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Managing ICT solutions for training and evaluation of C++ programming skills in e-learning ecosystem

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Abstract

A set of functional upgrades to the existing e-learning ecosystem for the C++ programming language, which provides a solution where students can use their own computers during training and practical exams, is presented in this article. The ICT solutions applied in this case offer a supervised and protected the online environment, where each student has their own working account. The rights and privileges for accessing and using various software services are customised according to the educational tasks (training or exam). Depending on the purpose, the described software solutions are realised as web services for education and training and network services for collection and evaluation of the students' solutions during the practical exam. During the training, web services are used, and each account has its own folder, in which the solutions are stored, and if necessary, those can be opened, modified, tested and shared for collaboration or evaluation in an integrated C++ compiler. During practical exams, network services installed on Raspberry Pi are used, and for security reasons, there is no online access. Ready student solutions according to defined test cases are placed on the server. The principle of evaluation consists in comparing the solutions of each student separately with the pre-designed solutions set in the system for the same test cases. The e-learning ecosystem is developed and upgraded by managing various ICT open source solutions described in this work.

Keywords: E-learning ecosystem, C++ programming, Raspberry Pi.

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1. Introduction – correlation between e-learning ecosystem and learning process management

Speaking of correlation between the processes of e-learning and learning management systems (LMS), it can be observed that actually LMSs are developing support technologies to enable the concept of e-learning to be extended to wider areas of business and education. Basically, every LMS is composed as a set of interconnected software technologies, tools and applications for the administration, documentation, tracking, reporting and delivery of educational courses, training programs or learning and development programs (Ellis-Ryann, 2009). From this point of view, the LMS concept emerged directly from e-learning. The ICT environment supports e-learning processes, such as hosting of course content, assignments, grades, shared documents and study tools, allows them to work together seamlessly. This environment called digital ecosystem is a distributed, adaptive and open computing system. Like a natural ecosystem, a digital ecosystem needs to be robust, self-supporting and scalable (Global Educational Future Initiative- Report, 2018). For self-guided learners to be successful in achieving and evolving their intentions over time learning spaces must be designed to support learners' educational needs. Any given e-learning ecosystem, as a functional composition of e-learning materials and supporting ICT solutions, in order to be fully operable, needs to create tools and processes that support all of the following 'building blocks' for personal & collective learning journeys across the human lifecycle (Cooke, 2018). In times of rapid technological change, e-learning ecosystems are linking formal education and the need for continuous improvement of skills in the business sector, in an ever-evolving whole. The universities as equipped entities to bridge the gap between research and practice (Abdul-Jabbar & Kurshnar, 2015) have many opportunities to adapt their digital resources, and digitalise some activities, use of students as a beta tester of some adequate product, digital knowledge enriched with some market principles and many other options.

2. The role of LMSs in the development of e-learning ecosystems

The digital ecosystem metaphor and models have been applied to a number of business areas related to the production and distribution of knowledge-intensive products and services, including higher education (Damiani, Uden and Trisnawaty, 2007). A well-composed e-learning ecosystem can create a wider solution that enables organisations to up-skill their learners. It can offer advanced, automated and customisable tools to monitor, manage, evaluate, develop, assess/certify and communicate within a fluid cloud-based environment. All of them are focused on developing and evolving a community. In recent decades, the development of e-learning ecosystems has been greatly facilitated by the opportunities offered by the LMS. The statistics shown that the LMS market for North American higher education has increasingly dominated the 'Big four' (Infrastructure payroll, board learning, D2L lights, Moodle) which are used for adoption across the institutions; the total market share of the first four systems of the year ranges from 80% to 95% in the last five years. The same trends can be seen in Europe, Latin America and Australia/New Zealand (Lynch, 2018). The conclusion to be drawn is the main purpose of the LMS to support different types of e-learning ecosystem, offering pre-made ICT solutions for a wide range of educational needs especially at the development stage. In addition, some specific educational areas, such as programming, require conditions that are not fully offered in the existing LMS market. For those cases, it is necessary to develop inventive solutions, constantly in line with the development of software technologies and their needs.

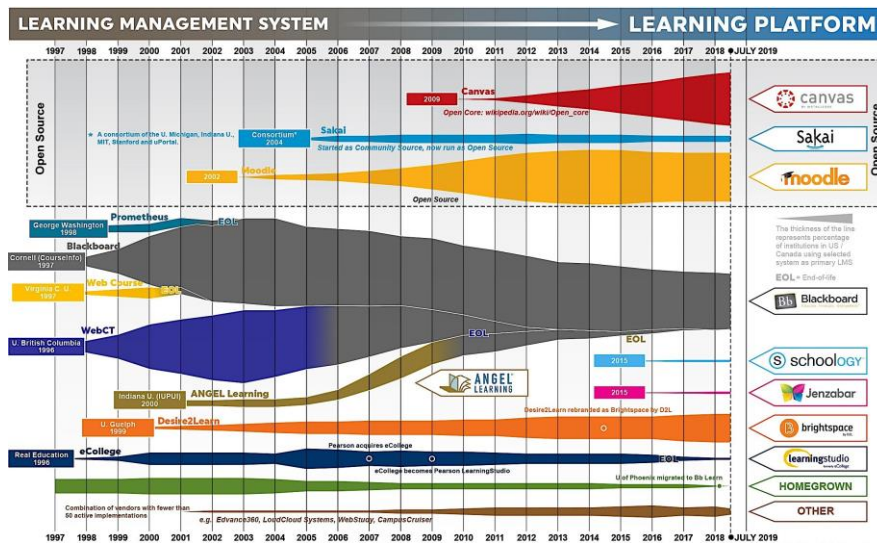


Figure 1. LMSs use around the world 2019 (Lynch, 2018)

3. Managing ICT solutions for training and evaluation of C++ programming skills in an e-learning ecosystem

This section explains how to upgrade an existing ecosystem with new functionalities, through ICT technology management, using real practical experiences, based on open source free platforms, with a special review of adaptability and crossover compatibility of individual parts, between the existing education ecosystem and new upgrades to the indicated C++ activities.

3.1. Main functional components of the existing e-learning ecosystem

Previously developed digital educational ecosystem, whose upgrade is implemented and practically shown in this article, contains the following basic components:

- The use of services, which are capable to create an embed code for different needs, like multimedia contents, free mail widgets, groups, chats or services, free storage services, forums, surveys, connections with social networks, statistic trackers and counters, translators of pages, etc.
- The use of code generators, which gave an opportunity to create an own code according to the needs of different kinds of users, like informational boards with some active elements, active banners with hyperlinks and other elements.

As a working option of many services and blogs, there are scalability of right and privileges over educational contents, like options to make changes, comment, download, read-only use, view in special working mode, different levels of access, flow control and behaviour tracking of visitors (Markoska, 2017). The newly introduced functionalities offer an inventive and different approach to the existing educational contents, providing opportunities for real-time monitoring and evaluation of student's programming activities.

3.2. Upgrade's description for training and evaluation of C++ programming skills

For the purposes of their explanation, the new additions for training and evaluation of C++ programming skills, to the existing ecosystem can be grouped as build-in functional components and preparatory and work activities, organised as follows:

3.2.1. Built-in functional components

- Link from the main page.
- Tutorial for C++ training and evaluation procedure.
- Page with embedded compiler for C++ 14 compiler, over free jdoodle services from a wide set of programming languages.
- Redirection to jdoodle main page.

3.2.2. Preparatory and work activities

- Creating a jdoodle account that provides editing, compiling, executing, collaborating, and sharing project activities and files in C++, including saving to a separate personal folder, upload and download files (code).
- Sharing project, loading and processing a student data form with a link generated from the C++ project.
- Recording and processing of student activities – assessment, checking, statistics.
- An explanation of the step-by-step procedure for integrating these functionalities and activities into the existing educational ecosystem.

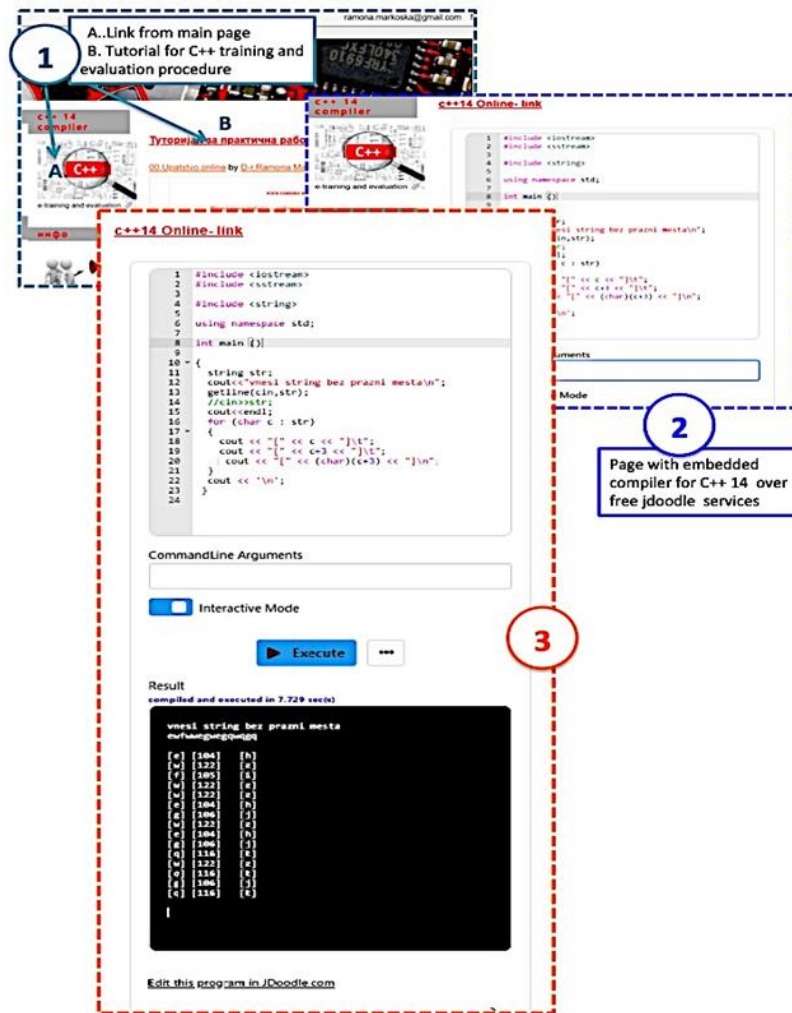


Figure 2. Built-in functional components on the updated C++ cloud's personal activities page

4. Practical realisation of e-learning ecosystem for C++ activities

In order to fully understand the essence of cloud-platform programming processes, the practical implementation of the e-learning ecosystem for C++ will be explained and illustrated below. Some of the previous items will be repeated to clarify them through the development and implementation processes correlation.

4.1. Practical implementation of build-in functional components

Built-in functional components on the updated C++ cloud's personal activities page are presented in Figure 2. For clarity and comprehensibility, the explanations are numbered according to the markings on those pictures:

1. On the main page of the pre-developed ecosystem, there is a tutorial with descriptions of how to use the built-in updates for C++, and there is a redirection option to the C++ compiler page 14.
2. The built-in compiler page for the C++ 14 was created by jdoodle services, selecting and customising from many different language compilers, offered on this page. The range and format of customisation depend on location where the embed code should be imported and implemented.
3. On this C++ embedded cloud compiler, several directly accessible functionalities are created, such as editing, compiling and executing code, importing command-line arguments, interactive mode and windows console for results.
4. By selecting the '...' tag or clicking the 'Edit link on jdoodle.com,' current activities are redirected to jdoodle.com main page. Jdoodle.com offers an augmented set of programming tools connected with personal account creation.

4.2. Organisation and implementation of preparatory and work activities

The realisation of many of these activities is closely related to the previous ones, but some of them are independent, such as personal account creation. Next, with each account created, goes a personal folder for project storage, and a set of collaboration opportunities. The most important of these are sharing capabilities that allow for simultaneous collaboration with owners of other accounts (students), and also share links to the code with the ability to be checked and compiled by others, such as teachers.

All of these procedures are shown in Figure 3:

1. My C++14 Projects is a personal account folder where projects are stored, and each of them can be created from the main page, or opened from My Projects.
2. Collaborate/Peer programming offers an option for online collaboration and code editing, with sharing between selected collaborators. This is very useful, during the training and educational activities.
3. Share-Embed in a blog or site is in use when the final project as an evaluation or editing file should be shared or embedded in another location, via custom links created in the jdoodle environment.

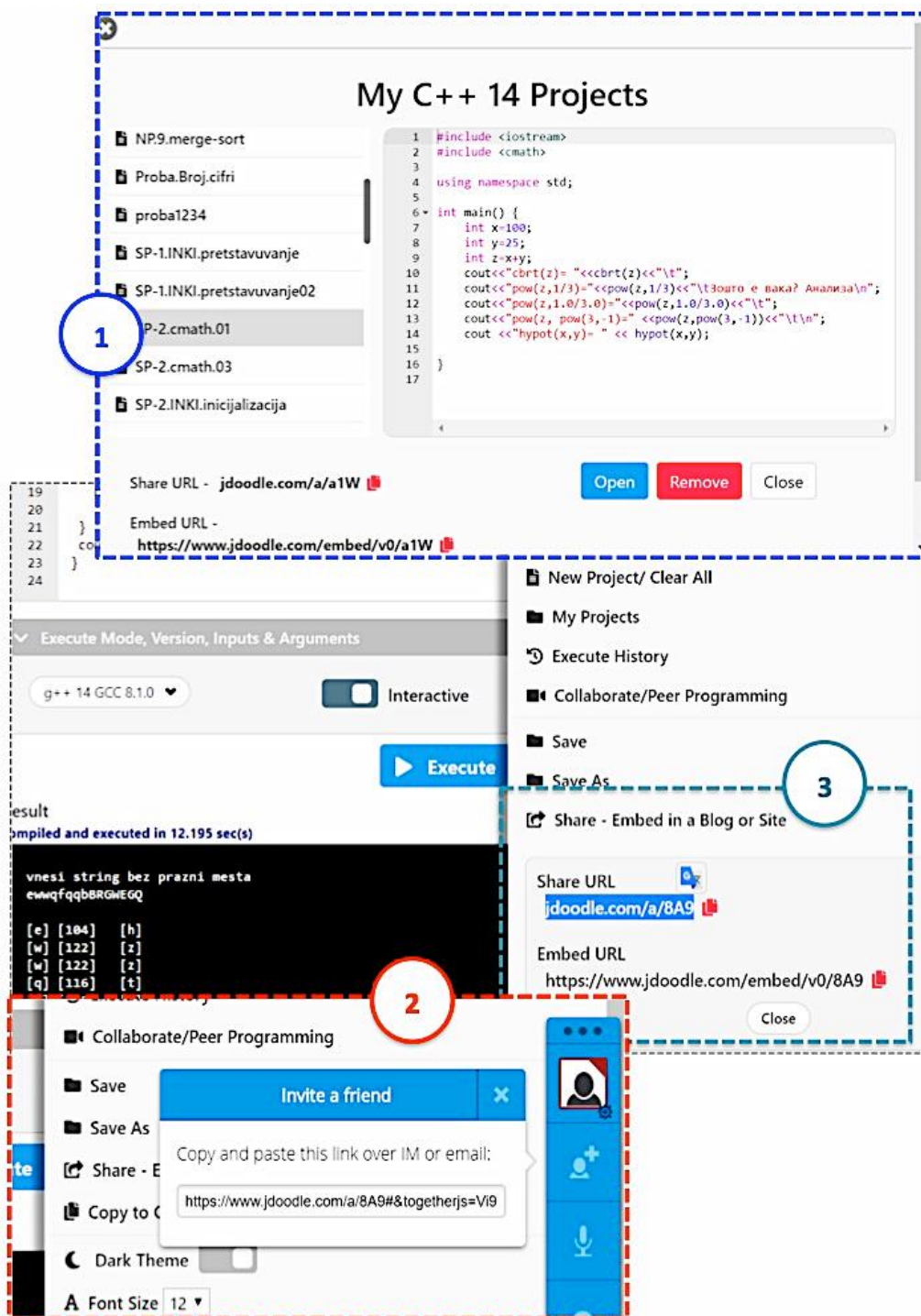


Figure 3. Preparatory and work activities

4.3. Processing and evaluating student's activities data-training and education

According to the previous explanation of this working idea, there are several modes of students' activities: training and learning, which happen during the education processes, and final estimation of

- *Operating System Raspbian* – An operating system is the set of basic programs and utilities that your Raspberry Pi runs. Raspbian provides over 35,000 packages, pre-compiled software bundled in a format for easy installation on your Raspberry Pi.
- *Lighttpd* – open source web server, designed and optimised for high-performance environments, with compliance, security and flexibility features. Its event-driven architecture is optimised for a large number of parallel connections.
- *GCC MinGW* – GNU compiler collection for various programming languages to the previous explanation of this working idea, there are several modes of students’ activities: training and learning, which happen during the education processes, and final estimation of programming skills, during the process.

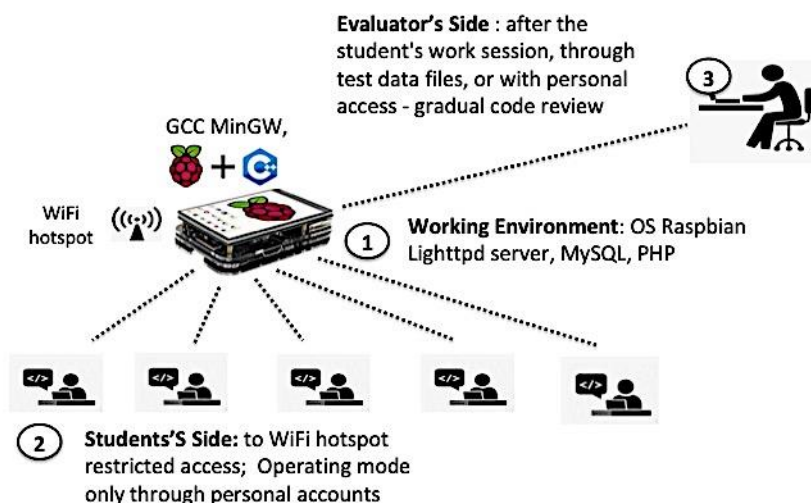


Figure 5. Raspberry Pi 3-based C++ evaluation – functional decomposition

Two ways of accessing and using the work platform are allowed:

- *Student's side*, according to working activities:
 1. Every student should access Raspberry Pi' S Home page, and sign up using a personal working account.
 2. The solving process of the requested projects can be for data input through the console using an interactive mode, or via an uploaded file with the testing data (similar to jdoodle.com).
 3. During the workflow, only wi-fi hotspot connection on Raspberry Pi is allowed.
- *Evaluator's side*, which consists of the following activities:
 1. When students set up their own solutions through a personal account and complete programming activities, an evaluation process follows through test data files or with personal access – gradual code review.
 2. Depending on the evaluation plan, this process can be performed in two ways: through data testing files or through personal access – a gradual overview of the code.

6. Conclusion

Regardless of the field of education and working activities, the 21st century brings rapid changes, which transfer their real material environment into digital work or education ecosystems. The development of these two types of ecosystems is linked through the use and application of ICT solutions. Digital business ecosystems and e-learning ecosystems are also linked through the

information and processes of their change. In both cases, the information is a raw material and a manufactured final product that generates capital, if used correctly. Therefore, modern higher education is in a state of continuous improvement not only requiring new educational tools but also developing and generating new ones. E-business workflows require new technologies, which lead to new educational needs. On the other hand, the trends of ICT new solutions use, through the implementation of the latest programming technologies in e-business processes, lead to continued growth. As in the business domain, as well as in education, the application of standard solutions enables the monitoring of development processes. But in both cases, the steps and efforts in creating non-standard solutions make development possible. This article uses an authentic development model to enhance an existing e-learning ecosystem. In parallel, the meaning of LMS, as well as their relationship to e-learning ecosystem, is explained. In the development and upgrading of the e-learning ecosystem, certain principles and experiences of the existing LMSs have been applied. This article describes the specifics and dynamics of program activities in the process of active (real-time) programming that requires an authentic approach to be developed and implemented, bypassing the classical LMS solutions.

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