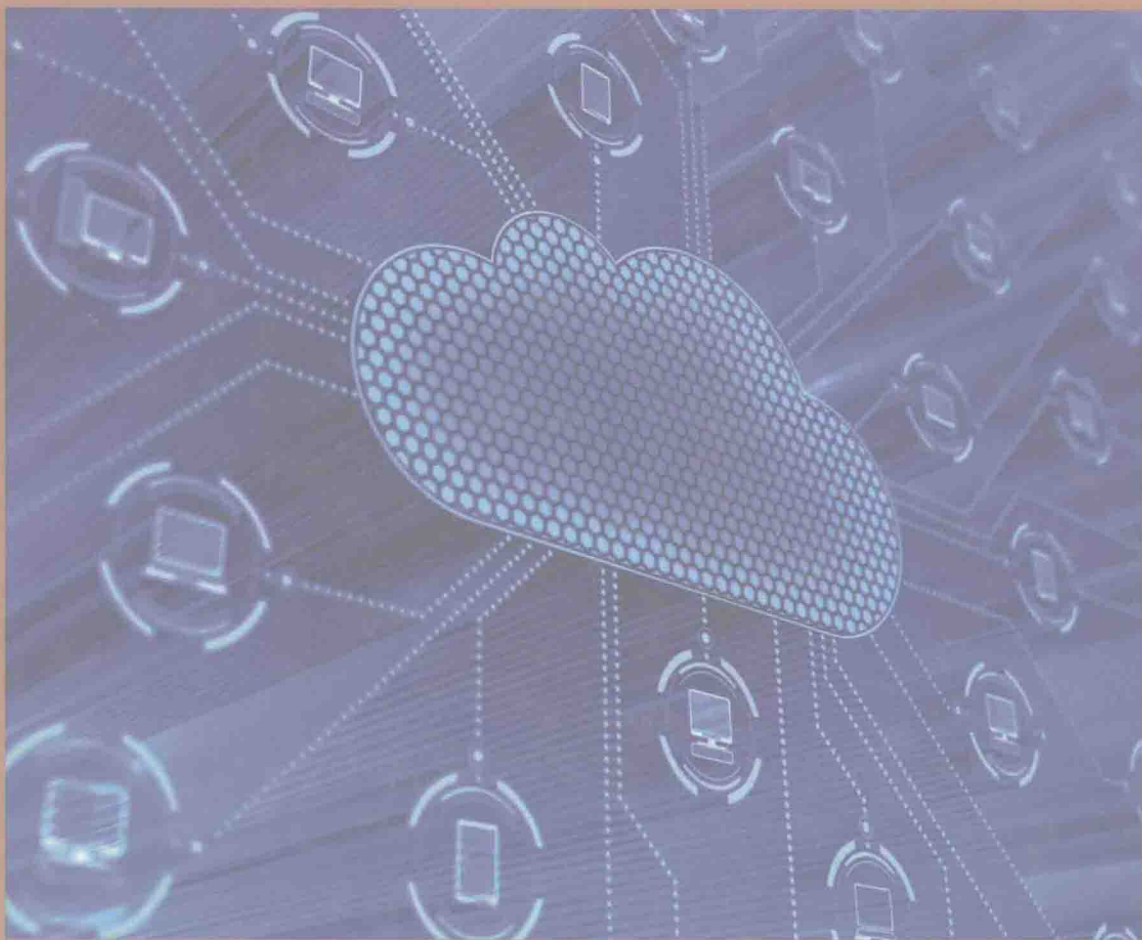# Cloud Computing for Teaching and Learning

Strategies for Design and Implementation

Lee Chao

Cloud Computing for Teaching and Learning:
Strategies for Design and Implementation

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Editorial Advisory Board

Preface

E-learning is an ever changing field along with the improvement of Information Technology. Educational institutions actively adopt new technologies to improve teaching and learning. More recently, educators have begun to pay attention to the newly developed cloud computing technology. It is the goal of this book to assist educators in integrating cloud computing to e-learning.

Cloud computing is a newly developed platform for providing IT services. Similar to the traditional utility services, subscribers of cloud computing only pay for the services and resources that they use. Major IT companies such as Amazon, Google, and Microsoft are currently providing cloud services and resources. These companies consider cloud computing the future for business and education. Subscribers do not have to build and maintain their own IT infrastructures. Cloud computing allows the subscribers to rapidly and inexpensively re-provision IT resources for various needs.

Due to its flexibility, security, availability, scalability, and affordability, cloud computing begin to attract the attention of educational institutions. Numerous research studies have been done in the area of cloud computing and its application in teaching and learning. The features provided by cloud computing are especially beneficial for small educational institutions that lack funding to maintain their own IT services. Nowadays, some of the universities start to offer cloud computing based courses. Research on cloud computing and its possible use in education are active. Cloud based computer labs have been developed to support hands-on practice. Some schools and universities have begun to subscribe various cloud services from public cloud providers for hosting and managing their Web sites and e-mail systems. As the trend indicates, more and more educational institutions will adopt cloud computing.

Although a large number of articles and books about cloud computing itself and its application in business have been published in recent years, a few of them are about the cloud approach in teaching and learning. The experiences with the cloud approach to support e-learning have not been systematically and comprehensively summarized and published for the e-learning society to share. This book provides the much needed information to help educators and technology professionals in understanding the theories and concepts of cloud computing and its application in e-learning. The book is designed to help readers better understand and apply the cloud computing technology in teaching and learning. The following are the main objectives of the book.

- Introduce cloud computing.
- Discuss the pros and cons of cloud computing.
- Discover the role of open source products in cloud computing.
- Examine the possible application of cloud computing to support technology based teaching and learning.

- Explore the strategies and practices of the cloud computing approach.
- Assist readers in developing the cloud computing platform for online labs, video conferences, collaboration mechnisms, and testing utilities.
- Supply readers with case studies on the implementation of cloud computing.
- Analyze security issues related to the implementation of cloud computing.
- Evaluate the impact of cloud computing on teaching and learning.

To achieve these objectives, the authors who are researchers, educators, and practitioners in various academic fields present their research and experiences to enrich the knowledge of cloud based e-learning. The book includes research studies in cloud system implementation and cloud computing architecture and its support to IT infrastructure. The book also covers policies and security issues related to cloud system implementation in educational institutions. In addition, class and lab management with the cloud approach is discussed in this book.

THE CHALLENGES

The cloud computing technology advances rapidly. It brings a new way to support Web based teaching and learning. However, switching from the existing IT infrastructure to cloud based IT infrastructure is a complex process. For many educational institutions, the educators, technicians, and administrators are not familiar with the new ideas, new concepts, new theories, new devices, new software, new architecture, and new terminologies. All these could create great challenges to everyone who is involved in cloud based e-learning.

Educational institutions need to make sure that the cloud based IT infrastructure complies with government regulations. They need to protect their students' personal data on the clouds. Unlike the campus based IT infrastructure where student data are stored within the campus network and protected by the firewall and other security measures, a cloud based IT infrastructure may store student data in an undisclosed location. By doing so, educational institutions lose the full control of the student data. Loss of control on student data may not be acceptable by many education agencies and governments. In addition, a storage device on a cloud may contain software from other subscribers. It is possible that some of the software is vulnerable to computer hackers. Some software on a cloud may be infected by computer viruses, which may harm other software on the same storage device.

As the teaching and learning environment is changing due to the implementation of the cloud infrastructure, teaching practice has to change accordingly. Class management and student management will be different from that of the existing system. Educators need to develop new course materials to take advantage of the new teaching environment. They also need to find ways to overcome the shortcomings carried by the new teaching environment.

There are many types of cloud computing technologies to choose. There are some misunderstandings on how these technologies may or may not work together. Cloud computing is a rapidly developing technology, and there are not many standards established to prevent shortfalls. Many of the cloud services are appealing at first. However, after an educational institution migrates its IT service to cloud based infrastructure, some problems related to less thoughtful designs may come up. The implementation of a cloud based IT infrastructure requires a thorough understanding of cloud computing. Different types of cloud infrastructures have their own pros and cons. It is necessary to conduct systematic analyses

before a decision can be made. A cloud based infrastructure involves many technical details. Developers and technicians need to experiment with the cloud computing technologies to make sure that the cloud infrastructure is able to meet the requirements of teaching and learning. Proper testing is necessary for successful deployment of the cloud based infrastructure. While implementing the cloud based infrastructure, the development team needs to consider the long term effect on an educational institution and not to use a soon-out-of-date technology.

By common understanding, the expenditure on the IT infrastructure by subscribing cloud services will decrease dramatically. However, if these subscribed services are not efficiently used, the payment to these services could add up significantly. An educational institution needs to plan ahead on what services it should subscribe. On the other hand, educational institutions may not be aware of the capability issues on the cloud provider side. After the adoption of cloud computing, the educational institutions may face performance related issues. The compatibility of the subscribed services and the existing IT technology is another challenge to an educational institution. Instructors and students are used to the technology provided by the existing IT infrastructure. The overnight change of the IT infrastructure may cause chaos on campus. Training and tutoring services need to be in place before the cloud based IT infrastructure is deployed.

THE ANSWERS

Facing the challenges, this book aims to help everyone who is involved in the development of cloud computing for e-learning. It provides the reader with the information and solutions related to the challenges they may face during the development process. Chapters in this book provide readers with the real word experience in dealing with those challenges. Strategies and solutions are also given to guide readers who conduct research and teaching with the cloud technology.

To develop a successful cloud infrastructure to support teaching, learning, and research in a cloud environment, educators, researchers, technicians, and administrators need to understand the cloud computing environment from the e-learning point of view. Several chapters in this book describe the cloud environment and how teaching and research can benefit from the cloud environment. A semantic knowledge base is presented in the book, which can be used to assist learners in finding educational services on the cloud. Web 2.0-based research models are introduced to researchers for enhancing collaboration. For cost reduction and flexibility, open source cloud computing environments are discussed.

This book is dedicated to help educators teach classes in the cloud environment. It introduces cloud services and their application in e-learning. A good way to help educators better understand cloud computing and its application is through case studies, which present some firsthand experience. This book includes strategies and practices of teaching cloud computing and its application. Some case studies are provided in the book. Topics such as the development and implementation of cloud based online teaching materials and cloud based online computer labs are also explored in this book. These case studies demonstrate how the cloud based computer labs are designed to support teaching and learning. Through a case study, this book demonstrates how new IT education courses are developed by taking advantage of cloud IT infrastructure. Readers can plan their own cloud based IT infrastructure based on the actual work that has been done in the real world.

This book also addresses the policies and legal issues related to the adoption of cloud computing in education. It explores potential benefits and risks on implementing the cloud based IT infrastructure. The policies and security related discussions are particularly informative for decision makers who will decide if an educational institution should carry out the changes. The discussions explain how cloud services are used in making changes in education and pedagogy. To help with decision making, the contribution of cloud services to the next generation education is also presented. Legal and security related issues attract a greatly deal of attention. Once switching to the cloud based IT infrastructure, educational institutions mainly rely on cloud providers to provide protection for their student data. In general, the cloud architecture is not automatically compliant with the security requirements from an educational institution. The discussions emphasize that an educational institution must negotiate with the cloud provider to have some sort of guarantee that student data are safe. Some chapters in the book also examine the potential risks due to lack of security measures. Measures should be implemented to restrict the access to student data before a cloud base IT infrastructure can be adopted. Since cloud providers are responsible for monitoring activities on the cloud, the book recommends establishing a notification mechanism so that an educational institution can be promptly informed once a security problem occurs.

To help educators better understand cloud computing and its technical foundation, this book has a few chapters that provide the technical background of cloud computing. It introduces the technologies used by a cloud for supporting a large scale system. For the management of mega-scale cloud databases, the book introduces non-relational data management. Intelligent clouds are also introduced for handling multi-agent systems. It is also reported that the cloud IT infrastructure is used in managing large distributed IT infrastructure. To assist an educational institution in developing its own cloud-based infrastructure, this book presents some strategies for the development of cloud solutions. It includes discussions on issues related to requirement analysis, design, development, implementation, deployment, and evaluation of a cloud solution.

In summary, this book provides versatile solutions to combat the challenges raised in the development of cloud based IT infrastructure to support research and teaching. It provides readers with strategies, policies, security measures, experience learned, and development tools to overcome difficulties encountered in cloud computing.

TARGET AUDIENCE

In general, this book is for educators, researchers, technicians, and administrators who are involved in developing cloud IT infrastructures to support e-learning. It is designed for people who are interested in improving the availability, security, and affordability of teaching and learning with the cloud computing technology. It is especially useful for people who are planning the switch from the traditional IT infrastructure to a cloud based IT infrastructure. The book provides information to decision makers of educational institutions about the benefit and risk for switching to the cloud based IT infrastructure. It assists readers with case studies, real world projects, security measures, policies, and strategies on cloud computing design and implementation. Students can also benefit from this book with the help on setting up cloud clients to remotely access the services and resources provided by the cloud server.

To teach and take classes in a cloud environment, instructors, e-learning support staff members, and students need to know how to remotely access virtual instances created in a cloud. Instructors need to develop new pedagogies to adapt to the new cloud based teaching environment. They also need to cre-

ate new teaching materials that can take advantage of the cloud technology. It is also necessary for the instructors to come up with new course assessment methods to evaluate the instruction and the teaching materials designed for the cloud environment. It is crucial that the instructors design their own course materials to avoid the shortfalls of cloud computing.

Students also need to get familiar with cloud computing so that they can gain the competitive edge on the future job market. They need to learn how to solve real world problems with the cloud computing technology. They can familiarize themselves with the cloud computing environment and adjust their learning behavior accordingly. By working in the cloud computing environment, the students will be more proactive, more collaborative, and more self-disciplined.

It is important for technicians to keep up with cloud based IT infrastructures. They need to know how to create and delete user accounts and set up remote access restrictions. They should know how to detect the vulnerabilities of a cloud infrastructure and enforce security measures. They must make sure that only qualified people can access the course materials stored in a cloud at anytime and from anywhere. They need to provide technical support for the hands-on practice in cloud based computer labs. They should provide troubleshooting and training.

For the administrators of educational institutions, it is important to closely follow the development of cloud computing and its application in e-learning so that they can make right decisions on when and how to switch to the cloud based IT infrastructure. The administrators need to understand the cost and benefit of the cloud IT infrastructure. They should be actively involved in the project planning and development process, which depends on their encouragement and financial support. They need to be familiar with the government policies and regulations on student privacy so that they can negotiate with cloud providers on meeting the rules.

ORGANIZATION OF THE BOOK

Eighteen chapters are included in this book. The chapters are categorized into four main sections, Education and Research in Cloud Computing Environment, Teaching and Learning with Cloud, Policies and Legal Issues in Education Cloud, and Cloud Computing and its Technical Foundation. The following is a brief description of the chapters included in each section.

Section 1: *Education and Research in Cloud Computing Environment*: Five chapters are included in this section. These chapters describe the cloud computing environment. This section starts with an overview of cloud computing. It then describes a semantic framework for cloud learning environments. Web 2.0-based research models are introduced in this section, which construct a cloud based research environment. At the end of this section, details about an open source cloud computing environment are presented to the reader.

Chapter 1 provides an overview of cloud computing. The author reviews the brief history of cloud computing. The chapter introduces some main types of cloud services and how these services are used in e-learning. This chapter investigates how e-learning can benefit from cloud computing and the challenges and risks an educational institution may face when using cloud computing. It reviews open source resources available for constructing a cloud based IT infrastructure. It briefly discusses the cloud computing trend as well as the current research areas in cloud computing. To help readers get the big picture of the book, this chapter provides a section about the book's framework.

Chapter 2 presents a semantic framework for cloud learning environments. As illustrated in the chapter, the proposed cloud leaning environments have some advantages in supporting collaborative learning of user-chosen content and courses. The semantic framework introduced in this chapter establishes a semantic knowledge base used for finding educational services on the cloud. Various stakeholder clusters and their involvements in the maintenance of the semantic knowledge base are also explored. The chapter provides some information about the definitions of the mechanisms used in the development of the semantic knowledge base.

Chapter 3 is about open source cloud computing environments implemented at North Carolina State University (NCSU). The virtual computer lab project is currently supporting a diverse spectrum of educational and research missions. This chapter provides analyses on the capability of the virtual computer lab. The analyses show that the cloud based virtual computer lab is capable of supporting high performance computing research needs. This chapter also investigates the needs of cloud computing for high performance research.

Chapter 4 presents Web 2.0-based research models. Based on the research models, a cloud computing environment can be constructed to support research that involves highly collaborative and interactive activities. This chapter covers topics such as global communication, group collaboration, benefits of cloud computing for research, and future directions for cloud computing based research. The case studies demonstrate how a cloud based Web 2.0 research environment can be deployed.

Section 2: *Teaching and Learning with Cloud*: This section includes four chapters. The chapters in this section introduce cloud services and their application in e-learning. They focus on teaching and learning in a cloud environment. Through case studies, some of the chapters in this section present strategies and practices of teaching cloud computing. The other chapters demonstrate how cloud computing is used to construct cloud based online computer labs to enhance teaching and learning. Some of the chapters also cover topics such as the development of cloud based online teaching materials.

Chapter 5 demonstrates how to teach cloud computing. This chapter describes the teaching materials and a series of practical exercises created for a cloud computing course. The coursework presented in the chapter includes cloud computing principles, cloud services, and technologies used by clouds. This chapter discusses the implementation of a 10-week long cloud computing class. It summarizes the challenges and the lessons learned from teaching and learning of cloud computing. Class assessment related issues are also discussed in this chapter.

Chapter 6 is about teaching cloud application development. It introduces some commonly used tools for design and implementation of cloud computing applications. This chapter also provides the analysis of different strategies in teaching cloud applications. To take advantage of Google's free cloud services, this chapter provides the background information of Google's cloud services and information on how to use Google's cloud services to host non-cloud web apps.

Chapter 7 illustrates the implementation of a cloud based virtual computer lab. It indicates that one of the challenges of distance learning is to conduct hands-on practice in Web based classes. The virtual computer lab discussed in this chapter allows distance learning students to conduct their hands-on practice in the cloud environment. The students can either work as an individual or as a group at anytime and anywhere. This chapter also provides the reader with the technical details and the features of the virtual computer lab.

Chapter 8 demonstrates how to integrate cloud services into a university's IT infrastructure. By using cloud services, an on-demand virtual desktop is developed to support hands-on practice. The chapter shows that students can greatly benefit from the on-demand virtual desktop. The students are able to

implement their problem solving solutions. The on-demand virtual desktop provides a collaboration platform to support group activities in research. This chapter shows that the on-demand virtual desktop is capable of supporting multiple classes simultaneously.

Chapter 9 demonstrates how to implement an IP telephony laboratory by taking advantage of a private cloud. The implementation of the IP telephony laboratory requires a lot of computing resources. The chapter shows that the private cloud is a low cost and yet a powerful solution for the implementation of an IP telephony laboratory. The experience presented in this chapter is valuable for many IT departments that consider offering telephony related courses in their curricula.

Section 3: *Policies and Legal Issues in Education Cloud*: Policies and legal issues related to the implementation of cloud based IT infrastructures are covered in this section. The section discusses government regulations and student information privacy. It reveals the impact of cloud computing to the pedagogy and to the next generation education. The section also includes discussions of legal and security issues related to the cloud based IT infrastructure. Potential benefits and risks with cloud based IT infrastructures are examined in this section.

Chapter 10 discusses what changes can be made by implementing the cloud based IT infrastructure. It suggests that the cloud IT infrastructure can significantly reduce the IT expenditure. Implementing the cloud based IT infrastructure can relieve the financial burden for many higher educational institutions. The cloud IT infrastructure can also enhance scalability, accessibility, and flexibility of educational technology. However, there are many challenges in implementing the cloud based IT infrastructure. Therefore, the chapter recommends the use of hybrid cloud deployment to achieve a balance between risks and benefits of cloud computing.

Chapter 11 deals with mobile cloud services and its application in mobile teaching. It states that mobile cloud services are catalysts for pedagogical changes. The use of mobile devices and mobile cloud services has created a learner-centered environment, which facilitates the development of student-generated content and contexts. As pointed out in the chapter, the learner-centered environment has disrupted the traditional teaching and learning environment, and the mobile cloud service is the key technology that makes it happen.

Chapter 12 discusses the implementation of cloud services in educational institutions. It presents a scenario that illustrates the role played by cloud services in a major education system merger and acquisition. It describes how the cloud services can be used in the next generation education environment. The chapter also discusses some concerns related to cloud computing. In the conclusion, it presents some cloud computing application trends.

Chapter 13 deals with legal and contractual issues. When subscribing cloud services from public cloud providers, educational institutions may face a wide range of issues in complying with government regulations. As cloud computing is emerged recently, there is no specific law to follow. The author lays out some potentially business implications. The chapter outlines the complex contractual arrangements and serious legal problems an educational institution may be facing. At the end of the chapter, the author describes some key issues to be investigated before delivering cloud based IT services to students, faculty, and staff.

Chapter 14 explores potential security problems in a cloud based IT infrastructure. It points out that security issues must be addressed with highest priority. It discusses security risks presented in each type of cloud service delivered by cloud providers. To reduce risk, the authors point out that it is necessary to investigate the level of security provided by the cloud provider before adopting a cloud service. Some security measures are also recommended in this chapter.

Section 4: *Cloud Computing and its Technical Foundation*: The technology of cloud computer is relatively new to many educators and administrators. Therefore, the book uses this section to present the technical background of cloud computing and strategies for developing cloud solutions. It includes discussions on how solutions can be developed with cloud, how the cloud is able to handle data sets, and how large-scale systems can be implemented with the cloud technology.

Chapter 15 investigates the cloud based solution development process. Shifting from the traditional IT infrastructure to a cloud based IT infrastructure requires careful planning and thoughtful design. A well defined solution development process is necessary for an educational institution to achieve its goal with minimum capital expenditure. This chapter uses the five-phase solution development process to guide developers to implement a cloud based IT infrastructure that meets the requirements of e-learning. The five-phase solution development process includes the e-learning requirement analysis, solution design, solution development, solution implementation, and solution evaluation. Strategies and guidelines are provided for creating cloud based IT infrastructures.

Chapter 16 explains how mega-scale cloud databases are managed. For a mega-scale cloud database, the traditional relational database may not be the best solution for storing data. The chapter introduces the non-relational database and how it can be used to manage data generated in a cloud. It demonstrates how to establish sustainable and scalable data management architecture based on the authors' insights from real-world experience. The chapter describes various ways of partitioning non-relational data.

Chapter 17 compares the intelligent cloud with the multi-agent system. Both systems have a similar structure. Intelligent agents (IAs) share some of the features of the multi-agent system. These features allow intelligent agents to cooperate with each other to accomplish their particular objectives. This chapter provides details on how to form an intelligent cloud with intelligent agents and how to incorporate intelligent abilities such as learning, negotiation, collaboration, and communication to cloud systems by using intelligent agents.

Chapter 18 presents large-scale systems that demand a large amount of computation resources. To support such a large-scale system, a cloud based infrastructure is considered in the chapter. The cloud based infrastructure is able to create the required flexibility. This leads to the introduction of a teaching format for a cloud-based master course on large-scale systems.

Cloud computing is a field that is actively researched by IT companies, but the impact of cloud computing is not limited to the IT industry. It also has the potential to significantly change the ways of teaching and learning. Therefore, this book, with a comprehensive introduction and discussion of the cloud computing technology and its application in education, can greatly help educators and researchers in educational institutions. Through the book, educators and researchers will find valuable information about the cloud computing approach. Additionally, the book will provide resources and knowledge for improving the effectiveness of distance learning with cloud computing.

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Section 4
Cloud Computing and its Technical Foundation

Detailed Table of Contents

Section 1
Education and Research in Cloud Computing Environment

Chapter 1 presents an introduction to cloud computing and an overview of this book. First, a comprehensive coverage of cloud computing is given. This chapter reviews the history and recent developments in cloud computing. Then, application of cloud in e-learning is discussed. The discussion examines how teaching and learning can benefit from cloud computing and the development in cloud based e-learning. This chapter also covers current research areas in cloud computing as well as open source products for cloud computing.

Chapter 2 first discusses a semantic framework for cloud learning environments. It provides a semantic knowledge base to facilitate learners in finding educational services on the cloud. It introduces ontologies for modeling various aspects of the learning process. This chapter also examines various stakeholder clusters and their involvement in the creation and maintenance of the semantic knowledge base. The definitions of the mechanisms used in the development of the semantic knowledge base are introduced in this chapter.

Chapter 3 introduces an open source based virtual computer lab developed at North Carolina State University (NCSU). It describes how the victual computer lab is used to implement an open source cloud computing environment to support university education and research. The authors have conducted a capability analysis, which demonstrates that the virtual cloud computing environment developed at

NCSU can support high performance computing research needs. The chapter also discusses future trends in high performance research with cloud computing.

Chapter 4

Bay Arinze, Drexel University, USA
Cheickna Sylla, New Jersey Institute of Technology, USA

Chapter 4 discusses the cloud computing environment for conducting research. It presents Web 2.0-based research models and the way research can be conducted globally. In this chapter, the authors present the benefits of cloud computing for the research enterprise and future directions of cloud computing-based research.

Chapter 5

Hong-Linh Truong, Vienna University of Technology, Austria
Tran-Vu Pham, Ho Chi Minh City University of Technology, Vietnam
Nam Thoai, Ho Chi Minh City University of Technology, Vietnam
Schahram Dustdar, Vienna University of Technology, Austria

Chapter 5 presents a study of how cloud computing can be used for research and teaching activities in higher education and research institutions in developing countries. The authors in this chapter analyze the use of cloud computing for satisfying ad hoc needs of computing resources in research and teaching. They discuss the challenges in tackling the cloud adoption barriers and possible solutions to these challenges. They also provide some lessons learned and some experiences in developing and utilizing cloud computing for teaching and research in Vietnam.

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Section 2
Teaching and Learning with Cloud

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Chapter 6

Lee Gillam, University of Surrey, UK
Bin Li, University of Surrey, UK
John O'Loughlin, University of Surrey, UK

Chapter 6 is about teaching clouds. The author presents some teaching materials and practical exercises created for a course which teaches cloud computing. This chapter discusses cloud computing principles as well as cloud technologies covered by the coursework. A 10-week long cloud computing class has been used for this study. Hands-on lab activities have been implemented in the class. At the end of this chapter, the author summarizes the challenges and the lessons learned in teaching the cloud computing class.