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Integrating Free/Open Source Software in Computer Science Education

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Abstract: *Free/Open Source Software (F/OSS) has emerged as an alternate and dominant software development model especially during the last decade. This incredible model has encouraged software developers spread across the globe to collaborate voluntarily to develop wide array of software products. F/OSS movement has touched almost every sphere of software technology including education. The present paper reviews the successful initiates taken for usage as well as spread of F/OSS in education at global and national landscape. The paper also signifies the potential benefits of integrating F/OSS for teaching and learning in computer science. Then it highlights major challenges in the integration process and also suggests some effective measures to combat the challenges.*

Keywords: *Free Software, Open Source, F/OSS, Computer Science.*

1. INTRODUCTION

Software is a set of programs, each comprising collection of computer instructions written using some human-readable computer language. It can broadly be classified as Proprietary software or Free/Open Source Software (F/OSS) based upon rights granted to the software users. Proprietary software is generally distributed in binary format, denies rights to look into the internal details of the software and thus prohibits any change in its operations. In contrast, F/OSS is making the source code of software accessible to its users with the absolute right to inspect the source code and modify it according to changing requirements. It can also be passed on to others either with or without modifications. These characteristics have the intrinsic value of giving people the opportunity to participate actively in the development, creating local jobs and lowering technology acquisition and deployment costs [1]. The steady rise of Open Source Software (OSS) during the previous decades has made a noticeable impact on several sectors of society wherever software is being used [2]. Undoubtedly, F/OSS is influencing all aspects of ICT right from supporting core ICT infrastructure to areas such as government, business, healthcare, education and many more.

The Open Source Initiative (OSI) specifies ten criteria with regard to development of source code and its modification, licensing and distribution. It entails that anyone can modify the source code and the license must not prohibit distribution of the source code or its derivatives in any way (even commercially) [3]. The Free Software Foundation (FSF) outlines four essential freedoms for software to be considered free software [4]. There is subtle difference in the meanings and values associated with "Open Source" and "Free Software." While proponents of the "Free Software" term emphasize the ethical and philosophical aspects of community use and development of software, the "Open Source" proponents emphasize the pragmatic and business-friendly aspects of this technology [5]. There is still commonality in their outlook on issues such as open standards and patents. So the term F/OSS is used popularly to reflect these common values. F/OSS technologies support the broadest public participation, limited not by copyright restrictions but by one's ability to learn and modify the technology to meet present needs as well as laying the foundation for meeting future requirements. In order to contribute towards sustainable development of a society, F/OSS must comprise a strategic plan for training and learning to ensure that the present generation can archive, share and transfer the technology to future generations. Accordingly, the present paper focuses on leveraging F/OSS for effective learning of computer science students for myriad benefits.

The present paper is structured as follows: Section 1 is the introduction. Section 2 explores evolution of F/OSS in Diverse Domains of software usage. Section 3 presents usage of F/OSS for educational purpose at global as well as national landscape. Section 4 signifies the potential benefits of integrating

F/OSS for teaching and learning in computer science. The challenges in this process are highlighted in Section 6. In section 7, certain recommendations have been made to combat the challenges. Section 8 concludes the paper and points towards future work.

2. EVOLUTION OF F/OSS IN DIVERSE DOMAINS

During the last few decades, F/OSS has emerged as an innovative phenomenon with immense potential to revolutionize the software industry. It has already gained a firm footing in the server segment as well as significant share of market in variety of application domains [6]. The movement of F/OSS has inspired thousands of software developers spread across the globe to collaborate voluntarily to develop wide array of software products. Such products can be downloaded from the Internet free of cost and used in any manner. Lower cost is not the only reason for using F/OSS. F/OSS is considered to have better reliability, performance and security. The development methodology of F/OSS tends to assure high quality of the software [6]. It is viewed as being more stable and reliable due to the mass inspection implied by the F/OSS development process [7]. This is especially true for more mature F/OSS applications. One of the reasons for better security is the availability of the source software, which allows vulnerabilities to be identified and resolved by third parties. An independent audit of code is possible only with F/OSS and not with proprietary software [6, 8]. Thus, the process of development ensures that the best approach and the best pieces of software code become part of the final product.

An analysis carried out by Reasoning Inc. found that the F/OSS database MySQL has significantly fewer defects in comparison to proprietary databases [9]. Similar results have also been reported for other F/OSS applications. In F/OSS development, only the best and most powerful solutions and methodologies survive the test of time and the scrutiny of the whole community. Successful examples of F/OSS notable include operating systems such as Linux, Android; web browsers such as Mozilla Firefox, Google Chrome; database systems such as MySQL, MangoDB, several programming development environments such as Eclipse, PHP; multimedia tools like GIMP, Blender, VLMC and suites such as OpenOffice.org; the Apache web server and the list goes on.

3. INITIATIVES FOR PROMOTING F/OSS USAGE IN EDUCATION AND TRAINING

F/OSS has already exhibited immense potential for developing countries. Numerous measures have been taken such as implementing F/OSS policies, supporting R&D, initiating projects – all with the ultimate aim of bringing about innovation, sustainable ICT development and technology independence. F/OSS has the advantage of keeping the resources within the community and contributing to their socio economic development and empowerment, compared to proprietary software [10].

The International Open Source Network (IOSN) is an initiative of Asia-Pacific Development Information Programme (APDIP) and supported by the International Development Research Center of Canada. IOSN provides policy and technical advice on F/OSS to governments, civil society and the private sectors. It produces F/OSS awareness and training materials and distributes them under open content licenses. It also organizes awareness raising, training, research and networking initiatives to assist countries in developing a pool of human resources skilled in the use and development of F/OSS. IOSN works primarily through its web portal that is collectively managed by F/OSS community. The web portal serves as a platform for knowledge sharing and collaborations [11]. As the use of F/OSS gains prevalence, the issue of its outreach in an educational context arises [12]. In fact, the use of F/OSS to enhance the effectiveness of computer science education has been initiated in mid 1990's [13]. Developing F/OSS could help students not only in present learning but also in their future career paths [14]. F/OSS would provide a viable approach to strength Computer Science curriculum that is needed for the benefit of future students and faculty in computing. Several approaches have been suggested for inclusion of F/OSS in courses e.g., documentation, adding features, and removing bugs [15]. Efforts have been made to set up suitable F/OSS laboratory for teaching operating systems such as Linux and BSD [16]. Most of these studies of F/OSS usage in education are limited to specific F/OSS.

In India, several government departments and business enterprises have made policy to use and deploy F/OSS as far as possible. In the chairmanship of Sam Pitroda, National Knowledge Commission recommended F/OSS for e-governance and information management. ICFOSS

(International Centre for Free and Open Source Software) is the outcome of committed work by Free Software enthusiasts, advocates, developers and supporters in the state of Kerala and outside [17]. ICFOSS today carries out a number of F/OSS-related activities in a model that brings together Academia, Industry, Government and the F/OSS Community. Major activities includes R & D; Support to F/OSS software development; F/OSS Pilot Programs; technology assistance to Government programs and institutions; Local Language computing; Student F/OSS activities; Internet Governance; Studies on F/OSS; Exploring F/OSS Certification; and Capacity Building of students to enter the F/OSS Community.

To promote F/OSS movement, in 2005 Indian government setup a National Resource Centre for Free and Open Source Software (NRCFOSS) with joint venture between an university-based research lab (AU-KBC Centre) and the Centre for Development of Advanced Computing (C-DAC) to contribute to the growth of Free/ Open Source Software and serve as the nodal point for all F/OSS related activities in India [18]. The notable initiatives toward offering a low cost computing, flexibility and choice to the end users is the development of BOSS (Bharat Operating System Solutions) which is a GNU/Linux based localized Operating System for both desktop and server and Edu BOSS for schools that supports 18 Indian languages. The policy on Open Standards for e-governance notified by the Government of India in November 2010 mandates adoption of royalty-free open standards for all e-governance projects. A pool of F/OSS trained teacher and student community has been generated across India through awareness campaigns, training programs and workshops. But all these efforts are inadequate.

Free and Open Source Software for Education (FOSSEE) project is part of the National Mission on Education through ICT funded by MHRD, based at the Indian Institute of Technology Bombay (IITB) [19]. Main Activities undertaken in this include promoting the use of F/OSS through workshops, audio/video courses and virtual labs; creating educational content around existing F/OSS; taking necessary steps to include F/OSS in the syllabi of various universities.

The IT @ School, a project being run in the state of Kerala, replaced the Windows operating system on 50,000 desktop computers in 2800 schools across the state with F/OSS operating system [20]. This move from a particular operating system that the teachers were familiar with to a new one required extensive training of the teachers and the support staff. The tangible benefits obtained (cost saving from free OS minus training costs) were approximated Rs. 490 million. The project also accrued several intangible benefits in terms of local language customization, teacher confidence and many more [5].

The Institute of Informatics and Communication (IIC), a part of the University of Delhi, has integrated F/OSS within its curriculum, where students not only learn about F/OSS and its components but also practice F/OSS usage through training and support activities around the campus [5]. IIC has about 100 desktops on its premises, all of which run dual-boot operating systems that include a Linux component. IIC has saved Rs 15000-20000 per desktop for operating system and application software, and about Rs 50000 per server. Students have thus been able to fully integrate F/OSS in their academic and career profiles [5].

IBM has instituted the Great Mind Challenge, a national contest for students from engineering colleges who are required to develop solutions in a real-life scenario using IBM open source software. Through this contest, IBM is providing training on open standards-based technologies to more than 80,000 students in about 800 colleges in India [21].Several stories have been reported about gradually growing usage of F/OSS educational institutions. It is important that students should have the opportunity to use a wider array of F/OSS products. Hence, if they are exposed to certain products during their education, they will tend to continue to use them in the future [6].

4. Potential Benefits of Integrating F/OSS for Teaching and Learning in Computer Science

The development of curricular guidelines for Computer Science has always been challenging due o the rapid evolution and expansion of the field [22]. As per ACM guidelines, the education in computer science must prepare students in a more holistic way than simply conveying technical facts. Indeed, soft skills (such as teamwork, verbal and written communication, time management, problem solving, and flexibility) and personal attributes (such as risk tolerance, collegiality, patience, work

ethic, identification of opportunity, sense of social responsibility, and appreciation for diversity) play a critical role in the workplace. Successfully applying technical knowledge in practice often requires an ability to tolerate ambiguity and to negotiate and work well with others from different backgrounds and disciplines [22].

The current education system, especially in India, is little restrictive. This system highly requires collaboration in terms of resources, technology, and manpower. Our education system needs to inspire original thoughts instead of limited experiences and observations. It also needs to be more inclusive and F/OSS offers a strong and viable solution to the problem. F/OSS can be deployed in myriad ways for education and training in computer science.

F/OSS development can serve as a technology, method and channel to teach and learn computer science [23]. Acting as a technology, F/OSS can provide free or lower-cost technology in the classroom that otherwise is not affordable. As a method, OSS can be used to introduce our students to the larger computer science community and to the practice of peer- review. As a channel, F/OSS can expand teamwork past the classroom to include much larger projects and more distributed teams. Finally, Working within an F/OSS project brings many benefits to the students.

To create the awareness, students should be encouraged to use F/OSS in the beginning of their course. This can be done by removing the proprietary bias from the syllabus. Sometimes in the syllabus proprietary software are mentioned by brand names which prevent the students from choosing the alternative and better software. Live events/workshops in the teaching institute on F/OSS technologies can be organized regularly. These events introduce the students various aspects of F/OSS and motivate them in participation of F/OSS development. Initially students can participate in F/OSS project by providing feedback, recommending projects to others, exploring and requesting new features, testing and reporting bugs, writing or updating/translation of documentation etc. These activities help students to get acquaintance with F/OSS development environment and build confidence in F/OSS development. In later stage students can get involved in code analysis and code contributions and patch submissions.

The open philosophy of F/OSS is consistent with academic freedom and the open dissemination of knowledge, the vary basis of academia. Yet in many educational institutes, propriety software is used rampantly. Most of the students cannot afford the purchase of licensed copies of proprietary software especially for personal use or individual practice. If proprietary software is used for teaching, students would have no choice but to use illegal copies of the software to do homework and assignments at home or on their laptop computers. In contrast, there is no restriction against making copies of F/OSS for use outside institutions [6]. Thus the use of F/OSS also discourages piracy by students.

The availability of source code of F/OSS provides a unique opportunity for the educators to gain in depth knowledge of software internals and carry out experiments. This is particularly the case in systems software courses where, for example, the design of an operating system kernel of an OSS such as that of Linux can be discussed [12]. F/OSS provides a useful workbench for independent learning even outside classroom (at the library or at home). The availability of F/OSS source code enables students to experiment liberally and thereby enhance their knowledge and improve upon their skills [12]. F/OSS can be used as a basis for assigning course projects. F/OSS could be used as a basis for reverse engineering. For example students can be asked to create a high-level design model or improve some of its quality attributes while still preserving its functionality.

For students' participation in F/OSS development, they may be encouraged to select F/OSS projects according to their interests and capabilities from F/OSS project hosting sites such as Sourceforge.net. Codes are downloadable from the respective project web site. Students then can analyse the code; create documentation; provide feedback; request for new features and report bugs. Study of a well written program is a good way to improve programming skills. After analyzing and testing the F/OSS project, students can also improve their skills on finding and fixing bugs. This will help the students to understand the differences between the small programs that they write for themselves and the large scale software products. Students can also start new project by using this code or may start new project of their interest from scratch. Faculty members can act as advisor and mentor to facilitate the students work, review project proposals, maintain the center website, and facilitate peer group meetings and discussions.

By participating in F/OSS development, students get the opportunity to interact and collaborate with the best people in the field and learn from their experiences. As the student begins to contribute code to the project, these colleagues send feedback [20]. By fixing the problems reported by the reviewer, students can learn lessons from their mistakes and improve their skills. Such a peer-review process facilitates effective learning and sharing of knowledge. The ability to work with people makes students more responsive, accurate and effective at communication. F/OSS projects provide students great exposure to a variety of programming styles and encourage their critical abilities [21]. The students also get familiarization with version control, configuration management tools, regular automated builds, and testing and packaging issues. These are essential professional software development skills that are seldom well-taught in formal teaching.

Students who learn F/OSS development during their studies are more likely to convert their ideas into solutions. Participation in F/OSS development will give students valuable credentials, public portfolio of their practical work and a global recognition. Another benefit to the students is that they can showcase their previous work to potential employer after passing out from the course. They have a proof on the web for the whole world to see. It essentially means that the students worked with F/OSS project an edge over other candidates. The exposure to collaborative development practices gives prospective employer the confidence to recruit these people. So participation in F/OSS projects yields greater job opportunity. F/OSS also encourages entrepreneurship.

5. CHALLENGES

There is general lack of awareness of F/OSS applications, F/OSS principles and F/OSS licensing. Many colleges are not having stable, low-cost and fast Internet access that hinders the process of downloading F/OSS and participation in online discussion forums. Educational institutes are not able to evaluate a suitable F/OSS alternative for their requirements. If they opt for some F/OSS then they face migration difficulties due to lack of user training facilities. Current curricula and education do not adequately integrate F/OSS. Moreover F/OSS usage is also not integrated into government ICT strategy and policy. To many, F/OSS is seemingly made only for highly technical people. That misconception needs to be addressed. In case of several F/OSS projects, the lack of sufficient documentation and timely technical support can hinder to convert it into practice.

6. RECOMMENDATIONS

Undoubtedly, adopting F/OSS alternatives for every software requirement in education have several challenges but it has potential to offer huge benefits. To combat these challenges, certain measures need to be taken. Interactive workshops for teachers, curriculum developers and administrators in educational institutes need to be organized regularly. Such events should include training on F/OSS applications, F/OSS principles, FOSS licensing etc. IT workers at all levels should form a common forum, discussion groups for sharing F/OSS information and experiences as well as helping each other in query resolution. Some nodal agencies can be set up in universities and other higher education institutes to take lead in adoption of F/OSS for variety of usages. It has also been suggested that they can maintain and support a regional F/OSS repository distributed via DVD/CD especially for the colleges without reliable Internet access [10]. F/OSS developers should be encouraged by supporting Internet access and other resources. All the software must carry effective documentation that can be understood conveniently by naïve users also.

7. CONCLUSION

To put the power of information in the hands of those who need it the most requires low cost yet sophisticated solutions like F/OSS. F/OSS transcends geographical and cultural boundaries to usher in a new software development paradigm where volunteers collaboratively create software for the commons. F/OSS is easy to obtain, legitimate to copy and enables both teachers and students to freely use the software at no cost. A cohesive plan comprising reexamination and modification of the current curriculum can help in this direction. It offers computer science students to gain real world experience in their formative years. It provides opportunity to get global recognition and great job as well. F/OSS has immense potential that can help not only in cost reduction, but can also support in sustainable development and capacity building. The present consumer of F/OSS may emerge as future producer of F/OSS.

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