The Lessons of Forced Distance Learning: Software Engineering Approach in the Gap of Generations of Educational Software

Ekaterina Beresneva, Maria Gordenko, Olga Maksimenkova, and Alexey Neznanov

National Research University Higher School of Economics, Moscow, Russia
{eberesneva, mgordenko, omaksimenkova, aneznanov}@hse.ru

Abstract. Quite recently, considerable attention has been paid to distance learning due to mass schools and universities closing because of coronavirus disease. This fact brought to light not only strengths but also weaknesses of existing educational software and use cases. This paper is motivated by the questions which are rinsed by thoroughly adopted educational software and the deep gap between educational methodologies and up-to-date distributed information infrastructure capabilities. The lack of an engineering approach in the deployment of distance learning tools leads to both technological and methodological problems. We present exploratory analysis of data gathered from authority web sources. The significant ideological differences between educational software generations are discussed with special attention to non-cloud-based and cloud-based collaborative technologies and corresponding platforms. The authors conclude that the power of integration based on industry-wide interoperability standards is useful to solve current problems in distance education related to software.

Keywords: Distance learning · Integration · Interoperability · Educational software · Software engineering

1 Introduction

This year the World faces COVID-19 as a powerful driver of distance learning which created a unique situation for the real load testing of educational software of different kind. It became possible because educators all over the World started rapidly the force transition to online and distance learning.

As a result, the questions of technology and instructional design for distance learning become the cutting edge for lots of people from educational stuff to parents. These people run into difficulties due to the unplanned manner of this transition and great amount of unusual troubles with hard and software. It is well known that the education in general is a traditional sphere of great social responsibility regarding safety and security as of paramount importance.

Naturally, the shock to global education from COVID-19 is just seems something new and quite similar to World global conflicts of XX century which seriously affected and shifted education. Thus, Conner and Bohan [1] reported on great secondary
educational curriculum reconstruction during the Second World War. And, Jaworski [2] comprehensively studied change in women’s education in that period. On the one hand, it is good for society that such situations are very rare, but on the other hand that makes them unique enough and the solutions during rapid transformation should be fast, relevant the time, and easy to operate.

From this perspective, the educational society potentially can find help in the fields which focus on software and its use cases, such as Software Engineering. A short review reveal that software engineers have a number of modern software technologies and instruments used in distant working process that are expected to be applied in online learning activity [3, 4]. This work pays attention to the one of software engineering fields – Educational technology (EdTech or EduTech), which refers to fundamental issues of learning, teaching and social organization that makes use of technology [5].

This paper aims both to detect the troubles in the current state of distance learning infrastructure by investigating guidelines and recommendations from different educational governance and to expose their inadequacy from the software engineering point of view. Thus, the context of this paper lays between education and software engineering and it relies on transdisciplinary approach.

2 Overview

To make the context of the paper clear this section introduces educational generations and explains the significant ideological differences between them. It also overviews the impact of these generations on current education during a global pandemic.

2.1 Historical Overview of Educational Software Generations

For decades, the global educational community faced four paradigms of educational software which sequentially arise because of scaling.

The first generation is associated with the growth of personal computers (PCs). In the early 1980s the era of widespread personal computers began beneath the headline “You’ve just run out of excuses for not owning a personal computer”: devices were priced less than 1000$ and people could afford to buy and use them at home. It changed the field of software in general with specific implications for educational software: the cost of copying and distribution of a software product significantly decreased, so the first standalone educational tools came to the market.

The second generation is characterized by Sun Microsystems motto “The Network Is the Computer.” From a software engineering point of view that shift was marked by junction of PCs over the network. Since client equipment gradually became cheaper and more compact, mobile devices appeared. As a result, the emergence of the network and the spread of mobile devices lead the network to be mobile. The development of handheld devices and wireless network allowed applying new ways of learning. For example, United States, Australia and the United Kingdom became the pioneers of the 1:1 computing initiative [6]. Later One Laptop Per Child (OLPC) program was introduced in developing countries [7]. These ideas were aimed at mass introduction of
personal computers in educational practice in order to supply each student with computing device having Internet connection. It should be noted that not only PCs were used for educational purposes but also laptop computers (in the 1990s), handhelds (in the early 2000s) that were later transformed into smartphones or tablet computers (in the late 2000s). The net result is that one-to-one computing environments changed and improved classroom dynamics owing to computation and network communication capabilities that augment face-to-face interactions.

Later, with the advancement in technologies, network bandwidth increased significantly resulting in expansion of geography coverage. Increased number of users incremented their PCs load but even though the volume of information storage vastly multiplied, it still was limited. Users had a demand for the absence of these restrictions, as well as the no need for modernization and maintenance of their own hardware infrastructure. And they also wanted to receive durable services with a high level of availability and low risks of inoperability. Thus, cloud computing [4] gained its popularity as a result of convergence of telecommunication technologies and the convergence of computing and data storage based on virtualization, together with the advent of new server hardware and management of distributed systems.

Cloud computing technology started its ascendant in the late 1990s and provided an incredible cost reduction because of rapid elasticity and resource pooling: optimal use of software and hardware were achieved, hence increasing the efficiency and effectiveness of the available resources [4]. Other advantages that accrue from cloud computing are convenience and improved accessibility – due to transfer of computations to cloud server, the devices are not obliged to download and deploy any third-party software, and they have to provide only an access to Internet [8]. So, these devices became client terminals receiving data computed on a server side in a remote cloud data center [9]. These facts allowed educational software tools to become even more affordable and applicable to online learning process.

Classical learning management systems (LMS) and learning spaces was superseded by cloud-based ones, that have additional advantages owing to heterogeneity. Thus, more specific educational tools that need integration with LMS for adequate administration and methods of data exchange, commonly known as omnichannel communication, for comfortable usage became necessary. These tools should be based on modern interoperability standards, for example, from IMS Global (LTI and QTI APIP).

As a result, and converged computing results, known as cloud, edge, hybrid, fog computing, coupled with the omnichannel communication and ability to provide automatic context change forms the third generation, which the most modern educational software belong to.

And the transition to the fourth generation will take place when all learning tools transform to intelligent and adaptive systems powered by artificial intelligence (AI). Squirrel, ALEKS, Smart Sparrow, IBM Tutor are examples of products sustaining the fourth paradigm shifting.

2.2 COVID-19 Impact on Usage of Educational Software Generations

Traditionally, users from the education area are not the early adopters of modern generations of educational software. Nowadays, most of the educational software
belongs to the second generation and there are only plans to transit to the next ones. Of course, there are educators who intensively use modern technologies before the outbreak, so they are not up against with the force distant transition. However, there are learning organizations which have not yet fully utilized the tools of the current generation in the learning process. And they are facing significant uncertainty.

The first issue is connected with the fact that educators can easily notice that the second generation has an extensive user base, advanced environment and numerous developments. Consequently, it provokes a continuing usage of second-paradigm technologies. So, the innovator’s dilemma arises, described by Clayton M. Christensen [10], but not reflected by the educational community. The book introduces a “disruptive innovation” concept implicating that old products become uncompetitive because of the parameters, used in an earlier comparison, ceases to be relevant. It means that COVID-19 impact on educational technology generations empower innovator’s dilemma; and a decision to stay on second generation of educational software is equal to defeat.

The next issue is associated with the practicability of switching to the fourth generation. Some people postpone the transition waiting for the future paradigm since the “fifth” one can be potentially around the corner. And in this regard, an undesired period of any transition rejection may begin. However, the outbreak pushes educational organizations to make this force transition, and here the gap of generations of learning software is emerged.

3 The World Distance Learning Infrastructure Readiness to COVID-19

To support the main idea of the paper it is crucial to understand the current with educational software all other the World. Thus, this chapter provides the overview of the main recommendations from World organizations and individual countries about transition to distance learning [11, 12]. In total, more than 250 various sources were analysed, including governments’ and international organizations’ websites, local school platforms and reports about distance learning shifting. The overview seems representative enough because there are over 90% of the world’s student population have been affected [13] by the April, 1.

The response of international educational organizations and communities to force transition to distance learning due to COVID-19 is analysed. In Table 1 it is shown that these recommendations sum up the existing open knowledge hubs, well-known MOOC platforms and supporting tools and software. However, it should be mentioned that despite the importance of resources presented, they can cause bewilderment among educators. It can be noticed that these tools cannot be used to fully construct educational process but only to complement it. It means that listed software can interfere the educational process with inept use.

According to the International Monetary Fund classification, there are advanced and developing countries. Some experience of advanced countries which is summarized in Table 2 demonstrates that almost all advanced countries created or refined their national educational platforms with video-lessons, assessments, videoconference
abilities. However, the rapid introduction of these systems has shown that they cannot fully and completely satisfy all the needs of the educational process, so the countries have published extra lists of supportive resources and tools. From Table 3 which contains findings about local guidelines of developing countries we can conclude that the situation is the same as in advanced, but there are the technical problems with internet or device accessibility. Consequently, some of the governments of these countries decided to translate lessons on public TV.

Table 1. The reaction of international and educational organizations

| Organization                        | Suggestions/Tips                                                                 | Lessons/webinars/courses                                                                 |
|-------------------------------------|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| The Commonwealth of Learning [14]   | The organization provides the list of learning resources separated by educational levels (Khan Academy, MIT OpenCourseWare and etc.) [15] | The guides about blended learning and pedagogical innovations are published                |
| The World Bank                      | The WorldBank collected resources and platforms in one guide to support remote learning. The guide summarizes information about national learning platforms and other platform and software with separation by needs (assessment, file manager, LMS, training, video conference system) [11] | On website the guide about methods and methodologies of distance learning can be found     |
| UNESCO                              | UNESCO provides the list of educational applications, platforms including resources providing psychosocial support, digital learning management systems, systems with strong offline functionality, MOOC platforms, self-directed learning content, mobile-reading applications and tools for teachers to create the digital learning content [12] | UNESCO provides support, holds webinars and provides a platform for the exchange of educators' experience |

Table 2. The reaction of advanced countries

| Organization | Suggestions/Tips                                                                                                                                 |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Canada       | The Canada provides for free the big collections of learning tools, databases and etc. for each province both in English and French [16]. For example, Manitoba Ministry of Education gave access to “Manitoba_My learning at home” platform with the educational resources and everyday learning activities [17]. Quebec states also provided own platform “Quebec Open school” with educational support for everyone from 9.00 am to 8.00 pm from Monday to Friday [18] |
| Germany      | The wide range of supportive tools were provided for educators and students in Germany. There are secured online platforms for teachers, supportive guides for teachers, databases, lists and overviews on learning tools and websites with materials for both students and educators [16] |

(continued)
| Organization          | Suggestions/Tips                                                                                                                                                                                                 |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Great Britain         | The UK government publish the list of useful online resources and tools for home education, including such subject-specific resources as math, English, science and etc. [19]                                      |
| France                | With support of Ministry of National Education, a 52-min Maison Lumini daily program for 8–12 years old students were launched. The “My class at home” is a national platform, where students can select interactive resources, do some tasks, and meet with teachers and classmates |
| Japan                 | The Ministry of Education, Culture, Sports, Science and Technology (MEXT) developed centralized website, where tips and all useful information for educators are collected. The project “Future classroom” shows EdTech events and platforms for support remote educational process [20]. On MEXT website the platform for support e-learning by age, level and subject was developed. Its platform the lessons and materials for self-education are presented [21] |
| Singapore             | There is a Ministry e-learning portal “Singapore Student Learning Space”, where helpful materials for students and teachers are available [22]                                                                          |
| South Korea           | The start of spring semester on 2020 was delayed from March to April. Korean Education Broadcasting System (EBS) contains a lot of multimedia content [23]. Korea Education & Research Information Service (KERIS) is an aggregator of different platforms, also provides digital textbook services [24] |

| Organization          | Suggestions/Tips                                                                                                                                                                                                 |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Angola                | The Ministry of Education and the Public Television of Angola shows online lessons on TV [18]                                                                                                                                 |
| Iran                  | Daily TV program for educational purposes for all learning grades was launched. The Ministry of Education developed the app “SHAD” to assist learning [18]                                                                 |
| Iraq                  | Lessons for all educational level are stored on YouTube-channel [25]                                                                                                                                                |
| Kazakhstan            | The educational website “Kundelik” with tools and materials for remote learning are the main platform [26]                                                                                                          |
| Russia Federation     | The Ministry of Education of Russia support “Russian e-school” platform, where lessons and assessment for school’ learners are available [27]                                                                     |
| Saudi Arabia          | The Ministry of Education developed national e-learning platform “Vschool” and official learning portal “Ien National e-portal” [28, 29]                                                                                  |
| Tanzania              | The Ministry of Education in Tanzania with supportive of the Tanzania Institute for Education launched a series of educational TV-films for learning due to COVID-19 closures [18] |
In addition to the list of recommendations, there are restrictions on usage of some tools, for example, popular among the educators video-communication platform Zoom was banned by governments, companies and educational organizations by various reasons including cybersecurity and politics, see the most interesting cases in Table 4. The full list of all restricted countries and regions can be found on Zoom official website [30]. This restriction also affected the educational process because teachers and children had already managed to adapt to it, and the prohibitions by states and educational organizations on its use forced them to switch to new tools.

Surely, the mentioned guidelines help lots of teachers and learners, but thoroughly absent users’ support led to several deep problems. Learners do not understand how to use educational resources and get confused in different tools. Moreover, parents worry about children’s health, as prolonged use of gadgets can adversely affect vision and the musculoskeletal system. Students cannot always concentrate on the lesson because there are many other interesting and entertaining content. Students are very tired of gadgets and are not able to perceive a lot of information at once [37, 38]. For example, Russian Federation, Ministry of Education published recommendation to exclude the usage of smartphones for distance learning. It is accompanied by the impact on the student by complex unfavourable factors: electromagnetic radiation, the small size of characters and images, the inability to comply with a rational working posture, strong tension of the muscles of the neck and shoulder girdle and others. Moreover, the duration of continuous usage a computer with a liquid crystal monitor in the lessons ranges from 20 to 35 min, depending on the class of the student. The total duration of such work is from 1 to 3 lessons per day. Such measures are taken to prevent the negative impact of electronic devices on the student’s healthy [39].

| Initiator        | Reason                               | Comment                                                                 |
|------------------|--------------------------------------|------------------------------------------------------------------------|
| Taiwan           | Security reason/Politics reason       | Taiwan was the first country, which banned “Zoom” for public institutions, because some traffic routed through China, which does not recognize Taiwan independence [31] |
| Rwanda           | Security reason/Politics reason       | Rwanda Information Society Authority (RISA) advised against using “Zoom” to public institutions because it routes traffic through China although it was said that traffic remains in the country where the call was made. There are also vulnerabilities that allow third parties to enter the conference and broadcast indecent content [32] |
| Singapore        | Security reason                      | On lesson two unknown men add lewd comments [33]                       |
| Google           | Security reason/Competitor reason(?)  | Google bans using “Zoom” for employees on their personal gadgets due to many security breaches from “Zoom” [34]. Also, Google has own videoconferencing system “Hangouts Meet” |
| SpaceX           | Security reason                      | Security issues and “Zoombombing” were the main reasons for ban [35]  |
| New York City    | Security reason                      | Zoom was banned to using in schools [36]                              |
The teacher burden increased because of ongoing communication with children and parents. Teachers are concerned that students do not receive individual consultations and do not always understand terms, especially mathematical. Learning creative subjects and art in the current distance format is almost impossible. The quality of education has decreased due to the lack of control over students [40]. Of course, most of the problem is related to the technologies, which used to distance learning. As far as the authors can conclude, recommendations from governments and professional educator organizations are limited with lists of software and distance learning methods without connections among them [3, 41]. Surprisingly, in spite of the development of modern learning management systems, most teachers control the learning process via instant messengers (e.g. WhatsApp, Telegram) or send the necessary information to students by e-mail [40].

Due to the abundance of educational resources, both teachers and students are confused in their accounts. Educators are often confused in the list of recommendations and do not understand what tools they should use. Not always competent use of existing platforms leads to variety entry points and the lack of integration of heterogeneous systems due to mixing products of different generations. Political, economic, competitive reasons also influence on educators and educational process.

It should me mentioned that all types of educational software experienced the sudden stress testing induced by the announced lockdown. It is observed that the educational systems had serious technical crashes and malfunctions caused by scaling problems [42, 43].

4 The Software Engineering View

Here we discuss the problems identified in the previous section from the software engineering point of view. It is important to emphasize that the generation gap was already predicted and recognized by system engineers. Software engineers succeed in such recognition and are currently developing “fourth-paradigm” solutions based on global network infrastructure and cognitive (AI) platforms.

The essential point is that coronavirus decease did not make great problems for software engineers because of their readiness. IT industry is get used to agile management methods, which brought on approaches for organizing virtual teamwork and state-of-the-art software substituted for tools of previous generation. Large-scale development of cloud computing technology prompted to the breakout of heterogeneity platforms and microservices. So, the solutions, constructed on their basis, have such features as rapid transformation, easy operation, and very fast and scalable deployment. So, actual generation of corporate information systems (CIS) not only reacts much faster to the COVID-circumstances than widely adopted educational software but also supplement functionality with specific education features (see examples of Zoom, Teams, etc.).

It is notorious that due to the COVID-19 many employees started working from home. Those organizations which utilized old technology stack and not used highly scalable cloud-based software, had more demand in anykey-men, support, and cybersecurity specialists. Most interestingly, 15% of cybersecurity staff said that they
did not have the tools and resources to provide security for remote working [44]. At the same time, 34% said they have only a temporary solution. However, almost half of cybersecurity specialists was transferred to the IT support for helping other employers in a new environment [44]. Thus, unfortunately, that decision is largely responsible for increase of the number of cyber-attacks due to the COVID-19. In a contrast, there were organizations which systematically supported early adoption initiatives; and they did not face problems with attack and vulnerabilities protection. So, the force transition did not put inconvenience to their working process.

In addition, there is a software engineering education sphere which requires a constant peg of knowledge of emerging professional standards to successfully train learners under the current labor market realities. There are not only special communities and conferences (for example, CSEE&T) to discuss education in this area, but also declared bodies of knowledge covering working process of IT specialists. For instance, SEBoK v.2.1 and SWEBok v.3 are the key knowledge sources of systems and software engineering. Another authority guide EITBoK contains a vast amount of material in specific areas of enterprise IT practice. ProdBoK and PMBoK v.6 with its Software Extension guides discuss the effective application of knowledge in professional practice of product and project managers, respectively. And DAMA DMBoK2 is a body of knowledge which presents a review of the best accepted practices and alternatives data management approaches.

Thus, we can conclude that educational organizations are not the pioneers in this technological evolution. In addition, the outbreak proves that those who was not put cloud-based tools and agile methodologies into usual educational/working practice were unable to painlessly adapt to new conditions. So, the educators are counseled to be in the track of the software engineers’ experience.

5 Lessons Learned

This section summarizes main findings obtained through previously classified and systemized data and introduces lessons learned. As a result, we can see:

1. Proof that the current state of telecommunication infrastructure as a very good basis for scaling cloud-based solutions (with many examples of CISs scaling up to billions of users);
2. Triumph of modern CISs in conjunction with open educational resources (OER);
3. Backwardness of many official recommendations from various worldwide and national wide organizations caused by the heterogeneity of use cases of educational processes and supporting software, which is the essential cause of confusions and uncertainty of the end users (e.g. teachers, tutors, learners, instructional administrators).

We posit underestimation of:

1. The rate of technological advancement (some recommend using previous generation of technologies that do not support diverse educational use cases);
2. The significance of integration and interoperability;
3. The significance of platform-based nature of actual CISs (some recommend tools without underlying platform and corresponding authorization and integration consideration);
4. “Engineering literacy” as meaningful addition to so called “digital literacy”; 
5. Pragmatic approach to information security.

The findings of this study indicate the following inferences:

1. The changes are not “so disruptive” from the technological point of view.
2. The burden of accidental complexity in addition to essential complexity of education process is high and it’s the consequence of “educational debt” by analogy with “technical debt” [45].

Overall, the emerged gap of generations of educational software is a very straightforward corollary from the history of five decades. However, fortunately, both software and system engineering experienced great technological breakthrough over this period. Thus, educators can rely on their practice and use time-tested technological solutions adopted to learning.

6 Conclusion

The sudden COVID-19 pandemic became a significant push to distant and online learning this year. Understanding the growing role of technical pros and cons in this type of education, the authors exploded the role of software engineering methodology in total distance learning deployment. The principle conclusion that can be drawn is that the main user roles of distance learning software are in want of personally configured sets of products that supply their needs. The above outcomes show that the lack of an engineering approach in the deployment of distance learning leads to problems and serves as an inhibitor of this process.

Summarizing, our findings demonstrate a strong effect of interoperability standards on usage of distance learning software especially in collaborative educational practices. For today the World educational society have already had software platforms with supported API, but we still have a long way to go to mutually integrated educational systems, and the authors see in this the widest field for the future work.

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