



Covid-19 Effect on the Assessment of the Use of Smartphone Apps in STEM Learning

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The purpose of the study is to analyze the impact of the Covid-changed learning environment on the assessment of mobile applications for learning STEM disciplines. The study presents the results of the surveys of teachers (n = 38, age 32-52) and students (n = 188, age 19-21) of Sechenov First Moscow State Medical University and Kazan Federal University. The participants evaluated the effectiveness of mobile applications designed to study STEM disciplines. A thorough analysis of three apps dedicated to STEM learning and nine auxiliary niche apps allowed revealing their pros and cons, in particular, expanded student opportunities, the ability to study while staying in the Russian Federation, the availability of a Russian-language version, and the ability to make an appointment (for teachers or students). Due to the increased use of mobile devices by young people, the time frame for completing lessons and motivation to accomplish assignments (tasks related to engineering, solving problems in a notebook, taking notes, completing assignments on the device and in the notebook) were also defined as important. The analysis of mobile apps in the context of distance and blended learning unveiled that, in addition to the well-known criteria, the assessment of such learning means should also make allowance for the possibility to complete tasks outside the digital space, screen time reduction capacity, and accessibility for users. Learning based on a mobile application must be planned to encourage student thinking, the desire to obtain good results, and involvement in project activity.

Keywords: application, content structuring, distance education, motivation, STEM, study

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INTRODUCTION

Working and learning from home due to the quarantine measures necessitates the integration of web applications to effectively address the challenges of online learning and teaching (De & Arguello, 2020; Wahyuningsih et al., 2021). Online learning can be more beneficial than attending offline courses (Ahmed et al., 2021). The impossibility of classroom learning and the loss of access to educational materials and resources, especially in STEM disciplines, puts students at a disadvantage. On the other hand, adequate use of digital technologies can solve the issue, although according to researchers, there is still a risk of an education quality decrease (De, 2020).

The practice shows that smartphones can indeed act as useful didactic resources for student development due to enhancing educational and personal interactions between students and teachers (Vázquez-Cano, 2014, Nethi & De, 2019). Thanks to mobile applications, learners can visualize content, get examples of the phenomena being studied, search for additional information, perform calculations, exchange knowledge and collaborate swiftly, as well as communicate with the teacher in real-time. According to Lachner et al. (2021), more than half of all Internet traffic is generated through smartphones and mobile applications.

In the digital age, the key predictor of learning opportunities is not socioeconomic status or type of educational institution but the way the learning technologies are utilized (Lachner et al., 2021). At the same time, students' results directly depend on motivation, cognitive skills development, and the ability to self-study (Olszewski & Crompton, 2020). Better learning outcomes require students to work on their technological skills constantly: during class time, when doing assignments independently, or when searching for training material (Tseng et al., 2018). The experimental results obtained by Rivera et al. (2018) show that advancing the technical capabilities of the educational institution is possible if their leaders allocate time and money to improve the skills of teachers and students in handling mobile applications. Nithia et al. (2016) point out that mobile learning can be quickly adapted to changing conditions and technological and pedagogical innovations. It allows learners to find and study information at a convenient pace and communicate with teachers and other students in virtual classrooms.

Mobile Applications in STEM Education

The combination of Science, Technology, Engineering, and Mathematics (STEM) in education emerged in the last decade as a more attractive and holistic alternative for students to traditional natural science education (Martinez et al., 2021). STEM education is an interdisciplinary approach that helps students understand the world around them by means of the simultaneous study of several disciplines. The study of STEM disciplines is closely related to the development of computational thinking (Al-Haj Bedar & Al-Shboul, 2020; Wahyuningsih et al., 2021). One of the effective teaching approaches able to boost computational thinking is a STEM environment containing data visualization, interactive elements, and online resources (Al-Haj Bedar & Al-Shboul, 2020). The results of the experiment by Jawad et al. (2021) evidence a notable favorable effect of the STEM approach on innovative thinking and mathematical

achievements of students compared to traditional teaching methods. No less effective in this field are augmented and virtual reality technologies. While being designed to improve the exploration experience, they can raise math and cognitive skills by making learning more visual and tangible (Mallik & Kapila, 2020).

Importance of Motivating Students to Study STEM Disciplines

Many researchers write that teachers and their motivation to develop knowledge and skills, as well as the desire to introduce technology into the learning process, play a significant role in stimulating students to learn (Lachner et al., 2021; Marín-Marín et al., 2021; Stolk et al., 2021).

For effective training, educators themselves should be provided with opportunities to learn and gain experience in virtual reality. Such advanced training can be ensured by attending seminars, self-study, and participation in the development of online learning programs (Lachner et al., 2021). In line with this, teachers' involvement in developing and customizing learning apps is an effective way to encourage mobile technology utilization among both pedagogues and learners. In the case of educators, this approach assists in teaching and understanding the content better. As for students, studying STEM disciplines in an interactive environment promotes cognitive activity (Rivera et al., 2018).

Teachers' motivation for effective job performance directly influences the creation of a learning environment, learning interactivity, and, ultimately, students' academic success (Lachner et al., 2021; Stolk et al., 2021). According to Reinholz et al. (2021), for teachers, a catalyst for change is dissatisfaction with the content of educational material and teaching practices. The enhancement and improvement of teacher qualifications in accordance with the trends and innovations in STEM education is the key to learners' educational success (Christian et al., 2021; Jackson et al., 2021; Sachmpazidi et al., 2021) argue that motivating students to learn using different technologies requires concerted efforts of all members supporting the learning process, as well as opening up opportunities and creating conditions for students to engage themselves in STEM careers (Luo et al., 2021; Kajonmanee et al., 2020). For example, conducting workshops in Japan on developing apps for adolescent girls positively influenced their beliefs about the balance between personal life and work, increased the level of creative confidence of participants, and changed their social beliefs (Kijima et al., 2021).

As mentioned above, the learning environment is critical in motivating people to learn. According to Marín-Marín et al. (2021), an informal environment promotes learning STEM disciplines (museums, parks, and other locations that facilitate learning in a non-classroom setting). Virtual reality can also act as an informal environment, which allows learners to interact with objects, study various phenomena, make virtual trips, etc. The virtual environment increases student motivation, engagement, and creativity (Yildirim et al., 2020).

Mobile Applications in STEM Education

In New Zealand, most STEM teachers rely on mobile learning based on the associative pedagogical approach. According to Lindsay (2016), the most common use of mobile technologies is splitting a task into phased activities.

The use of mathematical applications helps reduce the gap between the results of students experiencing difficulties and successful students as it allows educators to identify topics that are difficult to learn and provides visual examples of solving complex problems (Zhang et al., 2015).

Math apps offer ample learning opportunities allowing students to cope with difficulties at their own pace, which is beneficial for those lagging behind. Specifically, the Splash math application enables students to track their own progress, see their strengths and weaknesses, and plan learning (Bano et al., 2018).

A number of researchers have demonstrated the effectiveness of teaching students STEM disciplines using applications created by students themselves with the help of App Inventor (Karahan et al., 2021; Tseng et al., 2018). Using such apps is proved to enhance motivation to learn, promote confidence in one's studies, and awaken mental pleasure from developing own applications.

Effective adoption and use of mobile technology in schools can be achieved by understanding the complex dynamics of the interaction of learning and technology. The decision to adopt and use technology depends on many factors, such as pedagogical beliefs and confidence levels of teachers, socioeconomic gaps between students, choice of an application that combines benefits and costs, ease of use, or even factors promoting or hampering innovation (Al-Haj Bedar & Al-Shboul, 2020; Bano et al., 2018).

Research has shown that the use of augmented reality is a powerful lever for student achievement. Individuals benefiting from mobile augmented reality apps are likely to have notably better scientific accomplishments than those attending regular classes with no such technologies introduced (Wahyu et al., 2020).

Scholars note that implementing mobile technologies in STEM education through small mobile platforms such as Mobile Hands-On STEM is relevant as it provides students with unlimited opportunities for experiments – a core aspect of the work of an engineer. Learning platforms for exploring and experimenting are relatively inexpensive (compared to going to laboratories and doing real-life experiments) and allow thousands of students to learn and do hands-on and laboratory work (Vázquez-Cano, 2014).

Assessment of Mobile Applications for Learning STEM Disciplines

The coronavirus pandemic became a strong trigger for the growing popularity of using mobile applications in the context of STEM education development (Jawad et al., 2021). Among the first to implement interdisciplinary distance STEM learning through mobile applications were Slovenian researchers (they set a focus on the field of organic

agriculture). The aim of their program was to provide specific STEM knowledge (especially in chemistry and biology) as well as knowledge of ecology, technology, and engineering. This approach enabled students to solve environmental and statistical problems online to find the best solution within a short time. The didactic model presented by this group of scholars puts a special emphasis on an interdisciplinary STEM approach to environmental protection, ecology, and sustainable development while presupposing an active use of mobile apps. However, even though such a learning mode corresponds to the trends of digitalization of the modern educational world, it is more effective for students (Pajk et al., 2021).

The use of mobile applications is believed to be highly effective in STEM education. The assessment framework for mobile technologies in education developed by Joo Nagata et al. (2017) has five main categories: pedagogy, usability, content, connectivity, and context. During the experiment aimed at the assessment of mobile technologies, researchers identified such key characteristics of mobile technologies as interdisciplinarity, ease of access, free version availability, time saving, offline usage possibility (temporarily), assignment completing possibility, multilinguality, gamification, the ability to connect to other equipment. Another important aspect is visual content, especially videos. For example, according to Seo et al. (2021), in the context of learning based on video lectures, students have many visual-based tasks: reflection, note-taking (important facts), memorization, clarification, viewing, search, orientation (in the subject or topic being studied), rest. In line with this, different students may focus on different aspects of the video (Rabin et al., 2021; Sabirova et al., 2020).

In the study by Reyna and Meier (2020), the students positively perceived the co-creation of knowledge with the help of mobile devices. As was reported, they enjoyed studying the subject content using digital media and exploring digital devices. In addition, respondents appreciated the opportunity to be creative when using mobile devices as learning tools.

In general, both students and educators are pretty optimistic about the use of mobile technologies in STEM education. But the need for distance learning places its own demands on mobile applications and requires a slightly different method for assessing the effectiveness of learning with their use.

This research seeks to analyze the impact of learning conditions changing under the influence of Covid-19 on the assessment of mobile applications in the course of studying STEM disciplines.

Research Objectives

1. To study available mobile applications for learning STEM disciplines and assess their advantages and disadvantages;
2. To study the opinion of teachers and students regarding the criteria for an effective application for studying STEM disciplines in the course of distance and blended learning resulted from Covid pandemic;

3. To investigate the impact of distance learning on the assessment of mobile applications for learning STEM disciplines.

METHOD

To identify the impact of Covid-19 on the use of mobile applications in education, the state of affairs in the field before the pandemic was reviewed, and the criteria for assessing mobile applications before the forced transition to distance and blended learning were highlighted (Figure 1).

Research design

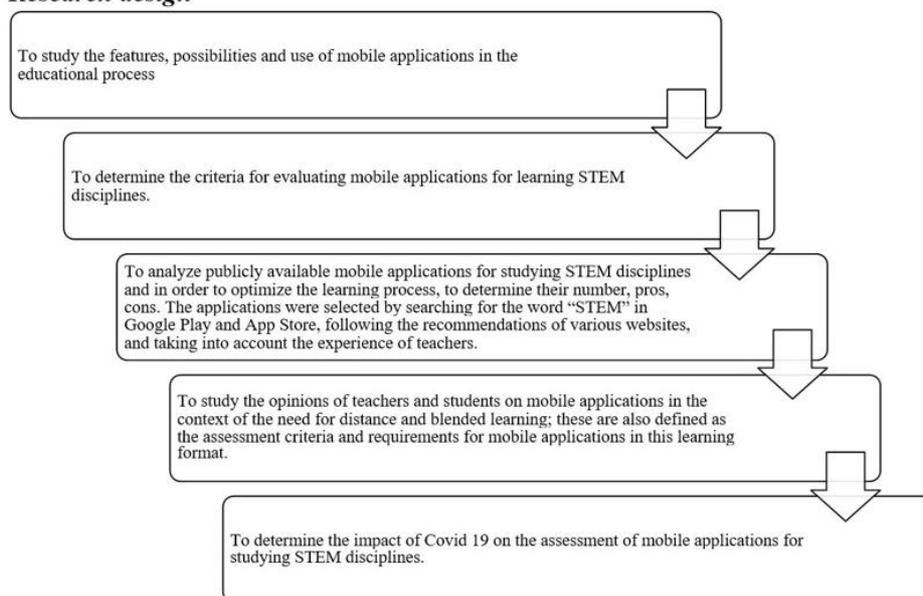


Figure 1
Research design

The chosen method of information collection (survey) was a set of open and closed questionnaires, which can most fully express the respondents' attitude to the implementation of mobile apps in the Russian Federation.

Sample

The study involved teachers of Sechenov First Moscow State Medical University and Kazan Federal University. They were invited to take part in the experiment at the faculty meeting, during which study conditions were explained. At the end of the meeting, all desiring to be engaged gave their written consent to participate and for the results obtained to be published.

Educators' selection was made following two criteria: teaching STEM disciplines for more than five years and having a scientific degree. In accordance with these

requirements, 38 individuals (24 men and 14 women) aged 32-52 were enrolled. Overall, the sample of teachers consisted of Candidates of Pedagogical Sciences (10 people), Candidates of Physical and Mathematical Sciences (12 people), Candidates of Technical Sciences (6 people), Candidates of Biological Sciences (5 people), Candidates of Chemical Sciences (5 people).

Criteria for students' selection were more voluminous: second- or third-year students with no bad marks who gave consent to participate in the experiment, to fulfill the research conditions, and to have the results of the study published. In total, the experiment involved 188 students aged 19-21.

Survey and Application Analysis

To achieve the research goal and solve the problems of the experiment, *the teachers were asked* to get acquainted with the applications for studying STEM disciplines by installing applications, analyzing their operation, and determining their advantages and disadvantages.

The teachers were given three months to install and use the applications. They were allowed to use the content and methods contained in the applications (if allowed by the developers), as well as in the assistive applications in order to test their effectiveness in the learning process. Each survey (before and after the use of the app) allowed respondents to send their answers to the questionnaire within two weeks only.

In general, the following criteria for the operation of mobile applications were assessed:

1. Possibility of registration from the Russian Federation;
2. Russian-language version of the content;
3. Content and structure of the educational material.

In additional applications (with a specific function), the following issues were also considered:

- Is this app effective for improving visibility?
- Does the app promote student laziness? (For example, calculating math formulas with the help of the application when the learner can calculate them themselves);
- Is it possible to get along the process of teaching STEM disciplines to this sample of students without this mobile app?

Having tested the mobile applications, the teachers discussed their advantages and disadvantages at seminars and meetings; all the responses were recorded.

After testing the open-source applications, the educators were asked to identify the characteristics of the applications that they believed would facilitate effective distance or blended learning.

The time needed takes to study a specific topic and discipline has a considerable impact on training effectiveness. Taking into account the consequences for vision and health, the factor of screen time was defined as one of the most critical ones.

In the course of the survey held on the seminars, the teachers were asked the following questions:

1. When do you find it effective to study STEM disciplines with the help of a mobile app?
2. Which structure of the lesson in a mobile app would appeal to you?
 - A. Video – text – task;
 - B. Text – video – task;
 - C. Review of the previous lesson and further studies according to the above schemes;
 - D. Chat to discuss and perform self-instructional assignments, discussion with the teacher, video, and text of the next topic.
3. Do you think students should complete tasks, note formulas, make calculations, and solve assignments on paper?
4. How can learning outcomes be assessed in a mobile application?
5. What is your opinion about the changes in the assessment of the mobile application for learning STEM disciplines due to the need for distance and blended learning?

The answers to these questions were recorded live at seminars and teacher meetings (during the experiment, there were three offline and three online seminar sessions).

To achieve the goal of the experiment, the *students were invited*:

- To get acquainted with the applications for learning STEM disciplines listed in the experiment conditions by installing and using them at their convenience during the experiment (three months);
- To mark applications that they have already used or use constantly (list them on paper or provide links to them);
- To describe whether they understand the learning content contained in the applications;
- To come up with suggestions on how to improve available applications and develop an online learning application or a complementary learning tool;
- To describe the opinion on the assessment of a mobile application in the context of distance and blended learning.

Data Analysis

The data obtained were processed in SPSS Statistics. This software enabled carrying out a quantitative collection of teacher and student responses.

Relevant search results were determined by the description of the functions of the mobile application (that is, whether the application found is suitable or not for learning STEM disciplines).

All research participants fulfilled the conditions of the experiment and met the deadline for answering the questions.

The program used was tested using Pearson's chi-square test in terms of the influence of the two studied indicators ($4.396 > 3.841$), i.e., it was defined as valid, and the dependence was described as statistically significant.

FINDINGS AND DISCUSSION

The analysis of publicly available mobile applications in App Store and Google Play showed their small number. Thus, only three mobile applications for studying STEM disciplines (Table 1) and nine auxiliary applications with a specific function that could facilitate learning were found.

There were no mobile applications with a Russian version for the Android OS or IOS intended for learning/teaching STEM disciplines.

Applications with an English version for teaching STEM disciplines are described in Table 1.

It should be noted that these applications are designed for educators (Table 1).

Table 1

Features of mobile applications for studying/teaching STEM disciplines (available on the Google Play and App Store platforms)

Application	Possibility of registration from the Russian Federation	For teachers	For students
STEM teaching	-	+	-
STEM learning	+	+	-
Learn TechWorld	-	+	+

The table above delivers the outcomes of the author's analysis of available Google Play and App Store apps in terms of their use in Russia. Affirmative (positive) assessment was formed on the basis of the capability of the application to be installed in Russia and the rationality of its use from the perspective of a teacher/student.

The applications mentioned are aimed at a comprehensive study of STEM disciplines. They contain ready-made content developed to train educators to use them in the teaching process. No applications that are designed to learn STEM disciplines and can be used by students were found. Apart from university students, the content of the apps is also targeted at school students. As for the location, only one application allows registration for Russian users, while another app can be used only if one is located in the USA or India. Hence, a conclusion can be made that most STEM-directed applications under consideration are oriented toward Western users and are problematic to be used by students and teachers from Russia.

Table 2 shows mobile applications that can be used as an auxiliary tool for studying STEM disciplines and describes their functions.

Table 2
Applications suitable for STEM education

Application	Function	Russian version
eBird and Merlin Bird	Study of biology, nature,	+
iNaturalist		+
Star Chart	Study of the starry sky	-
Lab4 Physics	Visualization of physics experiments	-
Google Lens	Description of the item from its photo	+
Qrafter	QR code scanner and generator	+
Photomath	Solution of mathematics formulas	+
WhatTheFont	Recognition of the printed text font	+
Shazam	Search for a piece of music	+

These applications can partially contribute to the development of STEM projects, problems solution, and information search.

The analysis of available mobile applications for teaching STEM disciplines shows that the development of such apps has great potential due to their small number in general, as well as the lack of apps translated into Russian and those intended for students.

Teachers' Requirements for a Mobile App Designed for the Effective Study of STEM Disciplines

Based on the results of the teacher surveys and discussions conducted after the three-month app testing experiment, requirements to mobile applications that will be effective for studying STEM disciplines and will reckon with the quarantine dictated online learning conditions were identified. In addition, the logical requirements of teachers for the application and the criteria for evaluating a mobile application in the context of distance learning were determined.

According to the educators enrolled in the experiment, the application should contain the entire curriculum of the educational institution (in this case, the university) and the learning material in the form of text, video, and other possible types of its graphic display (presentations, photos, audio, podcasts).

Thus, in the context of completely remote learning, students study the material in the application. In contrast, in the context of blended or in-class learning, the application acts as an additional learning tool that can be used to review the material, monitor progress, or study topics one by one in the classroom or independently in the app according to the teacher's requirements. App-based blended or in-class learning also creates conditions for conducting classes with the use of active learning methods. More precisely, students may study the material in advance while at the lesson (online or offline) they solve problems or complete design tasks based on the already available knowledge.

Another technique for self-study and the development of information retrieval skills noted by educators is the presence of instructions for downloading other applications

(for example, for solving mathematics formulas, visualization, design) in the basic app with a complete curriculum. If implemented, such a strategy eliminates the need to embed functions of applications designed for a specific activity (mathematics functions, 3D images, geometric shapes, modeling elements, design patterns, etc.) into the app used by a specific educational institution. Furthermore, this teaches students to search for solutions independently rather than wait for ready-made answers.

An important aspect is the assessment of the learning outcomes of students studying with the help of a mobile application. During seminar discussions, educators pointed out the importance of learning not for passing tests or completing levels of training but for solving real-life problems. Learning outcomes can be assessed based on testing, a photo of the completed project, a video report, completion of tasks online under the supervision of a teacher, or submitting a project in a digital format.

The majority of teachers (79%) noted that it is effective to use a mobile application for 30-45 minutes to study one topic, including video activities, text material, presentations, and instructions for completing independent projects and assignments or preparing for the discussion of the following topic (independent information search). There should be 2-3 such classes per day as students cannot remember and master more information due to the specifics of the natural ability to perceive information from the screen. The rest (21%) indicated that a productive period is 20-30 minutes for the same reasons. But all the teachers agreed that there is a need to consider this issue experimentally and develop lessons while studying the influence of different visual elements on learning effectiveness.

Although no consensus on the structure of the lesson in the application was reached, all teachers agreed that its choice should make allowance for the topic being studied and the diversification rule (the tasks should definitely be diversified).

The teachers recognized the importance of being able to transfer, design, and complete assignments on paper without a smartphone. That is, the material is studied in the app, but the tasks are completed without a smartphone. Students perform design activities, create projects, and, if required, submit the results by taking a photo or demonstrating them in the classroom. This factor is critical for consolidating the knowledge and skills gained in the application, as well as for the development of thinking, and not just the perception of information. Progress can be assessed in the application, but according to the teachers, independent work greatly enhances students' thinking.

In a similar vein, all educators noted that student knowledge assessment is more effective if independent projects are introduced. Even though they may not be perfectly completed, they encourage learners to study the material more deeply and get more involved in completing assignments. According to the teachers, it is important to eliminate the desire of students to quickly complete the task with the help of a computer or smartphone. To do this, the tasks should be designed in a way that does not allow the student to find all information on the Internet. It is necessary to make the student figure out facts and perform calculations and activities with hands, tools, or any other equipment. This is a common opinion of all teachers. Such tasks can partially replace or

supplement testing as students apply all their knowledge during the implementation of their projects. At the same time, the importance of test tasks is also recognized. But these tasks should awake learners' interest and be based on various techniques to activate thinking (shaping one's own answer to the question, selection of answer options from the list, leading questions, etc.). Teachers note that the material studied and consolidated with the help of a test containing answer options is quickly forgotten by learners.

Another point reported was that the requirements for a mobile application for teaching STEM disciplines have generally changed due to the forced transition to distance learning associated with the pandemic. Thus, learning apps used to be assessed based on their performance and students' achievements, and there was no need for the apps to contain tools for teaching students (full course content; online learning opportunities; opportunities for learning, design, testing). There is no doubt that it is possible to do without such an application in the context of distance learning, but this creates a need for a number of other applications and chats, which complicates the process of learning.

Students' Opinions on the Mobile Apps for Studying STEM Disciplines

All the students interviewed were enthusiastic about the applications for visualization, solving math problems, design engineering and noted that they would like to have an opportunity to select apps for solving problems and finding information independently. In the course of surveying, many of them reported that they did use auxiliary applications for solving problems, finding information, completing projects, and leisure activities (Shazam, eBird and Merlin Bird, Star Chart), as well as applications designed for educational purposes (iNaturalist, Lab4 Physics, Google Lens, Qrafter, Photomath, WhatTheFont). Apart from this, students also used other applications that they found themselves, following friends' recommendations, or on the Internet (on a daily basis, the use is occasional or systematic). Relevant data on the matter are presented in Table 3.

Table 3

Applications used by students

Application	% of students who use it	
	Regularly	Occasionally
Frequency of use		
Sketchup Mobile Viewer	10.63	6.38
Concept Idea Calculator	90.42%	9.58
BIMx	-	32.97
Engineering Cookbook	5.32	-
Mechanical Terms Dictionary	79.25	-
AutoCAD	-	12.23
Mechanics of Materials	-	10.63
CalcKit: All-In-One Calculator	84.04	-
TED	86.17	15.83

As was indicated by the majority of students (86.17%), they understand the educational material contained in the applications they use.

All students who participated in the experiment responded positively to the possibility of creating a mobile application for distance learning. Indeed, switching between Zoom, Skype, and WhatsApp, scattered tasks, and the inadequate structure of the training course do not contribute to effective learning. Instead, they provoke worries in students about whether they have learned everything and completed all assignments, as well as fears that the exams will come as a surprise.

According to students, the screen time required for learning is essential. Therefore, content structure and learning visibility are of key importance when developing a study plan for a mobile application.

The students also enjoyed the opportunity to perform tasks on paper (generalized opinion, 98%). As one of the respondents noted in this regard, students are tired of the endless search for a chance to present their ideas and solutions only as digital content. Sometimes it is much easier and more efficient to draw, design, and do the task on the spot.

Based on the summary of the opinions of teachers and students about the assessment of mobile applications for studying STEM disciplines in the context of distance, blended or traditional learning, the following criteria were highlighted:

1. Minimization of screen time – thoughtful content of lessons, presentation of visual materials, the ability to complete tasks on paper;
2. Availability of the studied program in the application and the ability to use it as the main learning tool in the context of distance learning and as an additional learning tool in the context of blended or traditional learning;
3. Possibility of choosing methods for completing tasks using other local mobile applications (which perform one of the functions: calculation, visualization, design, or drawing) or methods for solving problems (that is, a hint which application or formula can be used rather than a direct indication, as well as the possibility of choice);
4. Opportunity to complete assignments without mobile applications (on paper, in notebooks, or textbooks), which can be subsequently evaluated by photo or in the classroom;
5. Continuous relevance of content in the application, compliance with training standards and the latest trends in technology development in STEM education, requirements for STEM employees;
6. Assessment of learning outcomes with the help of various methods: testing, submitting a photo of the completed project, video report, performing tasks online under the supervision of the teacher.

These are the basic requirements for an application that can be assessed in accordance with other criteria that emerged after the stage of development and testing.

Changes in the Assessment of a Mobile App for Learning STEM Disciplines

Based on the results of surveys, during the discussions at seminars and meetings of teachers, the main differences in the assessment of mobile applications were identified. Before the forced transition to distance learning, mobile applications were assessed by their functionality, interface, and technology implementation. Today, these parameters have been supplemented by the flexibility of the learning process, the ability to learn, take tests, complete assignments, and communicate completely in the application.

An important feature is the conclusion teachers made during the seminars that they learned without mobile applications at all due to their absence or the primitive level of development at the time of their studies. It was more responsible and complex training with the need to study the features of a project being executed (without virtual reality or the ability to find information on the Internet). The use of digital technologies reduces the possibility of making mistakes, simplifies the solution of tasks, expands learning opportunities, and accelerates the assimilation of the educational content. That is, on the one hand, applications help students, but on the other hand, they somewhat relax them.

Distance and blended learning require certain conditions to ensure the quality of education. Based on the results of teacher surveys, it can be concluded that educational applications provide numerous opportunities for learning, which is confirmed by the data obtained by Ahmed et al. (2021), Jones et al. (2013), Lindsay (2016), Olszewski and Crompton (2020). However, these apps should not completely replace the ability to actually complete tasks, as argued by Jacinto and Carreira (2021). The results of the conducted survey confirm that the so-called “forced” turn to distance learning should be in harmony with the traditional needs of students (e.g., live sintering, doing exercises by hand).

In the predominance of cases, teachers consider the use of mobile applications in STEM education as an additional tool, which is proven by the data revealed by Jawad et al. (2021), Wahyuningsih et al. (2021). Modern conditions require the development of new applications that can be used in online learning. Though, there are many requirements for such applications (De & Arguello, 2020; De, 2020). The results of a survey of Russian students and educators support these inferences as creating new mobile apps that would be more implemented in the educational process is able to raise the effectiveness of their use in this direction. Despite the fact that almost all mobile applications are available in the USA, Europe, and other states, they are not available in full in Russia.

In the context of distance, blended or traditional learning, many criteria can be used to assess the effectiveness of a mobile application. These are the compliance with the curriculum, the ability to complete tasks without a smartphone, the need to reduce screen time to study each topic (it is necessary to structure and present the material in a way reducing the screen time), as well as the ability to download other applications for solving local problems (visualization, study and calculation of formulas) (Vázquez-Cano, 2014; Zhang et al., 2015).

The current study is largely in line with the research by Jacinto and Carreira (2021), showing that STEM tasks should be completed in the app and on paper to promote learning success. Solving problems in this fashion contributes to better understanding of the problem and a variety of ways to solve it, as well as activates students' thinking. Teachers agree that to develop a good STEM application, there is a need for teamwork (Sachmpazidi et al., 2021), good content visualization (Yildirim et al., 2020), and compliance with the educational standards (Rivera et al., 2018).

The experiment results are also consistent with data obtained by Karahan et al. (2021) and Reinholz et al. (2021), demonstrating that the success of learning using a mobile application depends on educators. In our fast-changing world, they must constantly keep abreast of new developments in the field of mobile applications, trends in STEM learning, and teaching standards (Jackson et al., 2021).

The survey results confirm the findings of Christian et al. (2021) and Rabin et al. (2021) that it is necessary to monitor the impact of mobile learning on student achievement, motivation to learn, knowledge checked without the use of a smartphone, as well as the ability of learners to design or complete tasks on their own.

The intention to develop a good application should always go in line with students' opinions collection. The evidence from practice shows that direct learners' involvement in application development may well increase their motivation and confidence (Tseng et al., 2018), as well as promote employment in the STEM field (Luo et al., 2021; Nethi & De, 2019).

Implementation of a mobile application for studying STEM disciplines faces numerous challenges these days. These encompass difficulties associated with the assessment of the degree of assimilation of the learning material and mechanisms for solving problems without the help of applications and many others. The introduction of distance learning models based on a mobile application (or applications) may be accompanied by problems related to content perception (Jacinto & Carreira, 2021; Nithia et al., 2016), failure to complete tasks (Ahmed et al., 2021; Tseng et al., 2018), excessive use of technology, and inability to complete tasks independently or find solutions to problems outside of the digital space.

The analysis of the experience of Turkey, New Zealand, the USA, and China enables the conclusion that before the pandemic, mobile applications were assessed according to the criteria of learning effectiveness, the introduction of technologies for better visibility or design possibilities, the availability of opportunities for communication with the teacher, and apps' design and technical characteristics (phone performance while the application is running, battery power). Today, in the context of the forced transition to distance learning, the effectiveness of an educational application is assessed in terms of its usefulness for knowledge acquisition, the implementation of projects excluding the attendance of classes but preserving the education quality, and the presence/absence of a detrimental effect on student thinking and memorization.

Research Limitations

This research analyzes a subset of applications due to the approach based on the selection of the most widely available applications, excluding those developed for individual educational institutions and those designed by teachers, students, or enthusiasts. Two other sources of possible error are that the study involved only two universities in Russia and that teacher and student responses were empirically summarized based on the general opinion of the respondents during discussions at seminars and meetings.

CONCLUSION

In order to determine the preferences of students and educators in relation to the mobile application (s) that can be used as an auxiliary tool in online or blended learning, this research turned to the method of survey. As a result of the discussion and general conclusion, some features were revealed. Thus, teachers consider it necessary to develop an application that includes the training program being studied. In the context of distance learning, students study and submit assignments online. In the context of blended or traditional learning, the mobile application acts as an additional tool for repetition, self-control, and consolidation of skills.

The vast majority of respondents (86.17%) reported well on the accessibility of the educational material offered in mobile applications, which suggests the great potential for their large-scale use. However, on the other hand, almost all students and teachers (98%) found the ability to store learning traditions (writing some papers by hand) quite important. While doing that, they also mentioned the potential of developing alternatives available in today's digital environment (design, drawing, checking, or performing calculations in a mobile app) but provided that the student has already submitted the assignment in a physical format.

According to students, the important characteristics of a mobile application are accessibility, the ability to review the material, teacher control, and the ability to choose a method for completing assignments.

Distance and blended learning via a mobile app have advantages and disadvantages. A focus on combining benefits and minimizing weaknesses is the key to the successful development, implementation, and use of a mobile app in STEM education.

The impact of Covid-19 on the requirements for mobile applications is complemented by the need to study online for a long time and use apps as a full-fledged learning tool rather than an aid. In this connection, demands to the content update, the ability to complete assignments, learning process completeness, as well as the ability to communicate with teachers and other students in the application are increasing.

The data obtained demonstrate the requirements for optimizing mobile applications for studying STEM disciplines, as well as additional programs and applications allowing students from various countries to get involved in design activities and work as a team.

Prospects for further studies. Prospects for further studies include additional research on the effectiveness of mobile applications for students of different ages, developing educational programs seeking to minimize screen time, the ability to complete tasks and projects on paper and with the use of devices, and creating mobile learning programs involving printed textbooks, magazines, notebooks, and other materials.

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