Open Source Software to Enhance the STEM Learning Environment

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ABSTRACT

This chapter examines the use of Open Source Software (OSS) technologies that can be used to improve the learning of Science, Technology, Engineering, and Mathematics (STEM). Explored are the various methods that can be utilized to improve the percentage of STEM majors in the American educational system with resources such as: Open Source as Alternative (OSALT), virtualization, cloud computing, Linux distributions, open source programming, and open source hardware platforms. Increasing the amount of students that pursue STEM majors is important because the projected job growth in the STEM field compared to non-STEM jobs is 33%. OSALT provides cost-effective alternatives to commercial products such as Microsoft Office Suite and Adobe Photoshop. Second, creating Virtual Machines (VMs) is another avenue to teach complex concepts in computer science, engineering, and Information Technology (IT). Third, cloud computing is an inexpensive way for clients to access information from multiple locations and devices. Fourth, universities can use the Operating System (OS) Linux and its various distributions as replacements for commercial operating systems like Windows in order to reduce IT costs. Lastly, open source programming languages like Python and their associated Integrated Development Environments (IDEs) provide comprehensive facilities for software engineers for application development or testing.

INTRODUCTION

This encyclopaedia chapter focuses on the evaluation and integration of OSS technologies to enhance the learning of STEM majors in the classroom. As the STEM majors at various institutions are looking for creative methods to increase their footprint at a fraction of the cost then OSS is vital to continued growth. Technologies reviewed include software languages, IDEs, virtualization, and integrated learning management systems (LMS). This chapter will review multiple methods of implementing OSS into curriculum to enhance the learning environment.
OVERVIEW

This chapter will cover the utilization of virtualization, OSS and simulation tools that are also open source. OSS can be defined as software that is made available in source code form. This is important as this source code may fall under the General Public License (GPL) which is a widely used free software license that is managed under the GNU Not Linux (Gnu) Project. Virtualization is important as this is an effective method to reproduce system learning environments on the same systems the learner is using reducing the overall hardware footprint and need to for a massive lab. This chapter will also cover various software applications that can be integrated into the university system.

STEM Outreach

The new millennium was the dawn of a new era in terms of technological advances. Technology impacts various aspects of our lives. In fact, President Obama believes that the key to enhancing our economy is by fostering education in the STEM areas. Pres. Obama stated recently stated, "...We must create an environment where invention, innovation, and industry can flourish... I am committed to doubling funding for key research agencies to support scientists and entrepreneurs, so that we can preserve America’s place as the world leader in innovation, and strengthen U.S. leadership in the 21st century’s high-tech knowledge-based economy” (Otto, 2012). Thus, federal policies are catering to the growing need for STEM based education that incorporates technology as a way to teach our 21st century youth. Moreover, the projected job growth for STEM careers is estimated to be three times as fast as job growth for non-STEM jobs (Langdon, McKittrick, Beede, Khan, & Doms, 2011). Along with this, the Economics and Statistics Administration states that STEM workers are less likely to experience unemployment than their non-STEM counterparts. Finally, workers with STEM degrees tend to earn higher salaries regardless of if they work in STEM or non-STEM careers. Furthermore, the numerous advances in technology have made our computers smaller, quicker and more accurate. From the premiere of the iPad three years ago, to the surge of smartphones in the market, mobile technology is permanently embedded in our daily lives. In fact, mobile Internet, digital textbooks and cloud computation are three technological advances that can positively change our educational approach.

When thinking about the long term goal of IT related employment it is necessary to view the Forbes 2013 Jobs List to understand the job demands. The number one position is software developer for applications and systems software with 70,872 jobs added since 2010, and overall 7% growth (Smith, 2012b). The number four position listed is computer systems analyst with 26,937 jobs added since 2010, and overall 5% growth (Smith, 2012b). The number six position listed is network and computer system administrators with 18,626 jobs added since 2010, and overall 5% growth (Smith, 2012a). In 2012, the number one position was software engineering with a midlevel pay of $88,142 (Smith, 2012a). The number nine position was computer systems analyst with a midlevel pay of $78,148 (Smith, 2012a).

OSALT and SourceForge

OSALT provides open source alternatives to popular commercial products (OSALT, n.d.). The open source programs LibreOffice, OpenOffice Draw, StarUML and Avidemux respectively are open source alternatives for Adobe Photoshop, Dreamweaver and iTunes. Sourceforge is an open source development Website that provides free services to aid developers create open source products and share it on a global scale (SourceForge, n.d.). Community collaboration is important for the proper implementation of open source projects. Consequently, Sourceforge’s directory provides the tools needed for 3.4 million develop-
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Open source software is increasingly being used in educational settings to enhance learning experiences. This is due to the wide availability of open source projects and software that can be customized to meet specific educational needs. For example, Sourceforge (n.d.) connects over 46 million consumers with various open source projects, providing a rich ecosystem for educators and students.

VIRTUALIZATION

In terms of virtualization, there are various tools available to create a virtual version of a system. This method provides educational institutions with the ability to train students on virtual machines (VMs), allowing them to experiment with complex techniques such as networking, programming, system administration, and information assurance (IA). There are multiple types of virtualization, including hardware, desktop, memory, storage, data, and network. In Figure 1, a screenshot of Lubuntu 12.04 running in a VM on the Ubuntu 13.04 desktop is displayed.

For institutions that want to provide a cloud-like environment, tools like Oracle Virtual Box and VMware Player offer this functionality at a fraction of the cost. However, it should be noted that new Linux distributions running that require GNOME 3.10 will have issues running on older hardware. With older hardware as a constraint, there are minimal Linux distributions like Puppy Linux and Damn Small Linux (DSL). VMs provide the ability for students to experiment with hundreds of OSs without the need to install or uninstall the base OS. Puppy Linux and DSL will allow institutions to take full advantage of older computers.

Additionally, this allows for the creation of baseline OS images for classes (Dawson & Al Saeed, 2012). For example, a data analytics course would have an OS created with all predictive analysis software, case studies, statistical packages, design tools, and etc. preloaded. This would allow an institution to have an image ready for every class to ensure consistency, and that the students have all required tools needed, which would ease the process for program accreditation (Dawson & Al Saeed, 2012). In the case of more technical courses such as systems engineering, students would have a baseline OS image with all the programming software, the IDE, the Unified Model-
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For professors, this virtualized environment would allow for the monitoring, distribution, and quicker deployment of available tools. This environment would be a cloud computing solution. Cloud computing is based on concepts of virtualization, distributed computing, networking and is underpinned in the latest Web and software technologies (Vouk, 2008). A useful definition of cloud computing is that it is a way of delivering applications as services over the Internet as well as a way of providing for the hardware and system software that act as platforms for these applications and services (Armbrust, Fox, Griffith, Joseph, Katz, Konwinski, & Zaharia, 2009). Cloud is also used to refer to a network of computers that are linked together and distribute processing capacity and applications to different systems (Johnson, Levine, & Smith, 2009). Cloud computing lets organizations add on to their IT and computing capacity without having to invest in new architecture, software or hardware or in training and developing personnel (Glotzbach, Mordkovich, & Radwan, 2008). A cloud environment could prove to be a cost effective implementation of which would allow for scalability if these right tools are utilized. Figure 2 provides an overview of how a VM environment looks like. The hardware is loaded with the selected OS platform. The OS platform can be Linux, Mac, Solaris, or Windows. Once the OS is loaded onto the hardware then the hypervisor is loaded. The hypervisor allows for multiple VMs to be hosted. The VMs act independently from the OS platform. This environment allows for testing, development, and integration of new OSs.

When constructing the VM environment it is important to think about the overall architecture which includes the hypervisor (Sailer, Jaeger, Valdez, Caceres, Perez, Berger, & van Doorn, 2005). There are two distinct types of hypervisors which are Type 1 and Type 2. The Type 1 hypervisor runs directly on the system’s hardware to control the hardware to include managing the guest OS. An example of this would be XenServer or VMware ESXi. The Type 2 hypervisor runs within the OS environment with the hypervisor layer as the

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**Figure 2. Scenario of VM environment**
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second application software layer. The guest OSs runs on the third layer above the hardware which is displayed in Figure 3 Two Types of Hypervisors.

CLOUD COMPUTING

Cloud computing provides services that are available over the Internet or the intranet and the customers can access them using their computers or even mobile devices like the PDAs or phones. Cloud computing also makes it possible for the employees of the organization to access the services from diverse locations instead of being tied to their desks. Cloud computing is therefore characterized by On-demand availability of the service and on the concept of self service. The cloud computing services are to be automated so that there is little interaction of the service provider or the service users. In cloud computing, the service provider pools resources and makes them available to different customers while these customers do not concern themselves about how and where the resources are getting pooled from.

Cloud computing is marked by the high elasticity of service – the services can be automatically scaled up or down and distributed among the different customers based on their demands. Cloud computing provides flexibility in terms of elasticity and scalability, meaning that the services can be increased or decreased on need basis and in an automated manner without the intervention of the IT personnel. As such, organizations that deploy cloud computing do not have to buy additional computing resources if they expect an increase in demand. The organizations also do not have to fear for redundant resources as the cloud services are paid for only on the basis of usage (Kundra, 2010).

The automation and the freeing of the IT personnel from the task of managing, updating and maintaining the IT systems means that organizational resources are freed up and there are additional benefits of using the resources for other business related needs. In addition to the benefits of automation, cloud computing also means that there is no requirement for the customers to go for selection of resources from individual service

Figure 3. Two types of hypervisors
Cloud computing also leads to a reduced information technology overhead for the end-user, as the service provider takes the responsibility of maintaining, managing, developing and integrating the systems and the services that the end-users use. Also, as the resources are pooled, it means that less organizations or departments are using their own resources and hence there is a tremendous scope for energy and power savings (Kundra, 2010).

Cloud computing leads to reduced costs as the services may be shared by many organizations and thus reduce the cost of access and maintenance. The services are also paid-for on the basis of need, and organization’s can better plan their IT budgets and tailor it to their specific requirements. It is also cost effective as it is easier to quantify and measure the usage of the services and thus it is easy to track the revenue and costs associated with that particular service (Kundra, 2010).

Cloud Computing, being managed and provided for by the service provider is managed in a highly professional manner that ensures that there are no or minimum service outages and the problems if any are rectified immediately. The service providers, being experts professionals in their field, are better equipped with the resources and facilities to ensure that the service is provided without any disruption (Kundra, 2010).

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**LINUX**

Linux is an Unix like OS that is built on the Linux kernel developed by Linus Torvalds with thousands of software engineers. As of 2012 there are over two hundred active Linux distributions. The majority of the kernel and associated packages are free and OSS. This type of software provides licenses which allows users the right to use, copy, study, change, and improve the software as the source code is made available. Providing source code allows developers or engineers to understand the inner workings of development. Imagine being able to study Mac or Windows by viewing all the source code to replicate similar developments. This exercise would be great for a developer to learn low level coding techniques, design, integration, and implementation. Students and faculty could actively participate in design groups in which they would contribute code or design guidance for the upcoming software releases. This would be an added exposure for the university, students, and faculty internationally. In terms of associated cost the majority of Linux distributions are free. However some distributions require a cost for updates or assistance that related to specific needs such as OS modifications for server hosting. In software, there is a packet management system that automates the process of installing, configuring, upgrading, and removing software packages from an OS. In the Linux OS builds the most common packet management systems are Debian, Red Hat Package Manager (RPM), Knoppix, and netpkg.

Since Linux does not have redistribution limits it can be used to replace proprietary OSs in computer labs to save costs. The cost that would be associated with the proprietary labs can be redirected towards additional hardware instead. With the many variations of Linux one can find the appropriate distribution for their targeted use. Tables 1 and 2 display the different distributions to include the potential uses.

Fedora is an OS based on the Red Hat Package Manager (.rpm) (Proffitt, 2010). Fedora has a side development project known as Fedora Spins which contains multiple spin off versions of the Fedora OS. These spins allow academics, researchers, and students the ability to perform tasks such as cyber security, forensics, electronics design, and more (Petersen, 2013). Two of the spins are lightweight distributions which are essential to reviving older systems. Kitten Lightweight Kernel (LWK) and other similar kernels allow individuals the ability to
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Table 1. Linux distributions and uses

<table>
<thead>
<tr>
<th>Linux Distributions</th>
<th>Description and Potential Use</th>
<th>Packet Management System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ubuntu</td>
<td>One of the most popular Linux OS developed to be a complete OS that can be an easily replacement for other comparable OSs.</td>
<td>Debian-based</td>
</tr>
<tr>
<td>Edubuntu</td>
<td>OS targeted for grades k-12. Contained in OS are tons of software applications that is useful to those who are education majors.</td>
<td>Debian-based</td>
</tr>
<tr>
<td>Damn Small Linux</td>
<td>This OS is designed to as a small OS to be utilized on older hardware. This OS is great for institutions that have old computers and want to revitalize them for use. OS is also great for VMs as DSL requires a low amount of memory</td>
<td>Knoppix-based</td>
</tr>
<tr>
<td>BackTrack</td>
<td>OS based on Ubuntu for digital forensics and penetration testing. Great tool for students majoring in technology fields. As cyber security is becoming a hot topic around the world this tool provides students the ability to learn from over thirty software applications that aid in penetration testing and more.</td>
<td>Debian-based</td>
</tr>
<tr>
<td>Fedora</td>
<td>This OS is supported by the Fedora Project and sponsored by Red Hat. This OS provides a great resource for learning Red Hat Enterprise Language (RHEL). As there are thousands of jobs requiring expertise specifically with Red Hat this OS is a great tool to prepare students for employment in IT. Fedora has over six Fedora Spins such as Design-suite, Scientific-KDE, Robotics, Electronic-lab, Games, and more.</td>
<td>RPM-based</td>
</tr>
<tr>
<td>CentOS</td>
<td>This OS is derived entirely from RHEL. The source code is developed from Red Hat which allows a student to learn RHEL with a small number of differences. CentOS can be used for teaching IT students on how to setup, administer, and secure a server.</td>
<td>RPM-based</td>
</tr>
<tr>
<td>Ubuntu Studio</td>
<td>This OS is derived from Ubuntu. This OS is developed specifically for multimedia production such as audio, video, and graphics. Departments for multimedia could use this OS for multimedia instruction and the development of projects. As many of the tools for multimedia production are expensive this alleviates large license costs for institutions.</td>
<td>Debian-based</td>
</tr>
<tr>
<td>Lubuntu</td>
<td>OS is based on Ubuntu and uses the LXDE desktop environment. It replaces Ubuntu’s Unity shell and GNOME desktop.</td>
<td>Debian-based</td>
</tr>
</tbody>
</table>

practice development on lightweight OSs (Brightwell, Riesen, Underwood, Hudson, Bridges, & Zaharia, 2003). The possibilities are endless for encouraging low level development, integration, and increasing overall lifecycle expertise.

OPEN SOURCE PROGRAMMING

Programming languages such as Python, Ruby, and Java have open source IDEs associated with them. These open source IDEs provide comprehensive facilities for software engineers for application development and testing. Eclipse, a popular IDE for Java developers, has gained a significant amount of popularity over the years (Murphy, Kersten, & Findlater, 2006). There are over twenty active IDEs that are maintained and distributed amongst the software community. Figure 4 displays the two Python IDEs in an Ubuntu Linux environment.

OPEN SOURCE HARDWARE PLATFORMS

Ouya is the Android-powered solution to the lucrative gaming arena that is open source. Ouya is a black and silver gaming console designed by Yves Behar, industrial designer and philanthropist (Benedetti, 2012). Ouya is an inexpensive
Table 2. Fedora spins and uses

<table>
<thead>
<tr>
<th>Fedora Spins</th>
<th>Description and Potential Use</th>
<th>Packet Management System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Lab</td>
<td>This spin is for designing, simulating, and programming electronics. This spin is dedicated to support the innovation and development of the Electronic Design Automation (EDA) community. Some of the design tools included as ASIC layout, circuit layout, Computer Aided Drafting (CAD) tools, project management, peer review, and budget tracking.</td>
<td>RPM-based</td>
</tr>
<tr>
<td>Security</td>
<td>Spin targeted for cyber security and forensics professionals. Contained are tools for code analysis, forensics, intrusion detection, network statistics, password tools, reconnaissance, Web application testing, wireless, and Voice over Internet Protocol (VoIP).</td>
<td>RPM-based</td>
</tr>
<tr>
<td>SoaS</td>
<td>Sugar on a Stick (SoaS) features the Sugar Learning Platform which promotes collaborative learning that encourages critical thinking. This spin is available in more than 20 languages and originally developed for the One Laptop per Child XO-1 netbook. SoaS can be downloaded as a 54K torrent file which can fit on a small USB thumbdrive.</td>
<td>RPM-based</td>
</tr>
<tr>
<td>Design-Suite</td>
<td>This Fedora Spin focuses on open creativity. Contained are free and open source software for design activities. The tools available are graphics editors, photograph managers, flowchart creation, document annotation, diagram creation, 3D modeling, animation, rendering, and post production.</td>
<td>RPM-based</td>
</tr>
<tr>
<td>Robotics</td>
<td>This spin supports STEM students interested in robotics as it contains a variety of free and open robotics software packages. Contained is a free and open robot server with hardware support for over 100 devices.</td>
<td>RPM-based</td>
</tr>
<tr>
<td>Xfce</td>
<td>This spin is a lightweight desktop that has aims to be fast and low on system resources.</td>
<td>RPM-based</td>
</tr>
<tr>
<td>LXDE</td>
<td>Spin is an extremely fast, performance, and energy saving desktop environment designed to keep computer resource usage low. The Lightweight SX11 Desktop Environment (LXDE) is targeted for computers with low hardware specifications like netbooks, mobile devices, and older computers. LXDE can be used to revive older labs with functioning systems.</td>
<td>RPM-based</td>
</tr>
</tbody>
</table>

Figure 4. Python IDEs
alternative for gaming aficionados, in that Ouya is based on open source development. Currently, Ouya retails for $99 and that is one of the least inexpensive television (TV) gaming consoles available. Unlike, the major gaming company, such as Playstation and Nintendo, Ouya does not require any licensing fees, retail fees or publishing fees (Benedetti, 2012). Ultimately, Ouya’s creators want to create a developer-friendly environment in which hackers and hobbyists are all welcome to create games for Ouya. The only condition developers must meet is that the games they create must offer some free elements, such as free demos which work well in terms of advertising the product (Benedetti, 2012). This opens up the market which allows for universities to truly afford to teach courses on game design and allow students to develop their own custom game to market. As gaming is a popular pastime among young adults this would be a method to inject a desire for STEM recruitment.

As for academia, Ouya has the potential to transform the educational system in the 21st century. Technology has advanced at an exponential rate in the past 20 years, and continues to improve in the near future. The skill sets that are required for successful 21st century students include proficient computer literacy. In fact, the next generation of jobs will be characterized by increased use of technology, in depth problem solving and complex communication (McClarty, Orr, Frey, Dolan, Vassileva, & McVay, 2012). What students learn is no longer the focal point of their education, how and when they learn is just as important. Today’s students have grown up with laptops, cell phones, tablets, and mobile Internet; naturally this technology should be applied to their learning environment as well. Advocates of game-based learning in education assert that digital games can teach students important skills, like thinking, planning, learning and technical skills that are vital for today’s workforce (McClarty et al., 2012).

Lastly, Fedora’s Electronic Lab (FEL) is a possible platform to utilize the Ouya gaming system. FEL is a free open source hardware design and simulation platform that is dedicated to supporting the Electronic Design Automation (EDA) community through innovation and development (Negus, 2010). FEL is important for the implementation of Ouya for various reasons. First, FEL “provides a complete electronic laboratory setup with reliable open source tools” to keep users current with technology (Negus, 2010). FEL solves a major problem for the open source community by providing real life open source EDA solutions. FEL utilizes three methodologies – design, simulation and verification – in order to give a better hardware design. Also, FEL bridges the two major open source communities: open source software community and open source hardware community. Finally, Fedora is available in alternate versions known as “spins” (Negus, 2010). The “Design-suite” spin for Fedora allows open creativity for users; “Security” spin has security analysis tools; “LXDE” spin is a faster, less demanding desktop environment; while “Games” spin is tailor-made for games in Fedora (Negus, 2010).

Raspberry Pi is “a credit card sized single-board computer” developed in 2006 by Eben Upton and three of his colleagues. Their intention was to stimulate interest in teaching of basic computer science in schools. Raspberry Pi has a Broadcom BCM2835 system on a chip (SoC) that contains an ARM1176JZFS; VideoCore IV GPU; and 256 megabytes of RAM (Raspberry Pi, n.d.). Lastly, Raspberry Pi uses an SD card for booting and long-term storage. Currently, two versions are available, Model A, which cost $25 and has 256 Mb RAM, one USB port and no Ethernet connection and Model B, which cost $35 and has 512 Mb RAM, 2 USB port and an Ethernet connection (Pi, 2012). The Pi makes it affordable for everyone STEM student to build on their own open source hardware platform. The possibilities for lab uses are limitless.
CONCLUSION

Open source technology is an avenue with unlimited potential to improve our educational system (Dawson & Al Saeed, 2012). Virtualization is a way to teach intricate computer science, engineering, or IT problems using a virtual machine (VM) (Dawson & Al Saeed, 2012). Also, VMs allows students to experiment with various OSSs without uninstalling the base OS. As mentioned earlier, this baseline OS can be equipped with tools that are needed for that discipline. Examples of these tools are statistics software, graphic design software, social marketing tools and case studies that are preloaded on to computers for business students. Cloud computation is a cost effective implementation of virtualization. Further, using Linux as the operating system will significantly reduce the cost of implementing virtualization into our educational system.

Since the majority of OSS is free, the money that is saved from technology can be used elsewhere. Open source is continually gaining popularity overseas in areas such as education and city government. In China, Germany, Estonia, and Russia, various versions of Linux are on the verge of becoming the main OS in the upcoming years. OSS is prevalent in the Spanish educational system as well. Open source software is changing the nature of organizational industries in project management. Lastly, gaming industry is another avenue that can be utilized in today’s educational system. Ouya and Linux are cost effective open source alternatives to popular commercial gaming hardware and software, respectively. Gaming may be utilized to teach important skills such as thinking, planning and technical skills for today’s job market. Finally, Raspberry Pi is a revolutionary computing device that may change the way education and technology are used in our society. Raspberry Pi is a way for students to access cheap programmable computers for today’s society. Ultimately, open source software and/or hardware are low cost and is an excellent opportunity to integrate technology into academia (Dawson & Al Saeed, 2012). With security risks to mobile devices (Marwan & Dawson, 2013) to technology entrepreneurship it is clear that open source is a way to accomplish the goal of enhancing the STEM environment.

REFERENCES


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KEY TERMS AND DEFINITIONS

Cloud Computing: Comprised of both the application delivered as services over the Internet and the hardware and systems software housed in the datacenters that provide those services (Armbrust, et al, 2010).

GNU Public License: A widely used free software license that is managed under the GNU Not Linux Project (Stallman, 1991).
**Hypervisor:** Allows for multiple OSs to run concurrently on a host computer. There are two types of hypervisors that are used in computing (Sailer, Reiner, et al, 2005). The two types of hypervisors are Type 1 and Type 2 which differ in the way they are hosted on the machine.

**Linux:** An open source version of the UNIX OS (Perens, 2009).

**Open Source Software:** Software that allows the original source code to be free available which may be freely redistributed or modified (Perens, 2009).

**Stem Education:** Defined as educational fields in science, technology, engineering, and math.

**Virtual Machine:** Self contained operating environment that behaves as a separate computer but hosted on a host OS. The VM has no access to the host OS thus both entities exhibit separate behavior.