Principles and tools of designing effective e-simulators for primary school students

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Abstract. This paper examines the use of e-simulators as an effective tool for developing study skills in young learners in primary school. The advantages of e-simulators are discussed, including providing variable and unique tasks, immediate assessment, adjustable difficulty, and elements of competition and gaming. The paper outlines fundamental principles for designing effective educational e-simulators, such as generating interest, providing visual appeal and positive emotional background, encouraging critical thinking, allowing learner control, utilising personal devices, providing assistance and verifying results. Examples of e-simulators created by teachers-in-training using standard software tools like Microsoft Office and specialised design environments are provided. The capabilities of well-designed e-simulators can help ensure successful knowledge and skill acquisition by primary school students. Teachers can use the design principles and tools discussed to create customised e-simulators tailored to the needs of their students and lessons.

Keywords: e-simulators · primary education · study skills · educational technology · instructional design · teacher training · interactive learning · student engagement · digital learning tools · teaching aids

1 Introduction

1.1 Problem statement

The education system in Ukraine faces significant challenges due to the ongoing war and the lasting impacts of the COVID-19 pandemic. The war has disrupted schooling for many children, damaging school infrastructure, displacing students and teachers, and shifting to remote learning in many areas [22]. This has exacerbated issues such as the digital divide and unequal access to quality education. Quarantine restrictions during the pandemic had already forced schools to adopt distance learning on an unprecedented scale, revealing a need for new approaches to teaching with limited face-to-face instruction [4].

In this context, the widespread introduction of e-learning tools and fundamental changes to the organisation of education have become urgent priorities. The transition to distance learning has been particularly challenging for primary school students in the early stages of developing learning habits and study skills. Young learners require special attention and support to adapt to new learning modes and stay engaged and motivated [4].

The problem is particularly acute in areas directly affected by the war, where schools have been damaged or destroyed, students and teachers have been displaced, and access to technology and internet connectivity is limited. In these situations, providing continuity of learning and maintaining the quality of education is extremely difficult [24]. Innovative solutions are needed to reach and support young learners, many of whom are coping with trauma and disruption to their daily lives.

Even in areas less directly impacted by the war, the shift to distance and blended learning models has highlighted the need for effective digital tools and pedagogical approaches tailored to the needs of primary school students. Teachers require support to design and deliver engaging online learning experiences that foster the development of essential study skills.

The teacher's main task within the distance form of organisation of young learners' education is the methodical design of the educational process as a sequence of actions and experiences that students master. In some recommendations [4] it is proposed to plan the remote work of students as a cyclical sequence of different activities (including submission of new information, training, practical exercises, etc.), and the forms of interaction should be selected depending on tasks, time and technical capabilities. However, regardless of the form of activity, the level of readiness for practical online activities among primary school students is lower than among secondary school students. There are several reasons for this. Let us cover them.

One group of reasons is related to objective factors – age. Thus, the processes of restructuring mental activity, transitioning from visual to verbal-logical thinking, and changing figurative and conceptual, concrete and abstract components just begin at primary school. In this perspective, practical online activities at a particular stage of learning should be feasible for each student. In addition, the distance form of organising the education of primary school students involves the complication of the information context, the active inclusion of the child in a specific information environment, where any material is a piece of certain interactive information (graphic, textual, associative, video information, etc.). At the same time, due to the individual way of perceiving reality, primary school students have different degrees of readiness to perceive such information online. We can also identify the following reasons:

– limited, and sometimes no experience in the use of distance learning technologies (for example, experience with virtual boards and placing completed tasks on them, etc.);

- limited experience of self-establishment by the student of mobile communication or adjustment of separate parameters of a network and, as a result, a delay in access to e-resources in real time;
- time limits must be observed when organising lessons using distance learning technologies. Such restrictions in the organisation of practical activities narrow the range of practical skills of students because some students require additional time, for example, for reflection, reasoning or, in case of difficulties, require an immediate response from the teacher, etc.;
- untimely correction when students perform practical tasks within distance learning (due to, for example, class size or technical malfunctions), which delays the student's transition to the next level.

The named reasons condition the need for new approaches to implementing information and communications technologies in teaching young learners. Primary school is focused on developing subject knowledge and general study skills, such as writing, reading, doing sums, spelling, and others, assured command of which is a prerequisite for further successful studying at school.

Achieving success in building subject and general study skills is a natural need of every young learner. Each child comes to school to aspire to be successful and gain recognition for personal achievements. For a young learner, the expectations of success are connected with the efforts to gain recognition on the part of people important to him/her – parents, teachers, principal, classmates – and get approval from them. Experiencing success by young learners affects the quality of education, the development of the inner child's world, and the formation of self-confidence.

As we know, success is a feeling of joy and satisfaction because the result, which the personality was striving for in his work, either matches his expectations and hopes or exceeds them. Success is always connected with actions, and it is not an end. This results from achieving the desired goal, being accepted, recognised and meaningful to a child, and experiencing joy after overcoming difficulties. Achievement provides for getting a specific result, and recognition can be public, local or individual [21]. Success supports a child's interest in learning, encourages him/her to overcome difficulties, and urges to achieve new goals.

One of the modern ways of forming general study and subject skills by primary students is e-simulators, which are educational software designed to shape and consolidate practical skills after preliminary mastering of theoretical data by young learners.

1.2 Recent work

The literature also holds many studies related to the positive effects of the educational use of information and communication technology (ICT) in general [23] and cloud technology, in particular [10, 16]; instructional design principles, their interrelationships, the overall process of designing effective teaching with ICT [7], engineering design thinking, teaching and learning with ICT [9].

Some issues about primary learning were discussed such as developing technological pedagogical content knowledge in pre-service science teachers [5, 17]; using ICT in primary school curriculum [1]; e-learning for primary teachers [3, 14], using ICT in distance learning [20].

We wrote some articles concerning such a significant investment in the theory as the didactic potential of digital educational resources for young learners [6, 19]; and in practice as the use of GeoGebra in primary students training [18].

1.3 Methods

This research uses both theoretical and empirical methods. Theoretical methods (analysis and synthesis) analyse the opportunities, advantages, and disadvantages of e-simulators as a new means of organising the practical activities of young learners at primary school.

Empirical methods employed in this study include:

- systematic observation of primary school students engaging with e-simulators was conducted to gather qualitative data on their interactions, behaviours, and learning processes;
- pre- and post-tests were administered to assess students' knowledge and skill acquisition before and after using e-simulators for measuring the effectiveness of the e-simulators;
- a controlled experiment was set up with experimental and control groups of primary school students;
- surveys were conducted with teachers and students to gather feedback on their experiences and perceptions of using e-simulators;
- semi-structured interviews with teachers provided more in-depth qualitative data on the benefits and challenges of implementing e-simulators in the classroom;
- student work samples and artefacts from their interactions with the e-simulators were collected and analysed: logs of student actions within the e-simulators, screenshots and screen recordings of their work, and worksheets used alongside the digital tools.

The quantitative data from pre- and post-tests and the pedagogical experiment were analysed using appropriate statistical methods to determine the significance of the results. Qualitative data from observations, surveys, interviews, and artefact analysis were examined using thematic content analysis to identify key patterns and insights.

2 Results

2.1 Interactive teaching tools in ensuring the success of young learners in practical activities

Many e-simulators have been developed to educate young learners, facilitating the acquisition of skills in Math, ICT, native language, foreign language, etc.

However, e-simulators are relevant if they allow us to work out exactly what caused the difficulty in a particular lesson when the specifics of teaching material are considered, especially the perception of young learners.

Unlike traditional manuals, E-simulators provide real variability of interactive tasks and the uniqueness of exercises designed to form appropriate skills. In particular, for training young learners in performing calculations and sums, e-simulators can generate an unlimited number of numeric values for each task type, which allows for diversifying the learning objectives and avoiding memorising answers.

The advantage of using e-simulators during both traditional and distance learning of primary school students is to provide an opportunity to expand the possibility of presenting educational tasks aimed at primary school students – to present tasks in schematic, tabular form (figures 1, 2).

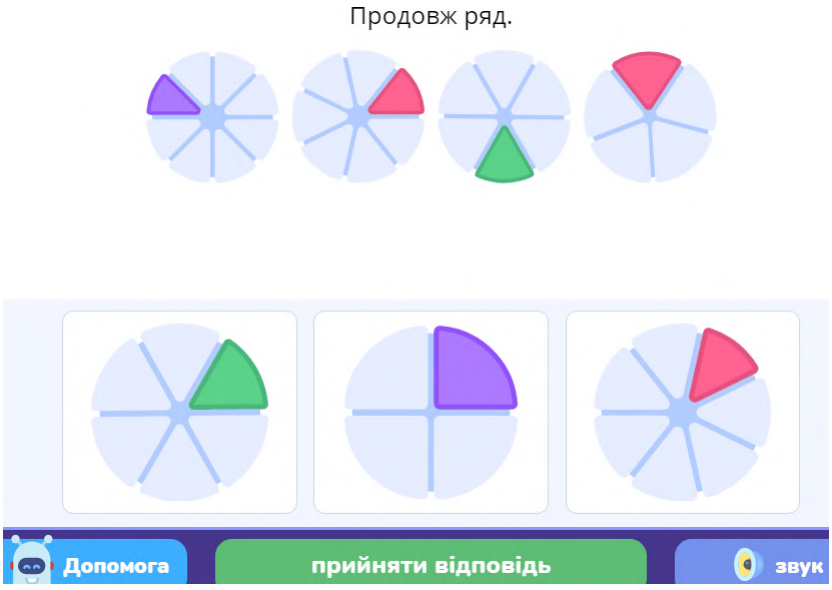

Fig. 1. The task of logical load "Logiclike".

An important feature is the adjustment of task difficulty (figure 3). The difficulty level can be preset and designated by a teacher or selected by a learner can have several ways of solving (each time, you can increase the level of complexity of tasks, offer solutions to examples that require guesswork, intelligence (figure 4), thereby stimulating the intellectual feelings of young students).

Some e-simulators that implement adaptive algorithms are of particular interest and, based on learners' performance of the first proposed tasks, automatically adjust the level of subsequent tasks. Such adaptive interactive e-simulators are helpful, especially in primary school, because the difference in learners' back-

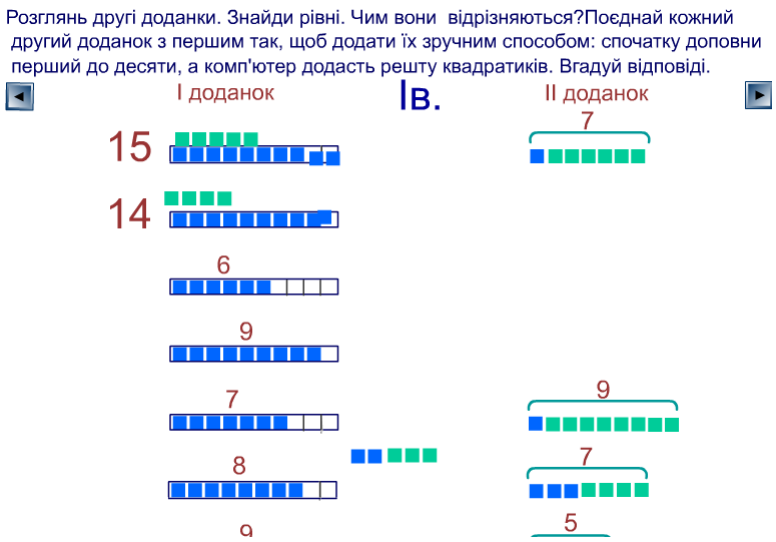

Fig. 2. Exercise for addition "Samouchka".

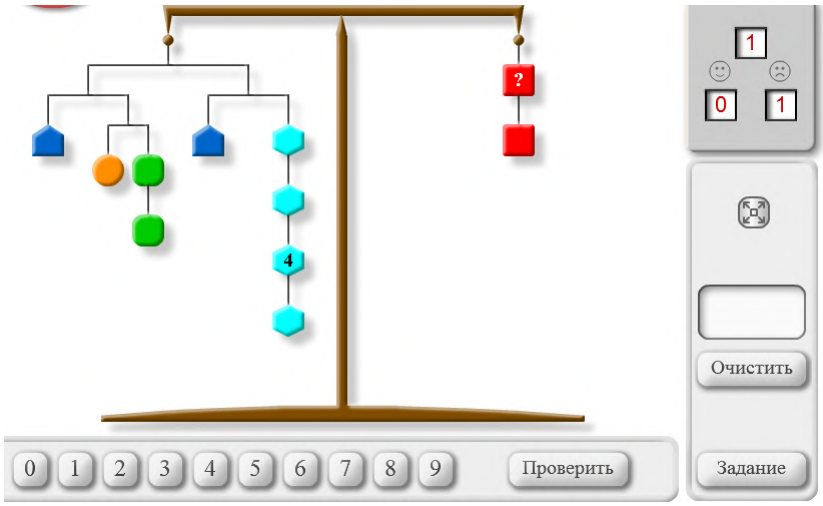

Fig. 3. Scheme in "Maths-and-games".

ground, in the level of their habits and skills is the most notable among children: in a class, some perform calculations efficiently, read quickly, etc., and those who are only acquainted with basic rules, learn to form syllables.

Automatic control of the difficulty level of tasks enables a teacher to identify gaps in learners' knowledge and eliminate them quickly. E-simulators allow learners with skills already formed at a high level to test their skills by doing

Fig. 4. The complex of educational games "Learn".

more challenging exercises. Thus, tasks for each learner are in the zone of their proximal development.

E-simulators feature the ability to provide a shade of competitiveness and gaming to the exercises. It is worth noting that games are not the main activity for primary school children, but they play a significant role in a child's life and educational activities. Playful learning requires substantial intellectualisation of primary school children's activities, such as the prompt realisation of tasks, analysis of possible solutions, and search for the optimal variant. Moreover, the game encourages learners to show initiative, develop activity, stimulate memory development, initiate thinking, and release emotions.

Using computers can help us realise the full extent of the benefits of playful learning. Exploring the specifics of computer games in education, there are the benefits as we know: increased learning motivation, encouragement of initiative and creative thinking, the inclusion of all learners into activities, the experience of cooperation and teamwork, the establishment of interdisciplinary connections, creation of an informal environment for learning, favourable conditions for different strategies formation for solving problems, etc.

The emotional appeal of computer games, competitive game aspect, and variety of events, exciting plot, realistic graphics, and ability to control characters by oneself can instigate learners to achieve only a gaming purpose. Therefore, an important prerequisite for using computer games in education is to provide conversion of a gaming purpose (to help the character, to win, to release someone, to get the prize) into achieving educational goals. For example, within the electronic simulator "PilasBloques", students are asked to compile software code

for a virtual hero, which will allow them to manage it (go a certain number of steps, say hello, etc. (figure 5).

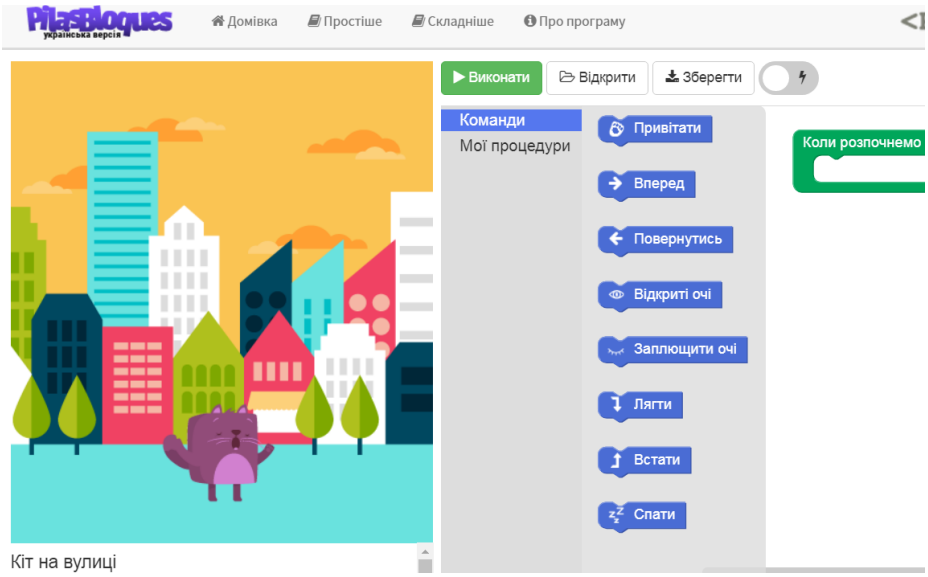

Fig. 5. E-simulator "PilasBloques".

Digital Mathematical Platform "Matific" contains simulators in Mathematics, focused on organising practical activities of students to add decimal fractions through visual models (figure 6), adding three-digit numbers and more. Playful presentation of a task, its dynamic nature, and the practical purpose (to colour a picture, collect garbage, feed the cat, etc.) turns routine work on developing skills into an exciting game that motivates learners to perform typical tasks. In addition, comparing the results of their work with those of other learners gives such activities as sports excitement and an incentive to improve the obtained results.

Among the advantages of using electronic simulators for the organisation of practical activities of young students during both traditional and distance learning, we also single out the provision of opportunities:

- to provide systematic practical work on solving by students a large number of similar tasks in a short time (figures 7, 8);
- providing an opportunity to organise the activities of each student on its own trajectory, depending on his skills, knowledge, and the need to deepen knowledge;
- providing timely assistance (which may be implicit, upon request, provided by the hero of the program, who accompanies and monitors the long delay in the exercise, etc.).

Fig. 6. E-simulator "Matific".

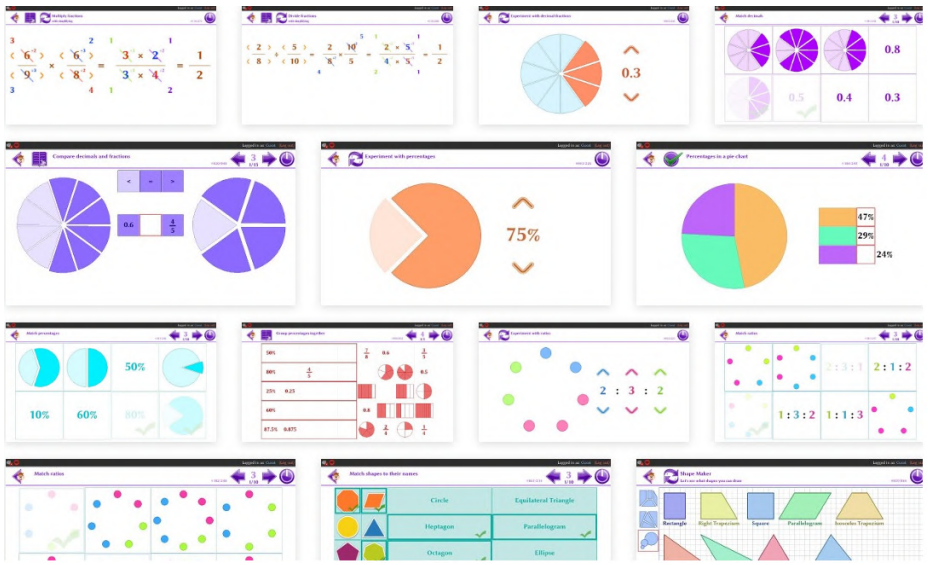

Fig. 7. Simulator "Educativ".

It should be noted that the peculiarity of using electronic simulators is the rapid assessment of student actions. Immediately after completing each task, the

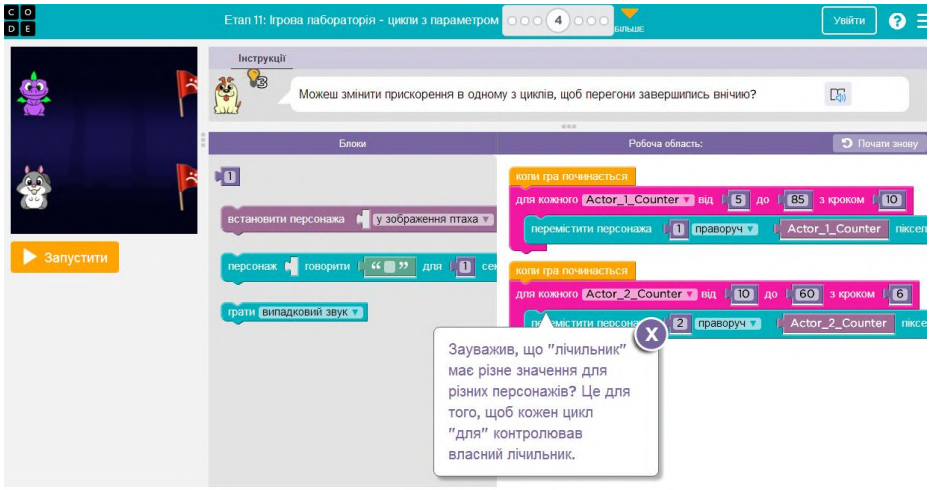

Fig. 8. Simulator "Code".

child may receive an appropriate reaction, indicating the solution's correctness (figure 9). Such an immediate reaction is essential when organising the practical activities of young students with electronic simulators because students expect approval for the successful completion of tasks or some kind of support in case of errors. The immediate reaction to the electronic resource will help increase students' confidence in their abilities.

There are some principles for building interactive authors' e-simulators. With the development of tools and the availability of information sources, a teacher-to-be can create interactive authors' e-simulators that take into account the specifics of training learners of a particular grade on a particular topic, their individual characteristics, and the hardware of the educational process. Authors' e-simulators can be directed to practice precisely the skills that cause difficulties for learners.

2.2 The principles of construction interactive authors' e-simulators

Based on the analysis of existing experience using e-simulators in primary education, we have identified the following principles of their construction to ensure the successful teaching of primary students.

The first principle to be considered in e-simulator design is the following: *developed e-simulators should generate learners' interest.*

The matter is that a child who works with an interactive model is unobtrusively involved in educational and cognitive activity. It is important to emphasise that a learner is involved in this activity not by direct teacher's instructions but by his desire to resolve the situation that occurred on a computer screen. Plot design of a training material encourages him/her to participate in educational activities. These actions require revealing subject knowledge and skills as

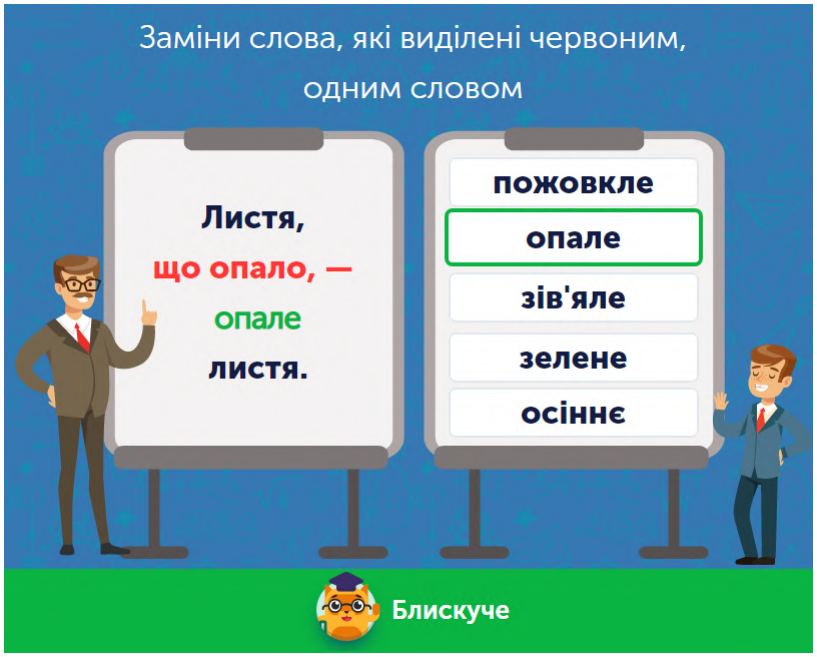

Fig. 9. Tasks for 4 grade students "Learning".

well as the ability to apply them to a new environment. The combination of training and practical purpose that is achievable and understandable for a child gradually transforms into a learning motive. The circumstance promotes such a transformation that when summarising the child's work with a didactic model, his attention is focused on the importance of the knowledge and skills that have helped to achieve a successful outcome [6].

Including real-life realities in the learning content is crucial in primary school. It implements the didactic principle of training and practice connection.

E-simulators must allow the learner to apply a learning task with all its attributes: for example, travelling cars, a chocolate bar being eaten, a pie being divided, etc. A learner can move the car, divide the chocolate bar, or cut the pie in different ways.

E-simulators allow the expansion of the diversity of training tasks, suggesting various solutions to the problem. So, a learner is assigned to solve the problem correctly and make a rational solution choice. The second principle to be considered in app design is the following: *e-simulators should be visually presented to create a pleasant emotional background.*

The child's emotions during classroom activity have a significant impact on it. The initiation of emotions in primary schoolchildren is usually associated with a particular situation. It might be a nice visual design, familiar objects or characters, or valid comments. All this calls up a learner's pleasant feelings.

The techniques also promote the development of positive emotions and aesthetic senses. They include a friendly interface of didactic, interactive models, harmoniously picked-up colours, and special techniques to attract and focus the learner's attention to develop his imagination, thinking, and memory. A positive emotional background of a child's learning with interactive models is also guaranteed by the possibility of cancelling his actions at any moment and returning to the previous step. A learner can feel free doing his trials at searching for the proper or effective task solving. He is not afraid of any negative consequences. It promotes the creation of a learner's positive emotions, forming his persistence and confidence. The third principle to be considered in e-simulator design is the following: *problem definition should involve learners in critical analysis of input data as for their adequacy, redundancy, actuality.*

For this purpose, the developed e-simulators have redundant information, so a child could choose what he/she needs – for example, additional measurements, additional data, etc. The fourth principle to be considered in app design is the following: *e-simulators should allow learners to operate free, for example, to perform transformations of geometric solids (rotate, drag, resize them).*

The peculiarity of young learners' perception is its close connection with action. For schoolchildren, especially at the age of 6–7, to perceive the subject means to do something with it, for instance, to touch, rotate, and change. Practical actions play a significant role in the development of children's cognitive processes. Therefore, e-simulators should allow manipulation with learning objects.

E-simulators focused on learners' research activities should provide the possibility of figure transformations, such as rotating geometric shapes and overlapping some shapes on others for comparing and resizing. Making changes with shapes meets a child's need to experiment. At the same time, it allows the child to see the results of his activities and to make his/her own conclusions.

The fifth principle is the *principle of reliance on pedagogical and research tools of personal IT devices* means the recognition of the power of modern personal IT devices and their feasibility of use in the learning process as effective and affordable tools of educational and research activities. Note that this principle is one of the main reasons for the further organisation of the practical activities of primary students with e-simulators because smartphones and tablets have become an integral part of modern children's lives. The implementation of the principle involves using educational mobile applications, through which the teacher can organise independent practical activities outside the school. A powerful database of e-simulators has been developed, some of which are available on mobile applications. Such mobile simulators provide a real opportunity to organise a multi-level (individual) approach within the lesson and during the organisation of distance learning, provide instant verification of the correctness of the tasks, provide opportunities to organise the practical activities of each student on their trajectory, depending on his skills, knowledge, the need to deepen knowledge. For example, the applications "Lightbot: Code Hour" (from SpriteBox LLC) and Programming for children (from IDZ Digital) are focused

on supporting the topic “Performers of algorithms and their command systems” (figures 10, 11).

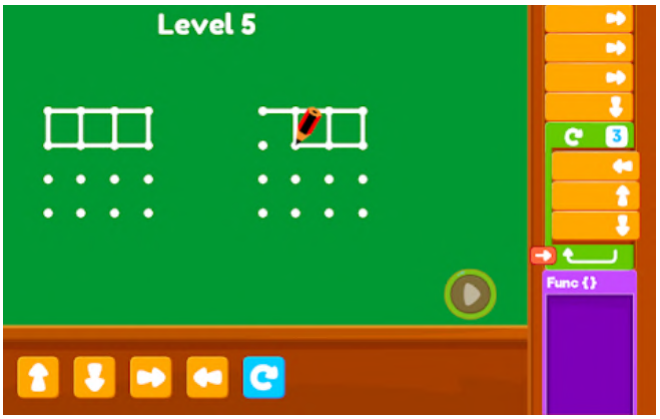

Fig. 10. The complex of educational IT devices’ games “Programming for children”.

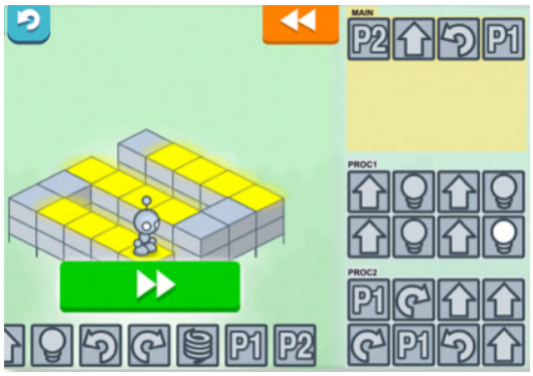

Fig. 11. The complex of educational IT devices’ games “Lightbot: Code Hour”.

It should be noted that the practice of students’ knowledge gained in class is a normal process. At the same time, the organisation of practice and consolidation of knowledge sometimes lose their didactic value due to the formality of this type of work and the uniformity of educational exercises. That is why the advantage of using in educational practice such educational applications as “Lightbot: Code Hour”, “Programming for Children” allows students to practice learning methods in a variety of game learning tasks, attractive, expressive forms of presentation of the material, availability of various forms of encouragement and provision of

timely assistance to educational institutions, which provides an activity approach of students to the acquisition and consolidation of knowledge.

Some additional principles to be taken into consideration in interactive model design are: developed e-simulators should provide support (step-by-step assistance) for learners' activities to achieve success and completeness in tasks performed; developed e-simulators should provide an opportunity to verify the correctness of the obtained result.

On the one hand, to succeed in learning, a child needs to have an opportunity to achieve his intended result. Timely assistance is crucial for learners who have just started learning. Developed e-simulators contain elements that provide the necessary support for a learner. Every child who works with the model can get help in time. A child can get help after his request through textual commentary, additional constructions, and solutions. The system of multi-level assistance in e-simulators focuses on each child's achievement of the result.

On the other hand, training should be accompanied by overcoming difficulties feasible for a learner. Depriving a learner of difficulties, we deny him the feeling of joy and pleasure of success gained through his/her own efforts. Difficulties in the learning process are essential to meet learners' cognitive activity needs. Therefore, the learner's assistance with difficulties should be dosed, not excessively, but sufficient to support his efforts and be aimed at helping him/her overcome obstacles himself/herself. Learners in their learning activities should not act on a pattern and algorithm and retain the right to initiative, possible errors and their correction. A learner should be relaxed in his actions. The experience in this activity is now appreciated more than well-learned rules in solving typical tasks, as this experience teaches a learner how to acquire knowledge.

Taking dosage help for learners in e-simulators is a complex task and is currently being implemented relatively rarely, but this assistance will help develop initiatives to identify creative abilities, creating a strong-willed child. Successful and progressing schoolchildren can employ the maximum available to overcome difficulty-level tasks for schoolchildren.

2.3 Interactive tools for construction authors' e-simulators by primary teachers-to-be

We want to show the essential tools for constructing interactive authors' e-simulators. A teacher-to-be can create e-simulators independently and use modern toolkits to create interactive exercises and didactic computer games. The interface of many tool kits, oriented to the design author's didactic resources, is simplified and intuitive for an average user and does not require additional training. In addition, as a rule, these tools include a set of templates for rapid development and offer the available examples.

To develop e-simulators, a teacher-to-be can create presentations using programs that are part of an integrated Microsoft Office package, as well as spreadsheets and applications.

The choice of these applications is due to several reasons:

– wide spread of Microsoft Office package among different specialists;
– preparedness of teachers-to-be to use office technology in teaching;
– presence of large collections of teaching resources developed by teachers for their educational activities. Ready didactic resources are available to teachers and can be adapted to the conditions of a particular grade and lesson;
– teachers' experience of usage software package for the preparation of teaching and learning materials, documents, etc.;
– possibilities to integrate various forms of information in e-simulators, so slides or books may contain the author's drawings prepared in appropriate graphics software, sounds prepared in music editors, and text fragments.

There are examples of authors' e-simulators. Electronic simulators developed by our students from H. S. Skovoroda Kharkiv National Pedagogical University, teachers-to-be for young learners for primary school to teach Maths in Microsoft Excel spreadsheets are presented in the form of tests, didactic games, crossword puzzles (figures 12-14).

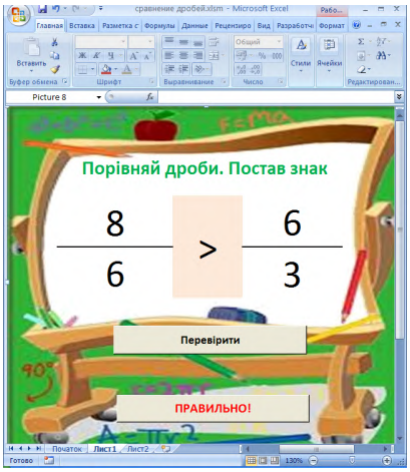

Fig. 12. E-simulator for learning fractions developed in Microsoft Excel.

Such capabilities provide convenience to create training systems in Microsoft Excel:

– data exchange between applications, which facilitates the process of preparing the environment for e-simulators and enables the provide an attractive appearance;
– modifications and additions to the tasks when they are needed;
– programmable generation of numerical values in the text of tasks and answers. This prevents learners from memorising the answers and provides variation of the tasks.

Fig. 13. E-simulators for learning analogue clocks.

Fig. 14. E-simulators for learning multiplication tables.

- simplification of the analysis of the assignment correctness by the relevant functions;
- presentation of the test results in the form of tables, charts, graphics, etc.;
- storage of test results and the ability to further analysis;
- availability of templates to create tests available to teachers-to-be at any time.

The advantage of using presentation software to develop automated tests is the possibility of their attractive design, providing a soundtrack, and the ability to support each task or question with a desired scheme or pattern. In addition, the PowerPoint environment allows the construction of matching tasks, where the correspondence between the elements of two sets is defined, the tasks of ordering the sequence of actions.

Of particular convenience for a teacher-to-be is the access to ready-made templates that have a programmed tasks check. In the environment of Microsoft PowerPoint presentation, the electronic simulators developed by our students are presented (figures 14, 15). The e-simulators include controls designed to automatically create tasks for learners and elements that analyse user actions.

However, developing electronic simulators in these packages requires knowledge of the programming language Visual Basic for Application, which is a painstaking task for a teacher-to-be. To create e-simulators, primary school teachers-to-be can use designing environments that include a substantial set of templates and patterns associated with school material. In particular, such app designers can be useful for a teacher-to-be. They are the designers: Classtools.net, Rebus1.com, Zondle, Learningapps.org, Studystack, and others.

Within the environment "Classtools.net" (https://www.classtools.net/) a teacher-to-be can develop interactive posters, charts, diagrams, computer educational games to support any school subject such as Maths, Science, Reading and more. The environment is an online resource that offers a set of templates for creating teaching tools. In particular, it enables the create computer games such as quizzes in the form of arcade games (search for pairs of questions and answers, hitting the target with the answer), creates tasks related to the grouping of elements, allows the create interactive posters in which an explaining text is shown when you hover your mouse on a specific part of the image. A special convenience for teachers-to-be is that developed e-simulators can be stored on servers for the organisation of joint work of learners, on local computers for future use in the classroom, or printed out.

An exciting experience is the work of young students with puzzles. For example, the Ukrainian-language puzzle generator "Rebus1.com" (https://rebus1.com/ua/) allows the teacher to generate any puzzle on a specific request (word, phrase). Within the environment, one can create unique puzzles for the first-second grade students, using fairy-tale and cartoon characters (figure 15).

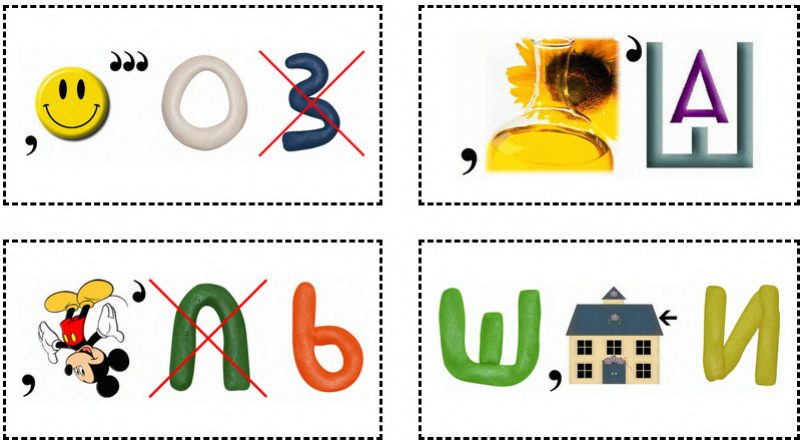

Fig. 15. The complex of educational games "Rebus1".

Even though puzzle tasks contain images that are easy for students to understand, their interpretation requires several mental actions: to determine the

primary/secondary information, to explain the meaning of the word (text fragment), to establish cause-and-effect relationships, to establish an algorithm, provide a description of the object, explain the purpose of the object (process), draw conclusions, etc. The advantage of using computer puzzles is that independence in such work is achieved due to the instantaneous reaction of the software to the actions of the student. If students have some difficulties, the program provides additional guidance. The correct solution to tasks is accompanied by various forms of encouragement, such as appropriate musical accompaniment and appropriate gestures from the program's main characters. Promptly and timely individualised assistance and various forms of encouragement stimulate them to solve problems of higher complexity, causing the student to have a positive attitude toward independent practical activities.

The didactic game's designer "Zondle" (https://www.zondle.com) allows a teacher-to-be to create e-simulators for any subject. The designer offers template games to fill in with the subject content. In this case, a teacher-to-be needs only to prepare assignments and choose a template for the offered. The designer offers to use certain types of tasks, among them the tasks that include:

- select the correct answer from the offered;
- enter the correct answer from the keyboard;
- confirms the correctness of a statement;
- insert missing words into the statement and others.

The environment also provides the option to develop the game plot, choose the characters, and complete substantive tasks by oneself. Creating author's games does not require programming and additional training. The educational games developed are stored in a network that allows learners to use them in extracurricular activities.

The designer of interactive exercises "LearningApps.org" [2, 12, 13] (https://learningapps.org) allows you to create training exercises that require practical actions from user: to place in the correct order, to choose the correct answer, to solve a crossword puzzle, to solve puzzles, to group etc. Many templates are offered to a teacher-to-be, as well as a set of ready-made interactive exercises that can be used as templates (figure 16). They help create didactic exercises appropriate for a particular grade in studying a particular topic. Ready projects can be stored on a local storage or network. In figure 17 shows some examples of interactive exercises developed by our students.

The designer of education games "Studystack" (https://www.studystack.com) allows not only the creation of interactive exercises using the set of templates but also offers practical tasks already available from a variety of subjects: Mathematics, ICT, Nature, Art, History, etc. Projects are stored on the server, which allows us to use them both at the school and as home training. The designer has been working since 2001 and has accumulated a significant amount of ready interactive exercises for children from preschool to high school. The advantage of using this designer is the ease of preparation of training exercises: a teacher-to-be simply enters tasks text and correct answers, on which base different versions

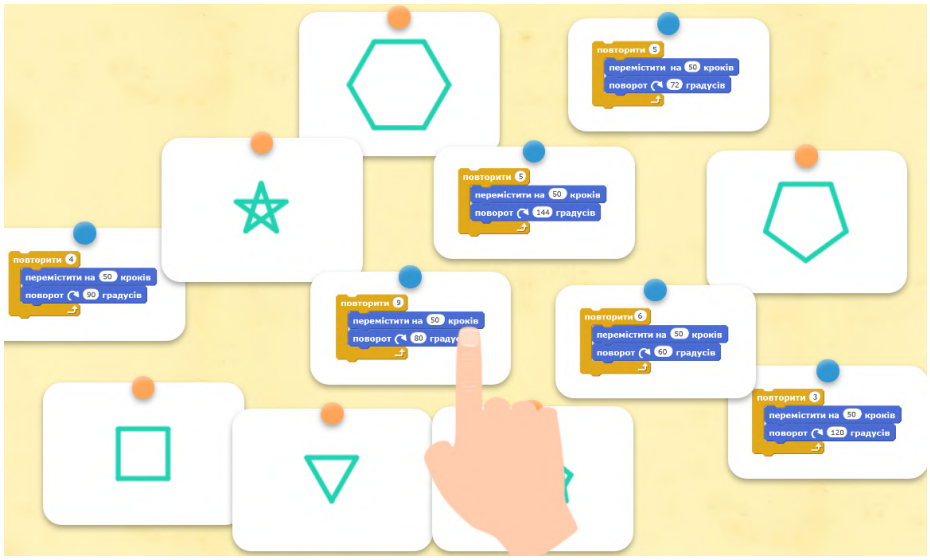

Fig. 16. Examples of interactive exercises "Algorithms with cycles".

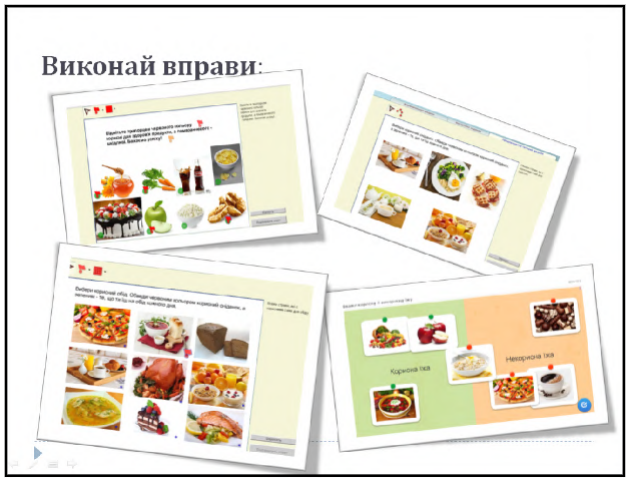

Fig. 17. Examples of interactive exercises created in the LearningApps environment.

of interactive exercises are created automatically, such as quizzes, crosswords, hit-on-target games, hangman games, etc.

To create e-simulators a teacher-to-be can also use an environment "GeoGebra" (https://www.geogebra.org). It is trendy nowadays [8, 11, 15]. Some examples of e-simulators developed by our students for young learners on GeoGebra are shown in figures 18, 19.

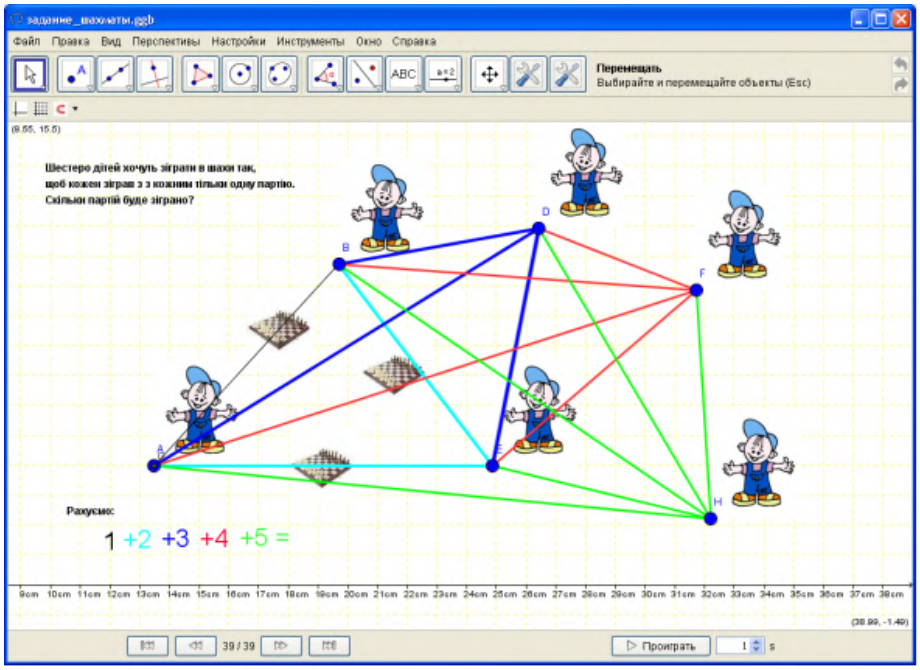

Fig. 18. E-simulator for task about chess: Six children want to play chess so that everyone plays with each player once. Find how many parties will be played.

All e-simulators were developed by teachers-to-be for primary school during their studies at H. S. Skovoroda Kharkiv National Pedagogical University. The e-simulators in the figures are original and tested by the students during teaching practice. They are always available for primary school teachers. We think that the experience of developing these e-simulators will be useful for teachers-to-be and teachers in their professional activities.

3 Discussion

Many scholars confirm the main results of the effectiveness of e-simulators, namely:

- instead of being knowledge-focused, e-simulators are built around the skills [5] necessary to carry out specified tasks in primary school; the focus is on what young learners can do at lessons rather than on what they know;
- young learners are expected to demonstrate practice-added skills, which are assessed by looking at outcomes of e-simulators rather than process [1];
- young learners' performance is evaluated during the instructional process against common learning standards [1, 5], and all assessment forms are standards-based and criterion-referenced [3]. After all, teachers-to-be will

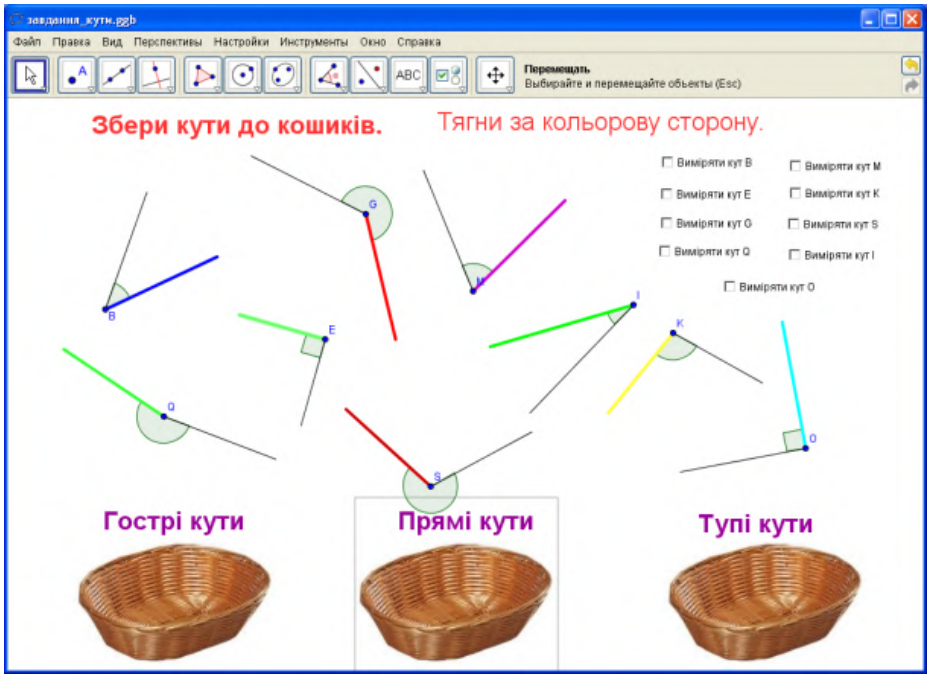

Fig. 19. E-simulators for tasks about angles. Children collect right, obtuse and acute angles into baskets.

be able to deliberately choose the most effective direction in learning young learners with e-simulators.

4 Conclusions

This study demonstrates that e-simulators are a powerful tool for developing study skills and enhancing learning outcomes among primary-education learners. The use of well-designed e-simulators can provide numerous benefits, including:

- variability and uniqueness of tasks, which helps maintain student engagement and caters to different learning needs and styles;
- immediate feedback and assessment, allowing students to track their progress and adjust their learning strategies;
- adjustable difficulty levels, ensuring that tasks are appropriately challenging for each learner;
- gamification elements, such as competition and rewards, which can boost motivation and make learning more enjoyable.

The principles for designing effective e-simulators outlined in this paper provide a framework for teachers and educational technologists to create digital

learning tools that are tailored to the needs of their students. These principles include generating interest, providing visual appeal, encouraging critical thinking, allowing learner control, utilising personal devices, providing assistance, and verifying results.

A key finding of this study is that e-simulators can be created using widely available software tools, such as Microsoft Office applications, as well as specialised design environments. This means that teachers have the power to develop their own customised e-simulators that are specifically aligned with their lesson objectives and their students' characteristics.

The empirical evidence gathered through this research, including data from observations, tests, experiments, surveys, and artefact analysis, supports the effectiveness of e-simulators in primary education. The results suggest that integrating e-simulators into classroom practice can lead to significant improvements in students' knowledge acquisition and skill development.

The findings of this study are particularly relevant in the context of the challenges facing the Ukrainian education system due to the war and the pandemic. E-simulators can play a crucial role in providing continuity of learning and support for skill development during periods of disruption and distance learning. They can help mitigate the negative impacts of the crisis on young learners' education and development.

However, it is essential to recognise that e-simulators are not a panacea and should be used in combination with other pedagogical strategies and resources. Teachers require ongoing training and support to integrate e-simulators effectively into their practice and adapt their use to the evolving needs of their students.

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