

Cloud technologies for STEM education

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Abstract. Cloud technologies being used in STEM education for providing robotics studying are highlighted in this article. Developing cloud robotic systems have not been used to their fullest degree in education but are applied by limited specialists' number. Advantages given by cloud robotics (an access to big data, open systems, open environments development) lead to work with mentioned systems interfaces improving and having them more accessible. The potential represented by these technologies make them worth being shown to the majority of teachers. Benefits of cloud technologies for robotics and automatization systems are defined. An integrated approach to knowledge assimilation is STEM education basis. The demanded stages for robotics system development are shown and cloud sources which could be possibly used are analyzed in this article.

Keywords: STEM-Education, Cloud robotics, Educational Projects, Cloud Resources, Robotic Projects.

1 Introduction

Cloud Computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [18].

The non-paying attention to disadvantages, with distrust to suppliers of cloud services being main, allows cloud technologies increase their popularity. Web-sites, emails, connection/communication sites and mobile services are among the most popular ones (see Fig. 1).

2 Related works

Having been developed technologies have occupied each activity sphere and caused new educational paradigm to appear "...ensuring equal access to quality continuous

education for everyone who have to study, who have a wish and a need for long-life learning and for those who have an opportunity to study” [3]. This paradigm following completely depends on cloud source usage, because of its features, which in turn are a part of digital learning environmental with the benefits bellow:

- equally easy data access, regardless of user location, users’ amount and time of logging;
- opportunity of team-working;
- no need of special programs installation, the most comfortable way of dealing with data would be ensured by cloud services;
- no problem with software updating as data bases and information (and services/staff) are being kept on server;
- no problem with special software installation, its license checking as cloud services are to provide comfort work level with data and information;
- increased speed of data shearing/decreased time;
- comparative safety level.

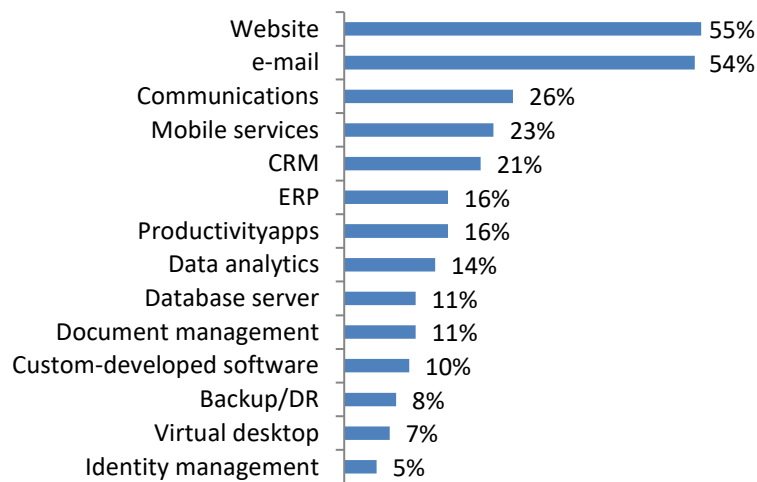


Fig. 1. Adoption Rate of Applications Fully Run in Public Cloud (2019) [5].

The traditional learning environment has been complemented by a digital one – the scope of information and communication technologies (ICT), including the Internet, mobile and related technologies and devices, as well as digital networks, databases, content and services [28]. Scientists note the cause of changes in education has been cloud technologies as part of the digital learning environment. The paper [17] identifies the relationship between cloud technologies and their place among learning technologies.

There are following changes [13]:

- subject-technological organization of information educational environment,
- regulation of accumulation processes and storage of electronic educational resources,
- equal access ensuring to educational resources for students,
- improving of ICT support of learning processes,
- measuring and monitoring of student's knowledge level.

The cloud environment serves as an integrative and system-forming function in the educational environment of an educational institution [30]. It provides resource support and serves as an independent learning tool. From the point of view of teachers and students, educational technologies fulfill five basic functions [16]:

1. Communication between students and teachers.
2. Making of documents, drawings and other works by students and teachers.
3. Dissemination of the work.
4. Saving lessons.
5. Internet access to special resources.

Due to cloud technologies development, innovative models of student's learning have acquired the new content and forms. New features are [7; 33]:

- Conducting experiments in virtual laboratories.
- Study of online courses at a pace, according to the possibilities.
- Web conferencing
- Digital technology use to organize the learning process in the classroom and outside it.

Peculiarities of the organization of learning by means of cloud technologies are reflected in the forming process of a personal learning environment, in strengthening of their role in learning, in the emergence of new roles of teacher, such as: master in the studio, learning administrator, tutor [11; 15; 32; 35]. Therefore, the training of future teachers should take into account the changes in the technological world.

The issue of the quality of future teachers training with the use of cloud technologies has reached a new level; the motivation determines the content and nature of activities. Meaningful choice of activities, advanced settings, adaptive system of tasks, the possibility of real feedback and creating an atmosphere of cooperation allows developing of the comfortable learning environment [2; 14; 25; 26; 36]. The organizational factors are [20]:

- ICT competencies forming in teachers and leaders as a driving force of pedagogical innovations,
- organization of appropriate technological infrastructure as a basis for the ICT introduction in the educational process,
- reorientation of curricula and methods to the widespread use of electronic resources,
- e-learning tools and online interaction of participants in the learning process as tools of modern educational information environment.

Despite all pros mentioned above, cloud technologies usage has several cons that are to be considered at educational process supported with such a technology is being organized. For instance:

- depending on electricity availability;
- the cloud service provider is empowered with absolute access to and control on data;
- resource is being worked and supported until the cloud service provider does it;
- resources may change monetary policy and limit the functional or they are no longer available;
- the data typing and standards lacking limit the cross-platform transition between resources.

The analyze of reporting (NMC Horizon Report) over the past seven years was carried out by educational association Educause [1] and main trends, challenges and higher education technologies' breakthroughs having been paid attention were made distinguish. Rise of new forms of interdisciplinary studies, cross-institution and cross-sector collaboration, proliferation of open educational resources, deeper learning approaches, collaborative learning, growing focus on measuring learning, advancing cultures of innovation, redesigning learning spaces were mentioned among the most interesting recent trends. The usage of cloud computing is needed for the majority of them being realized.

Cloud technologies are highly likely to effect on learning tools, methods and forms changing and to cause education modernization. There are some technological developments taking contemporary educational process over [1] (see Fig. 2):

- Adaptive Learning Technologies, Artificial Intelligence (AI) usage possibilities are related to switching to personalized learning [8; 24]. Such technologies as data analytics, machine learning, natural languages processing and chat bots applying is needed for this process [10; 27; 37]. Cloud computing provides an opportunity of producing and collecting big data which in turn allows to track education effectiveness and to personalize it with using adaptive technologies aimed to improve further learning direction. Not only technology applying during lessons is not enough but profound understanding of connection between digital tools and expected results is demanded. It has to be deeply integrated into learning process.
- Next-Generation LMS, Analytics Technologies – cloud technologies allow getting learning result not only at the end of the term but keeping it up to date. The most of educational institutions manage developing their own learning platforms which organize communication and cooperation. This platform is known to deliver personalized information about schedule, email, payment, learning courses and current progress.
- Interactivity, Mixed Reality – is an essential feature of any course or technology [23]. Moreover, increasing learning result and involving greater number of students are ensured by this characteristic.
- Microlearning, Mobile Learning [19] – a possibility of learning material fallen apart caused by practice of quickly changed and visual content consumption commonly

seen from youth. Besides, a need for rapid skill achieving while work being done leads to short-term courses implementation that are accessible at any time.

- Robotics, The Internet of Things, Makerspaces – not only the work is being taken away from people by robots but they provoked a workplaces appearance. The brand-new laboratories opened students could try their skills in practice. Educational institutions tend to start up vast number of innovations.

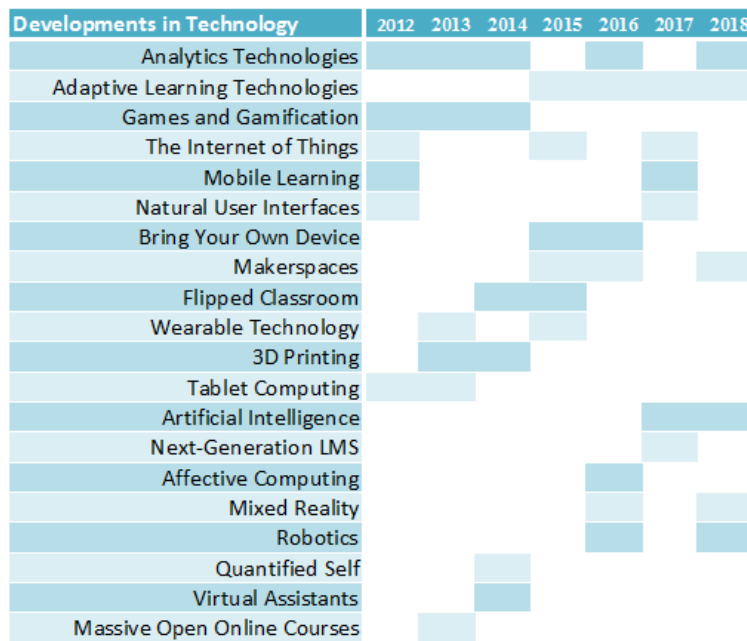


Fig. 2. Seven Years of the NMC Horizon Report Higher Education Edition (from [1]).

According to “Strategy of informational society development in Ukraine” development and application of supercomputer systems especially based on grid or cloud technologies ones are being one of the strategy realization stages in 2013-2020 years [4]. Hence, it means new digital infrastructure formation and educational digital environment reorganization.

The requirements of modern society to the level of digital media mastering, understanding of the principles of their functioning have grown significantly. It requires specialists with good natural-mathematical training. However, only about 10% of students in Ukrainian schools choose this profile as their specialization. Therefore, one of the goals of the education system is to increase students’ interest in the study of mathematics, physics, programming and other disciplines. One of the ways to achieve this goal is to develop STEM education (STEM – Science, Technology, Engineering and Mathematics) [12]. The greatest interest among students is caused by such a direction of STEM education as robotics. However, a prerequisite for the development of this trend is the availability of specialists, teachers willing to develop STEM-projects

with students. It requires updating of teacher training system and advanced teacher training and mastering of necessary technological base and the corresponding cloud services.

The current stage of robotics implementation in education is reflected in scientific publications of Ukrainian scientists such as Nataliia V. Morze, Oksana V. Strutynska, Mariia A. Umryk, Olena S. Kuzminska, Mariia A. Gladun, Serhii M. Dziuba and others [20; 21; 22; 31]. The number of publications in robotics from 2012 to 2019 is indicated in the Table 1 (data taken from scientific journals in Google Scholar and in Vernadsky National Library of Ukraine). By 2016, robotics was exclusively a discipline of non-formal education for schoolchildren and professional education of future engineers. In 2016, in Ukraine, robotics became part of education, which led to its popularization. Most publications are devoted to robotics use for teaching students, including future teachers, in the context of STEM-education. Another part is devoted to the use of robotics in lessons at school. But among them there is no topic about cloud technology used to learn robotics.

Table 1. The number of publications in robotics in Ukrainian scientific journals

| Year | University education | School education | Total |
|---------------|----------------------|------------------|-----------|
| 2012 | 1 | | 1 |
| 2013 | 1 | | 1 |
| 2016 | 5 | 2 | 7 |
| 2017 | 4 | 1 | 5 |
| 2018 | 2 | 4 | 6 |
| 2019 | 4 | 3 | 7 |
| Total: | 17 | 10 | 27 |

The idea of STEM technological component is widespread use of digital technologies, including cloud technology. We overviewed the cloud resources for robotics learning. The purpose of the article is to analyze modern cloud technologies of STEM learning for robotic systems designing.

3 Results of the research

It should be noted the term “cloud technology” in scientific publications refers to cloud services. Robotics is not limited onboard resources for computing, storage, or software thanks to technology advances. It has the added capabilities owing to cloud-based technologies; they enable the development of automation systems and robots that exchange data and perform calculations using neural networks or artificial intelligence [29; 34; 35]. Cloud robotics relies on network data to support its work. It has integrated storage into a single, standalone system [6].

Robotics has a number of potential benefits of the cloud [9]:

- Big Data: access to libraries of images, maps, trajectories, and descriptive data,
- Cloud Computing: access to parallel grid computing on demand for statistical analysis, learning, and motion planning,
- Collective Robot Learning: robots sharing trajectories, control policies, and outcomes,
- Human Computation: use of crowdsourcing to tap human skills for analyzing images and video, classification, learning, and error recovery.

However, the main problem of the practices introducing is teacher training. The large inertia of the education system does not allow the rapid change of the training technologies. These technologies should be tested in the educational process. A sufficient number of supporters, teachers-innovators, who will use it and share their experience, should also be formed. To accelerate the stage of introducing robotics into educational activity, there is a need to train future teachers in natural-mathematical disciplines in the use of robotic systems. So, we see the first stage of robotics, when we use SaaS for “desktop” robotics. In the next stage, cloud robotics will be used for learning.

As robotic projects require not only a technical base, but also specialized knowledge of physics, programming, and digital literacy, the use of the following free SaaS cloud resources and platforms will help to organize the work or approach to the project.

- Cloud information resources
 - Try Engineering (<http://www.tryengineering.org>) – the platform contains examples of engineering professions and information about engineering in general, for teachers there are examples of lesson plans.
 - Diy (<http://arduino-diy.com>) – portal for students, who are fond of electronics and robotic projects. Hundreds of projects for the Arduino platform have been introduced. There are tutorials with step-by-step explanations and examples.
 - Arduino.ua (<https://doc.arduino.ua>) – this resource contains all the necessary information for the beginner in robotics: electronic boards, connections, components etc.
- On-line programming resources
 - Made with code (<https://www.madewithcode.com/projects/>) – a free resource from Google for programming studying. It has examples of educational software for children from the age of five. The resource is aimed at engaging girls in programming. Visual editor develops Blockly programs. It has step-by-step instructions and guide users. For children from 8 years old.
 - Scratch (<https://scratch.mit.edu>) – licensed by the GNU GPL. This programming environment is free to download and free to use in school or after-school education. Multilingual visual editor designs Blockly programs. It has step-by-step instructions for beginner users. For children from 8 years old.
 - Scratch for Arduino (S4A) – is a modification of Scratch that allows simple programming of an open source Arduino platform. Visual editor develops Blockly programs. For children from 10 years old.
 - mBlock (<https://www.mblock.cc>) – this platform is also a modification of Scratch and supports programming of robotic systems based on Arduino microcontroller

such as: ArduinoUno, Codey Rocky, mBot, Neuron, MotionBlock, micro:bit. Visual editor designs Blockly programs, and usual programs with commands. For children from 8 years old.

— Virtual labs

- Tinkercad (<https://www.tinkercad.com>) – design models that will be printed on a 3D printer (Fig. 3) and modeling for connection Arduino sensor circuitry on a breadboard (Fig. 4). It allows making device connection layouts, write applications, and test them online. Visual editor designs Blockly programs, and usual programs with commands. For children from 8 years old.

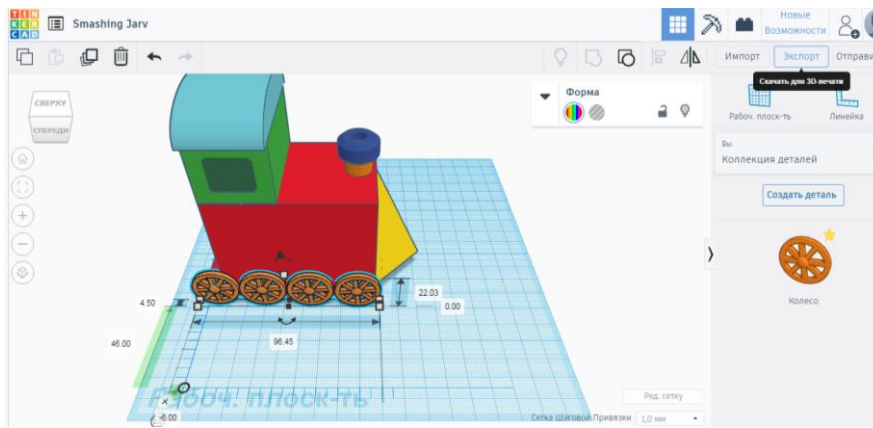


Fig. 3. An example of building a 3D model in Tinkercad

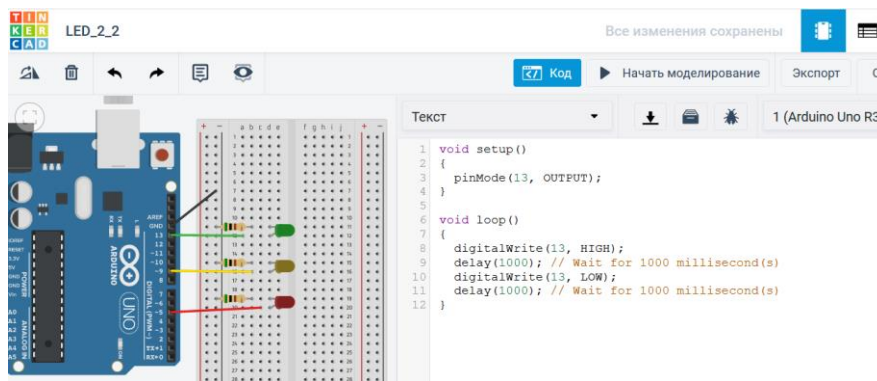


Fig. 4. An example of create device connection layouts and write applications in Tinkercad.

- Circuito (<https://www.circuito.io/>) – online layout of electronic circuits and creation of electronic boards. It has step-by-step instructions and guide for users. Visual editor designs programs with commands. For children from 12 years old.
- Easyeda (<https://easyeda.com/>) or CircuitLab (<https://www.circuitlab.com>) has an online resource for creating electronic circuits (Fig. 5). It has step-by-step instructions and guide for users. For children from 12 years old.

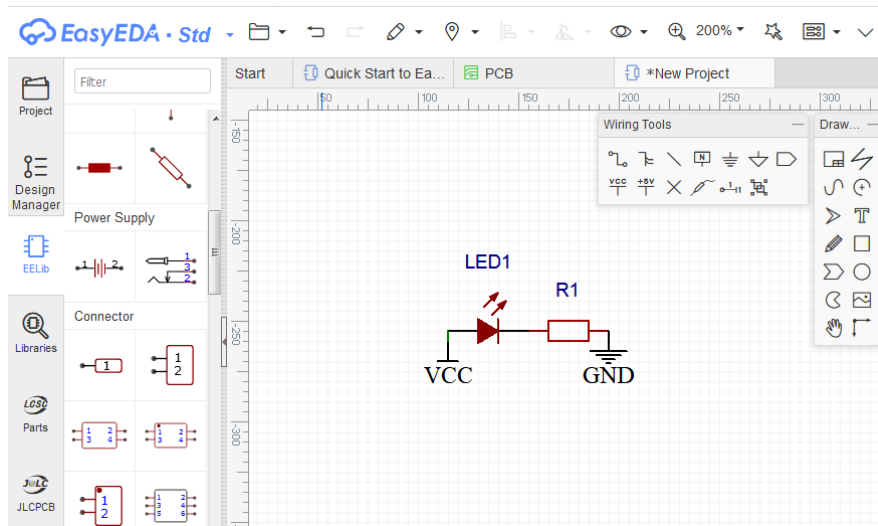


Fig. 5. An example of building electronic circuit in Easyeda.

- Professional communities – the purpose of such communities is to activate teachers and organize subject communities, join them for collaboration, and engage students in the learning process. Particularly, the most interested in information technology and robotics are the Ukrainian communities on Facebook “STEM-school”, “Digital Educator Group”, “IT scholar”, “Robotics and 3D modeling”, “Robotics of Kherson region”, “STEM step for everyone”, “Mobile Robotics Laboratory” etc.

Robotics is one of the areas of STEM education, which combines design and research activities. Such activities are different from laboratory ones by the lack of instructions on the sequence of actions, measurements, data processing, drawing conclusions. The educational projects are students drawing up an action plan, choosing a method of decision and processing of the results.

Educational scientific projects are necessary component of curricula in Physics, Informatics, Biology and Chemistry. The projects can be developed by using robotics.

Robotic project development requires the following steps:

1. Formulation and research of the problem and search for a technical solution – at this stage, theoretical and experimental modeling of reality and the search for a technical solution are performed. Organizing this stage requires robotics information resources contained the examples of projects or technological solutions
2. Robotic system development is a stage of carrying out research of a technical solution, its design, developing and approbation. At this stage, the structure, mechanical and electrical units are assembled.
 - a. Modeling – at this stage, the choice of materials for the design, justification of the reliability of the selected scheme of connection of parts, an instructional scheme of assembly of the structure development are made. At this stage, the question of the functionality, ergonomics and interface of the future design is resolved. It

affects such aspects of the technical solution as convenience, safety and simplicity of use. An integral part of this stage is interface design. For this purpose, for example, on-line platforms of 3D models development are involved.

- b. Design, prototype making – mechanics, electronics. At this stage, the collection of functional units, the assembly of the structure is conducted. It is important to test the design and make changes to the design. At this stage, it is functioning important to make an electronic circuit for the interaction of all robot devices and its sensors. The presence of cloud platforms allows creating a team project and schemes for working together. It also solves the problem of continuity if a project moves from one research group of students to another.
 - c. Programming is the developer environment. It is a stage of functioning algorithms development, writing/adjustment of the program, testing of the
3. Results sharing – the stage of presenting the work, drawing up documentation, evaluating own results.

The cloud resources use in the educational process makes possible to develop the complete educational and methodological support of the discipline “Educational Robotics”. The implementation of these technologies requires specialists who have knowledge of mathematics, engineering and scientific approach to solving technology-based issues.

4 Conclusions and future work

The use of cloud technologies for robotic systems extends the capabilities: access to neural network and Big Data training databases, open competitiveness of automation and robotics systems, access to open source software. It solves problems of the educational process technologicalization, the integration of the engineering component into the learning process, the cost of experiments of electrical appliances and the training of robots. However, there is another problem that needs to be answered in the near future, such as data privacy.

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