaknesses of using virtual labs?”
- “Only basic 4:3 resolution in OSX using Remote Desktop Connection”
- “Slow internet connections may be a problem, but I managed to connect to the virtual machine and use it just fine with 1.5Mbps. There’s also the risk that, in the event of failure, students who depend on them exclusively for assignments are at risk of being unable to complete their work.”
- “If the server is restarted, IP addresses are lost, which results in a lot of downtime and can make assignment work difficult.”

In the closed questions, students’ responses are highly positive in terms of virtual labs enhancing the quality of studying IT (83% agree or strongly agree), students’ preference to use virtual labs in future and in other courses (83% agree or strongly agree), and student satisfaction with virtual labs (92% agree or strongly agree). It is interesting to note that when it comes to importance to learning in the course, 50% agree or strongly agree that virtual labs are important, 33% are neutral, and 17% disagree, notwithstanding a very high rating in the previous questions.

Analysing the open-ended questions, the authors conclude that the major strengths of virtual labs include ease of use, ubiquitous access, flexibility and convenience due to remote access to virtual lab machines 24 hours a day without the overheads of configuring machines, licensing software etc. The major limitations of the virtual lab implementation include limitations of Remote Desktop Connection (such as resolution) and the need to remember IP addresses. The authors believe that configuring web access to remote VMs rather than Remote Desktop Connection will resolve these issues in future. Also, some concerns with virtual labs include the need to have internet connectivity to access VMs and the risk of losing work in the event of server failures (which can be addressed through high-availability server solutions and server backups).

5. Conclusion

In today’s higher education, access to computer laboratory facilities is imperative for teaching and learning activities, particularly but not exclusively for computing education. Higher educational institutions have invested large amounts of resources in creating computer laboratories for teaching and learning purposes. However, the usage models of traditional computer laboratories bring a number of limitations. Cloud computing and related technologies enable the creation of virtual computing laboratories that can be accessed remotely at...
any time, addressing many of the limitations of traditional computer laboratories. The literature offers a number of reports of the use of virtual computing laboratories, but the field is still in its infancy and many questions are yet to be answered.

This paper presents a pilot implementation of a virtual lab to teach an advanced database management systems course in an undergraduate IT program. The pilot implementation uses a private cloud and a VMWare virtualisation platform. Students' perceptions on using virtual labs are analysed and some useful insights are gained.

Many of the issues of traditional labs are resolved with the implementation of a virtual lab through remote flexible access to virtual lab machines from any device at any time. However, in the current context virtual labs by themselves do not replace traditional lab spaces from students' and pedagogical perspectives. From the pedagogical perspective, a number of factors favour the continued use of traditional labs. For instance, traditional lab classes provide access to interaction with peers, tutors, and group work partners, access that is not provided by virtual labs. From our analysis, we can safely conclude that the use of virtual labs in conjunction with traditional lab classes provides a rich, flexible, convenient learning environment to students, improves students' satisfaction, and addresses some of the shortcomings of traditional labs without impacting on pedagogical aspects.

References

[18]VMWare Inc., “Getting Started with ESXi Installable”, VMWare publications, p. 13.