

Integrated use LearningApps.org and information devices in secondary school Biology teaching

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Abstract. This paper explores using the LearningApps.org online resource and information devices such as computers, interactive whiteboards, tablets, smartphones, and websites in teaching Biology in secondary school. An experimental methodology involving LearningApps.org exercises, smartphone apps, interactive whiteboards, and websites was developed and tested. The methodology aims to increase the effectiveness of biology education by leveraging educational technology. Experiments conducted in secondary schools demonstrated increased learning outcomes in plant morphology, anatomy, physiology and systematics topics. The use of multimedia and interactive exercises facilitated the learning process. Results highlight the benefits of integrating online learning tools with traditional classroom teaching. The methodology provides a model for modernising biology instruction through technology.

Keywords: biology education, secondary school, LearningApps.org, online learning, mobile learning, educational technology

1. Introduction

The contemporary information society's specificity has brought about significant changes in human lifestyles, leading to profound transformations in the educational system. This shift towards a qualitatively new state necessitates optimising and managing interaction mechanisms among all stakeholders in the learning environment. Notably, the educational landscape now involves multi-vector information flows, requiring consideration in the learning process. The traditional subject-subjective educational paradigm is being replaced by a polysubjective one [21], where all participants in the educational process interact as active, mutually influential contributors. This interaction extends to modern information technologies (IT), social networks, and Internet services, giving rise to a new educational, communicative paradigm centred around polysubjective learning environments.

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The challenges posed by the COVID-19 pandemic have compelled biology teachers to reevaluate the technical capabilities of information technologies in distance learning [27]. Leveraging online resources like LearningApps.org [10] has proven advantageous, allowing the integration of tasks into distance learning systems and facilitating self-directed learning for students. This approach enables diverse remote tasks related to biological content and streamlines the assessment process for teachers.

Modern information technologies, including various social networks, offer extensive opportunities for student development. The interactivity, immersion, and collaborative learning facilitated by these technologies make them effective tools for education. The relevance of IT use in the Biology school course aligns with the bio(eco)centric concept, recognising the life of any organism as the highest value.

In Ukraine, the secondary school Biology curriculum aims to cultivate ten key competencies [18], including information and digital competence and competencies in natural sciences and technologies. Integrating modern information devices such as computers, interactive whiteboards, multimedia projectors, tablets, smartphones, and Google Chromecast adapters into the educational process is essential for fostering these competencies.

Numerous studies [5, 14–17, 22] have explored the possibilities of using computers in Biology teaching. They emphasise the necessity of leveraging technology to enhance lessons' effectiveness and the learning process's efficiency. Additionally, mobile learning has been studied theoretically [1, 4, 6–9, 11, 13, 15, 19, 20, 24, 26], and the methodology of website use in Biology teaching has been explored [23]. Despite this, there needs to be more literature regarding the practical application of the LearningApps.org online resource with information devices in educational studies in biology.

This paper addresses this gap by outlining the possibilities and appropriateness of using the LearningApps.org online resource in the Biology school course with the application of information devices. The objective is achieved through tasks that include clarifying the current state of the problem at pedagogical and student levels and developing a methodology for using LearningApps.org in the educational process, substantiating its effectiveness through experimental testing in a secondary school.

2. Research methods

To achieve the abovementioned objective and tasks, several methods have been used, namely: theoretical – comparative analysis to find out different views on the problem and identify areas of study; modelling to develop a methodology for using the LearningApps.org online resource in the process of Biology school course studying with the application of information devices; systematisation and generalisation to formulate conclusions and recommendations for improving the educational process in biology; empirical – generalisation of pedagogical experience, scientific observation, interviews, content analysis, questionnaires in order to determine the state of implementation of the problem in practice and to develop the content of experimental teaching methodology; pedagogical experiment, which verified the effectiveness of the proposed methodology.

Experimental research has been conducted based on Ternopil general secondary schools

No. 24, 26, 28, Terebovlia general secondary school No. 1 (Ternopil region) and Sumy general secondary schools. The summative experiment involved 528 students, 212 biology teachers, and 68 future biology teachers who are now students of the second (master's) level of higher education at Ternopil Volodymyr Hnatiuk National Pedagogical University and Sumy State Pedagogical University named after A. S. Makarenko. Forming experiment lasted for two years in 6th grades in the process of Biology school course studying. 1006 students participated in it.

The effectiveness of the proposed methodology was checked during the forming experiment.

The goal of the forming experiment was to test the effectiveness of the developed methodology of using the LearningApps.org online resource in combination with information devices. We concluded the quality of the experimental methodology according to the criterion "coefficient of completeness of knowledge acquisition" (A. A. Kyverialg's method). It was determined using formula (1) [12]:

$$K = \frac{\sum I_0}{n \cdot I_a} \cdot 100\%, \quad (1)$$

where K is the coefficient of completeness of knowledge acquisition;

n is the number of students who performed the work;

$\sum I_0$ is the sum of elements of knowledge acquired by each student;

I_a is the number of elements of knowledge communicated to each student.

According to the criteria of completeness of knowledge acquisition, developed by Bepalko [2], the educational material was considered to be acquired, and knowledge formed if the coefficient of knowledge acquisition was higher than 70%. It is believed that a student with such a coefficient of knowledge acquisition can further improve his knowledge through self-education.

The forming experiment was conducted in the conditions of a natural educational process of Biology studying in the 6th grade. It involved creating experimental (EG) and control groups (CG) of students. In EG, students absorbed botanical knowledge (anatomical, physiological, systematic, agronomic and ecological notions) in studying themes according to our experimental methodology of using the LearningApps.org online resource in combination with information devices. Experimental training was carried out during the study of Theme 3 "Plants" (approximately 20 hours) and Theme 4 "Plant diversity" (approximately 12 hours) [3]. Students in CG studied according to the traditional, dominant modern secondary school methodology of forming biological notions.

Thematic controls of the results of students' from control and experimental groups acquisition of elements of botanical knowledge (notions) – morphological, anatomical, physiological, systematic, agronomic and ecological were carried out in three stages: Stage I – after studying the themes "Root, stem: structure and basic functions. Variety and modifications of vegetative organs. Photosynthesis as a characteristic feature of plants, nutrition, respiration, plant movements"; Stage II – after studying the themes "Plant reproduction: sexual and asexual. Vegetative reproduction of plants. Flower. Inflorescence. Pollination. Fertilisation"; Stage III – after studying the themes "Algae. Mosses. Gymnosperms".

The choice of these themes is determined by the carried-out content analysis of their content and the results of the summative experiment. It proved that acquiring anatomical, physiological and systematic notions causes significant learning difficulties for schoolchildren.

After conducting each stage of thematic control, the mistakes made by students, their causes, and ways to adjust and improve the methodology were analysed.

3. Results and discussion

Aiming to study the state of the problem in Biology teaching, we surveyed 212 biology teachers and 528 students of the city schools in Sumy and Ternopil regions. We analysed how teachers train students to work with different sources of information. Thus, 43.87% (93 teachers) train students how to work with the catalogue, 73.58% (156 teachers) train how to work with the textbook orientation apparatus, 24.53% (52 teachers) form the ability to search the necessary information on the Internet.

198 teachers (93.40%) use the computer as a tool for Biology teaching, an interactive white-board Smart Board is used by 46 teachers (21.70%), 86 teachers (40.57%) use a multimedia projector, a tablet and a smartphone is used by 10 teachers (4.72%), and 8 teachers (3.77%) use Google Chromecast adapter. All 212 teachers (100%) use the computers to prepare the lessons. However, only 154 teachers (72.64%) give their students home tasks to search for additional information on the Internet, and 198 teachers (93.39%) offer students to prepare presentations in the form of a report on the performance of a specific task. There are the following reasons for the inadequate use of modern information devices by teachers in the educational process: insufficient level of their computer literacy – 104 teachers (49.06%); lack of material and technical as well as educational and methodological support for Biology school course teaching – 148 teachers (69.81%); the reluctance of teachers to study phenomena and processes of wildlife using a computer – 52 teachers (24.53%). Only 10 teachers (4.72%) know that a mobile device can be used to teach Biology. Only 23 respondents (10.85%) use the LearningApps.org resource in the Biology school course studying process. At the same time, only 13.04% of them know the feasibility of integrating this resource with mobile devices during the lesson.

To find out the main advantages and disadvantages of using the LearningApps.org software in school practice, a survey of 64 future biology teachers, now students of the second (master's) level of higher education, was conducted. The students were introduced to the LearningApps.org resource during practical classes in advance. They completed a teaching practice, in the process of which they modelled and conducted lessons using this online resource. The results of the questionnaires showed that future biology teachers identified the following positive aspects of working with LearningApps.org: many opportunities to create a variety of didactic tasks (90.63%); expanding opportunities for the use of visual and illustrative applications (67.19%); doing exercises it is possible not only to check, but also to correct mistakes (56.25%); exercises are effectively used to train students' attention and memory (39.06%); it is not necessary to print the material on paper, it is enough to send it to the students' personal account on the phone (100%); a large number of convenient templates that are available and easy to use (90.63%); the ability to view students' learning outcomes statistics and control their knowledge (78.13%); the exercise can be accessed using a unique QR code, which facilitates students' access to the exercise and saves time at the lesson (75.00%); the online resource is entirely free (100%); possibility to create tasks in Ukrainian (100%); possible acquaintance with exercises from different countries, which were previously developed by other teachers and use them in the own work (56.25%); availability of video, audio and graphic materials (89.06%); the use of the online resource is easy and saves a lot of time at the lesson and when the teacher checks tasks (46.88%); convenient use of the program during remote work (100%); it is always possible to change, improve, expand and differentiate already created tasks by the teacher (78.13%); the online resource is easy to use for

students' independent work and learning additional material (90.63%).

Among the disadvantages of using the LearningApps.org resource future biology teachers named: the primary condition for using the program is the Internet connection (not all students may have sufficient access to the Internet, and not all schools still have full access to the Internet) (100%); when updating the interface of the LearningApps.org site, some tasks may not work if there were changes in the structure of the task template (56.25%); in some templates, in the instructions to them the translation into Ukrainian is not wholly available (18.75%); not all the exercises that are available for use are accurate and may contain mistakes (39.06%); the teacher can use only ready-made exercise templates, but cannot create templates himself (18.75%); logging in to the program is possible only through an Internet browser, there is no specially created application that will facilitate logging in (45.31%).

All the respondents had a positive attitude towards the opportunity to use the LearningApps.org resource in practical activities and its combination with mobile devices.

Most students have shown moderate interest in TV programs about nature (77.65%). Only 7.20% claimed that they are not interested in such programs at all. 60.23% of students like observing plants and animals, and 16.10% demonstrate moderate interest in such an activity. 74.43% of students sometimes address Internet sources to answer questions during the lesson, and 19.70% of the students often address various information sources in this case. 5.87% of the students stated that they do not search for answers in additional sources.

The majority of teenagers (87.31%) possess mobile devices (smartphones, tablets), but they use them mainly for fun or socialising with peers on social networks. 18.56% of students know that a mobile device can help conduct research at school and beyond, but only 4.55% of respondents use smartphones for this purpose.

However, the study of the practice of modern secondary schools and personal teaching experience shows that using the Internet facilitates better learning of educational material by students. The LearningApps.org online resource is designed for developing and storing didactic multimedia interactive tasks, through which the teacher can form, consolidate and test the acquired knowledge, skills and abilities of each student in educational, play-based form, which contributes to the formation of cognitive interest, motivation to learn, critical thinking and independence. At the same time, lessons' effectiveness increases significantly, encouraging students to study. The educational process is intensified through the increase of its informativeness. Due to this, students improve their ability to orient themselves in the information space, and, in this case, the teacher acts as a mentor or consultant. All those mentioned earlier show the necessity of developing the methodology of studying biology using the LearningApps.org online resource and information devices.

Our experimental methodology involves using the LearningApps.org online resource with the following information devices: a computer, an interactive whiteboard Smart Board, a multimedia projector, a tablet, a smartphone, and a Google Chromecast adapter. The primary attention is paid to the use of the m-learning technology. The main advantages of its use are bringing new technology into the classroom, the possibility of using portable devices to support the learning process, the possibility of using the technology as an additional tool for learning, as a useful add-on tool for students with special needs; available synchronous learning experience; allows widened opportunities for timing, location, accessibility and context of learning [25].

The challenges of introducing m-learning technology were also taken into account. Among

them are as follows: accessibility and cost barriers for users; incompatibility of some mobile devices with other applications and devices; frequent changes in device models, technologies, functionality; number of file formats (assets) supported by a specific device; risk of distraction and fragmentation of learning; restriction of educational information visualisation; required bandwidth for nonstop and fast streaming; tracking of results and proper use of the information and the lack of well-developed students' self-control skills; insufficient "technical" training of school teachers in creating of mobile application [28].

Smartphones and tablets based on the Android operating system allow you to use online resources and various free applications downloaded from the PlayMarket server. Analysing the PlayMarket server, it has been found to contain many applications that are permanent helpers in biology learning with the possibility of free downloading. All applications are installed on the teacher's smartphone and displayed on the multimedia projector screen using the Google Chromecast adapter.

There are some examples of using templates from the LearningApps.org online resource for teachers to create their exercises for the Biology lesson:

Exercise "*Find a pair*" is a universal task that the teacher can use at any lesson stage and while studying various themes. Students like images, text information, or videos to help them match the correct pairs. A bright example is to match the image of the plant to its name (which taxonomic link does it belong to). If a student forms a pair correctly, the colour is green, but the pair is shown in red if a mistake is made.

Example: you can see images of the main representatives of the Gymnosperms group and their species names on the Smart Board (figure 1). Students come up to the board in turn and try to match an image and a species name. There is an exercise check at the end (highlighting correct and incorrect answers in colours).

Exercise "*Classification*" selects statements, notions, videos, audio, or images according to a common theme. Preparing for a Biology lesson, a teacher can use it for the systematisation of knowledge, matching, or consolidating of the corresponding educational material.

For example, you can see statements on the board, which can be referred to two groups: Gymnosperms and Ferns. Students classify the statements, explaining which of the groups it can be referred to. There is an answer check at the end (the correct answer is highlighted in green, and the incorrect answer is shown in red colour).

Figure 2 presents an illustration of the exercise "Classification", which should be used when studying the types of inflorescences with the help of the LearningApps.org online resource at different stages of the lesson: perception of information, clarification and expansion of knowledge, reproduction of information, generalisation and systematisation of knowledge.

Another bright example of this exercise is the classification of statements. Students are offered to sort all the statements according to their belonging to a specific class: Monocotyledons and Dicotyledons. If the student's answer is correct, it is highlighted in green, and incorrect matching is shown in red.

Exercise "*Simple ordering*", the primary goal of which is to arrange the proposed statements and images in a specific order (establishing a sequence). Numbering is in the upper left corner, which changes when students move the statements. It can be used during Biology lessons for the sequential arrangement of development cycles, body structure, physiological processes, etc.

For example, during the lesson on the theme "Subclass Equisetidae," students get acquainted



Figure 1: Illustration of the exercise “Find a pair”. Learning of plant species “Gymnosperms group” in the LearningApps.org online resource (<https://learningapps.org/display?v=pk1msmk7321>).

with different stages of the equisetum development cycle. It is necessary to determine the correct sequence. The correctly determined stage is highlighted in green; the false stage is shown in red (figure 3).

Exercise “*Quiz (1 correct answer)*” can be practically used when the teacher develops test tasks. Using clear instruction, the teacher can create questions with different numbers of answer options. Questions can be in text, audio or video format. The teacher decides on the number of questions himself. Students’ answers are sent to the teacher’s account, which makes it easier to check the tasks and does not take much time.

Exercise “*Fill in the blanks*” fills in certain text parts. Students are offered certain parts of the text with blanks in it. It is necessary to fill in the blanks: choose from the proposed options or choose the statement independently from the learned material. Each of the students can do this exercise using his mobile phone. Advantages of use: each student can test his knowledge himself, online discussion of this exercise is possible, and the results of the answers are automatically sent to the teacher’s account; students can also see and analyse the correctness of the completed tasks themselves. The exercise can be used at the motivation stage, homework checking, consolidation of knowledge, or reflection.

Another example of this exercise is the work with a textbook [14]. Students should study a part of the theme based on the textbook, namely the example of the main features of flowering plants (Angiospermae). The text without answer options is provided on the board or the mobile phone (if the teacher sends the task to students in advance), and students, in turn, at the board

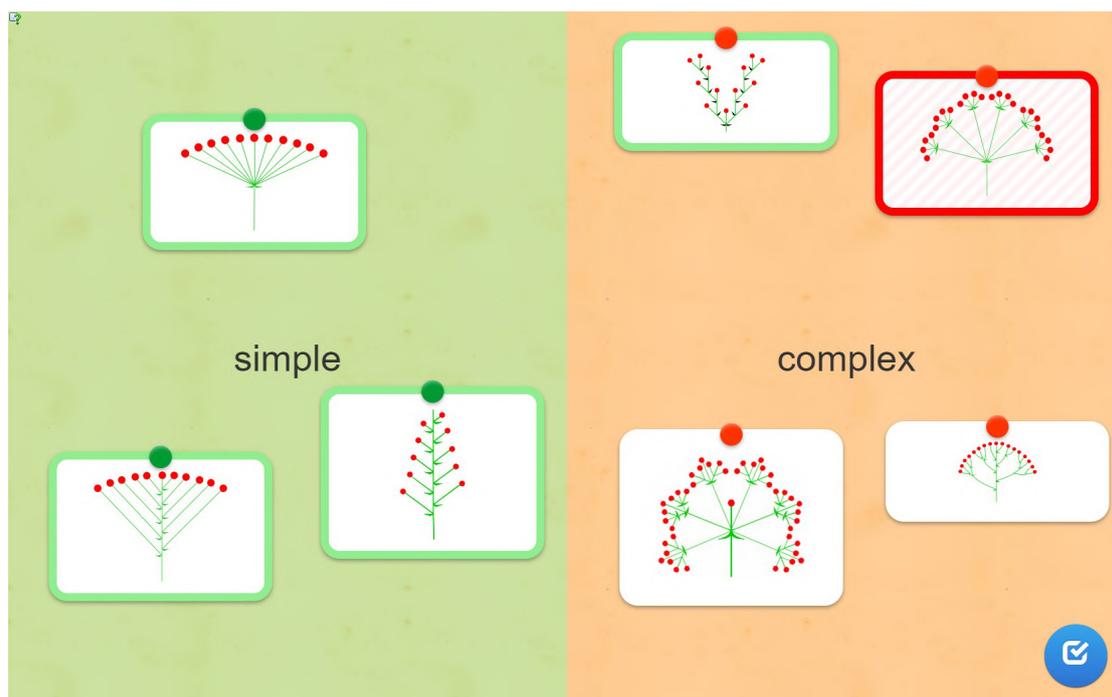


Figure 2: Illustration of the exercise “Classification”.

(or on the mobile phone independently), fill in the answers according to the learned material. The correct answer is highlighted in green; the incorrect answer is shown in red. The answers are sent to the teacher’s account, then there is a mutual reflection with the class and correction of mistakes with students’ explanations, and if it is necessary, the teacher may add something.

Exercise “*Crossword (puzzle)*” has a user-friendly interface for building a layout and creating tasks. Using the template, the teacher only needs to create questions and choose the correct answers. The program builds a crossword puzzle by placing words vertically and horizontally and determining the appropriate intersections of words. The teacher can also choose a keyword relevant to the lesson’s theme. The exercise can be used at the motivation stage, revision of the learned material, and consolidation of knowledge. The development of this exercise is relatively easy and clear. It can be used for independent students’ work if they have sufficient knowledge of how to use the LearningApps.org online resource. Example:

1. In the life cycle of the considered groups prevails... ? (Sporophyte)
2. What do extinct plant species form? (Coal).
3. Where does photosynthesis take place in horsetail (Equisetum)? (Stem).
4. What is the limiting factor in fertilisation of the considered groups? (Water)
5. What is the underground part of Lycopodium? (Root).
6. How are horsetails (Equisetidae) dispersed? (In groups).
7. Where are spores of the considered groups formed? (Strobilus).
8. Give a clear name for the sexual generation of horsetails (Equisetidae) and lycophytes. (Gametophyte).

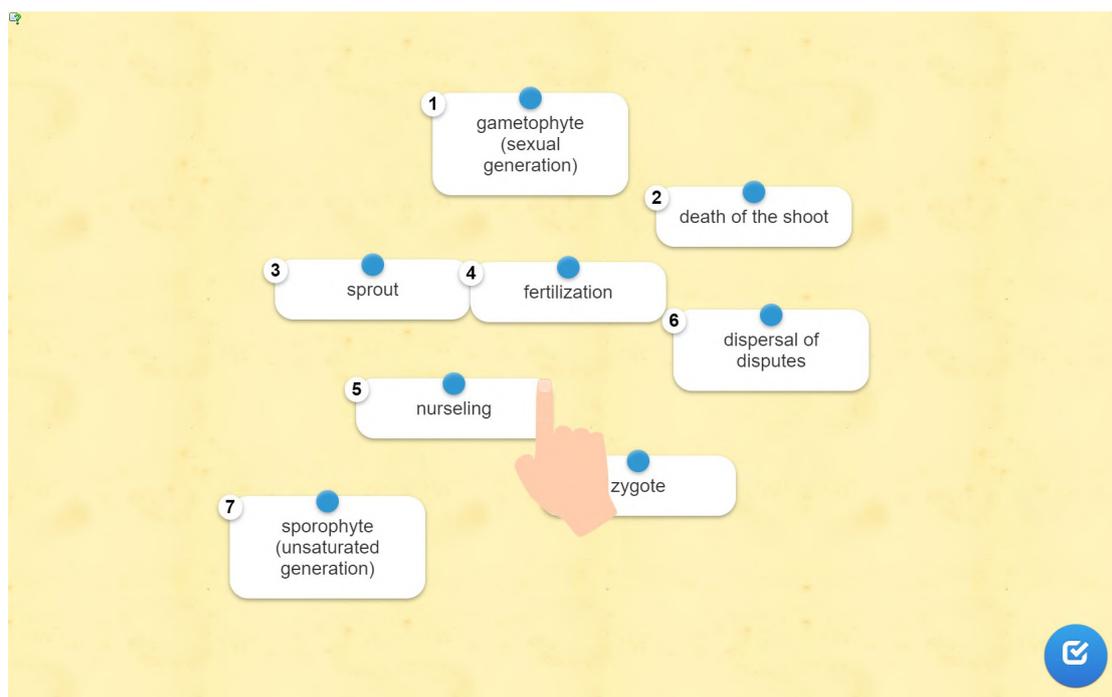


Figure 3: Illustration of the exercise “Simple ordering” – arrange stages of the life cycle of field horsetail (*Equisetum arvense*) in the right order using the LearningApps.org online resource.

9. What is the photosynthetic organ of *Lycopodium*? (Leaf).
10. What do young horsetail (*Equisetum*) stems contain in great amounts? (Starch).
11. What part of lycophytes is used to make baby powder? (Spores).
12. What is the indicator for soils with high acidity? (horsetail (*Equisetum*)).

Students can see the illustration of a crossword puzzle on the Smart Board and immediately answer the questions on it, checking the correctness of the answers at the end.

Exercise “*Find the words*” is an educational game. Students are offered a list of questions to answer and find them on the word search board, one next to the other. The program creates a word search board where the words are arranged horizontally, vertically and diagonally. This exercise is used at all stages of Biology lessons, especially when offered for knowledge actualisation. Example:

Questions:

1. Embryonic leaves that are found and developed in the seed? (Cotyledon).
2. Modified stem of flowering plants (Angiospermae) group? (Flower).
3. What fertilisation (give the name) leads to seed and fruit formation? (Double).
4. Which class do the Lily and Cereal families belong to (give the class name)? (Monocotyledons).
5. What type of root system do Dicotyledons have? (Taproot).
6. The diversity of which organs of flowering plants (Angiospermae) group improves and increases the species composition of vital functions performing? (Vegetative).

7. What class do Rosaceae and Asteraceae families belong to? (Dicotyledons).
8. Name the type of Dicotyledon venation. (Reticulate).
9. The root system of Monocotyledons is...? (Fibrous).
10. Where is the seed protected by a pericarp that has an adaptation to the dissemination? (Fruit).

Students are given a table with encrypted words and questions to them. They answer the questions and find the appropriate answer in the table. The correct answer is highlighted in colour.

We present examples of educational applications involved in our methodology.

In our previous research [24], the effectiveness of using such free applications of the Play-Market server as “Anatomy 4D”, “Animal 4D+”, “Augmented Reality Dinosaurs – my ARgalaxy”, “BioInc – Biomedical Plague, BioInc”, “Plan+Net” in the process of Biology studying in a secondary school was proved. Their choice is caused by the specifics of the object of biological cognition (life in all its manifestations) and the concept of bio(eco)centrism, which recognises the life of any organism as the highest value. Comparison of the content of these applications with the content of the program material in Biology for the 6th grade allowed us to conclude that it will be the most appropriate to use the “Plan+Net” application for our experimental methodology, which is a powerful tool to identify plants in the photo. During an excursion, the teacher takes a picture of an unknown plant with his smartphone and then, using the mobile application, analyses the information he has received. After the work is completed, plant details can be checked using the printed version of a plant catalogue. Students can use such an educational application in Biology lessons and during their independent work in the research process at the centres of research and experimental activities.

Using information devices at a lesson at the stage of homework checking allows for diversification of the forms of students’ learning outcomes control. Thus, Miracast wireless technology can be used for this purpose in addition to computer testing. This requires the ownership of a smartphone, a multimedia projector, and a Google Chromecast adapter. Much educational content is available on the Google Play Market application of smartphones, including programs for students learning outcomes control. One of them is Plickers [29]. This web server lets you survey classes during the lesson and conduct instant checks to understand the learned and current material in a test form.

To start working with it, it is necessary to download a free application, Plickers, to the teacher’s smartphone. Then, in a separate application, prepare the tests and print cards. One set of cards can be used for different classes. Each student is assigned a unique Plickers card with a black-and-white image similar to a QR code. The card number corresponds to each student (according to the list). Then, you will need to take your smart device and choose the Plickers application.

Choose the class and the necessary question from the list. The chosen question on your mobile device will be automatically displayed on the screen with the help of a projector. Using your smartphone’s scanner, scan your students’ cards and record their answers. Students should hold their cards so that the letter of the correct answer is located at the top. Coloured highlighting helps to find out how well the students answer the questions quickly: grey marks the students who have not answered yet, red means incorrect answers of students and green stands for

correct answers.

The use of Smart technologies makes it possible to solve the following topical issues: use the latest IT in training; improve the skills of students' independent work in information databases on the Internet; improve the student's knowledge, skills and abilities; make the learning process more exciting and meaningful; develop creative potential; control through testing and a system of questions for self-control; increase the cognitive activity of students due to various video and audio information [5].

A Smart Board is a touch screen which is connected to a computer. A multimedia projector transmits an image from the computer screen to the Smart Board. The latter acts as an interactive touchscreen monitor for the computer. By touching the Smart Board, the user can click on buttons, highlight text and drop and drag items right from the Smart Board.

An interactive whiteboard helps the teacher to work with a variety of multimedia visual aids that allow them to display an object in a variety of ways. In his work, a biology teacher can use everything the student can perceive clearly.

While working with the Smart Board, there is a rapid increase in the amount of visual information, increasing the quality and effectiveness of the lessons. Unique possibilities of Smart involve students in active cognitive activity and enhance their creative potential. There is a chance to work with a large amount of information in the lesson that creates the optimal conditions for students' research work in biology. Students work with computer models; during such work, they can conduct experiments and check hypotheses.

During the work with the Smart Board, many traditional didactic principles are implemented: sequence, systematic character, scientific approach, visual training, students' activity and consciousness, connection of theory with practice, availability and duration of knowledge. The principles of visualisation, availability and systematicity are realised through adding tables, video and audio materials, and analysis of materials of electronic textbooks during the explanation of new material. However, the interactive whiteboard is mainly used during the principle of visualisation, due to which teacher can present educational material in the form of schemes, dynamic algorithms or generalising tables, which are a concise statement and an illustration of the main conceptions of the material and its use at the lesson.

Our methodology involves the use of a website as a means of increasing the effectiveness of the learning process. Nowadays, any teacher can create a website. There are hundreds of different website-building platforms and website builders. Anyone can get free or for payment information base and real resources in electronic space, modules, templates, and control systems.

Site pages can be simple static file sets or created by a special computer program on the server. It can be either custom-made for a specific site or a ready-made product designed for a specific class of sites. The structure of a website consists of two parts: internal and external. The internal part of the structure is represented by the headlines, sub-sections, site sections, labels and other navigation elements. The external part of the structure of a website is a scheme of the content blocks, that is, how the header, the main content, the comment block, and other elements of the site are located. A well-designed website layout, where a convenient and interesting interface is combined with actual information, is a significant point in the development of this resource, and it is better perceived by users [19].

Having analysed the functions and tasks of various websites, we chose the website builder Wix. The appropriateness of this website builder choice is caused by the fact that it contains all the

necessary components for creating a training website and allows the creation of multi-functional universal websites free of charge. It involves a sufficiently large number of educational category templates with an appropriate interface, convenient ways to add and edit existing web pages, and site management options from both the control panel and the admin panel that rejects force majeure during learning because if you have problems with logging into the admin panel, the teacher will be able to manage the site through the control panel. This builder contains a specific, comprehensible control panel requiring registration and a definite password to log in. It will protect the site against hacking and illegal spreading of stored information, as the website administrator has particular copyrights.

In the context of experimental learning, we have developed a methodology for organising a biology teaching process in a secondary school using the LearningApps.org resource and various information devices. We used them variously in lessons of different types: in the introductory lesson, to activate the cognitive process and to report new knowledge; in the lesson of studying new material; in the combined lesson in order to expand and deepen the students' knowledge; at the lesson of checking and correction of knowledge for final control and correction of knowledge.

The LearningApps.org resource was used together with other information devices at different stages of the lessons: at the stage of actualisation of basic knowledge: tests (Plickers application), video clips (Smart Board), models of objects and phenomena (Smart Board); at the stage of learning activity motivation: coloured drawings, animated snippets, virtual biological experiments, website; at the stage of learning new material: photos, slideshows, animated plots, interactive models (website), video clips (Smart Board); at the stage of summing up of the studied material: multiple-choice tests (Plickers application), mute pictures (Smart Board), establishment of sequence of biological processes (Smart Board); at the stage of generalisation and systematisation of obtained knowledge: thematic control with automatic verification (Plickers application), control – diagnostic tests (website).

They were also used in various forms of learning: during class work and practical classes (website), during virtual excursions (Smart Board), during students' independent work and research (website), while doing students' homework (website, mobile applications).

Conducted research allows us to conclude that using a training website in the biology teaching process greatly facilitates student-teacher interaction. It is advisable to use a training website to prepare students for independent work on the tasks that the teacher places in advance in the suitable section on the website. In the lesson preceding the lesson on generalisation and systematisation of knowledge, the home assignment will be as follows: the students should refer to the website, the address of which is reported by the teacher, and in the section "Preparing for independent work" do the assigned tasks (there may be different variants). In the lesson on generalisation and systematisation of knowledge, it is necessary to do the tasks placed on the site or use them to survey students. Thus, they can revise, generalise, and systematise the obtained knowledge and fill in the gaps. By using the website in preparation for the student's independent work, we give them more time to prepare and diversify the process, which will positively impact the learning outcomes.

Using a website is also productive for the lesson that precedes practical work. Biology teaching involves performing practical work that requires certain conditions that cannot be created in the classroom. For the fairness of the experiment and to obtain accurate results, it is

better to ask students to carry out this practical work at home with the help of their parents and to place the plan of work and instructions on how to carry it out in the section “Practical work” on the website before conducting it and, to discuss the results at the stage of actualisation knowledge at the next lesson.

It is convenient to place some research themes on this training website, as this will help to prepare for students’ conferences because they will be able to get the theme at the beginning of the academic year and work on it throughout the year and, after that to defend it at conferences. The website can store all the theoretical information necessary for conducting lessons so the student can access it anytime. This way of placement is convenient for students who were absent from the lesson, as they can independently study the material missed in the home environment.

Generalised results of the thematic assessment on the themes, during which the experimental methodology of using the LearningApps.org online resource in combination with information devices in the 6th grade was implemented, are presented in table 1.

Table 1

Results of acquisition of the elements of knowledge by experimental group students.

No.	Program themes	Elements of knowledge (notions)	I_a	n	$n \cdot I_a$	$\sum I_0$	$K, \%$
1	Root, steam: structure and basic functions. Variety and modifications of vegetative organs. Photosynthesis as a characteristic feature of plants.	morphological	6	491	2946	2254	76.51
		anatomical	3	491	1473	1089	73.93
		physiological	6	491	2946	2185	74.16
		agronomic	1	491	491	405	82.48
2	Plant reproduction: sexual and asexual. Vegetative plant reproduction. Flower. Inflorescence. Pollination. Fertilization	morphological	11	503	5533	4188	75.69
		anatomical	1	503	503	386	76.73
		physiological	3	503	1509	1104	73.16
		agronomic	1	503	503	437	86.87
3	Algae. Mosses. Gymnosperms	morphological	2	482	1928	1467	76.08
		anatomical	2	482	964	773	80.18
		physiological	5	482	2410	1695	70.33
		systematic	3	482	1446	1115	77.10
		agronomic	2	482	964	710	73.65

Analysing table 1, we can see that students acquired knowledge in all the themes taught using experimental methodology. This is evidenced by the average value indicator of the coefficients of teaching information acquisition (76.42%).

The results of Stage I of students’ thematic assessment on the themes “Root, steam: structure and basic functions. Variety and modifications of vegetative organs”, Photosynthesis as a characteristic feature of plants, nutrition, respiration, plant movements” are shown in figure 4.

According to the state requirements for the level of students’ general educational background, laid down in the current program in Biology, the study of the themes “Root, steam: structure and basic functions. Variety and modifications of vegetative organs”, Photosynthesis as a characteristic feature of plants, nutrition, respiration, plant movements” involves students’ learning of morphological, anatomical, physiological and agronomic notions. Analysis of the results of doing the tasks with morphological content showed that students had learned this

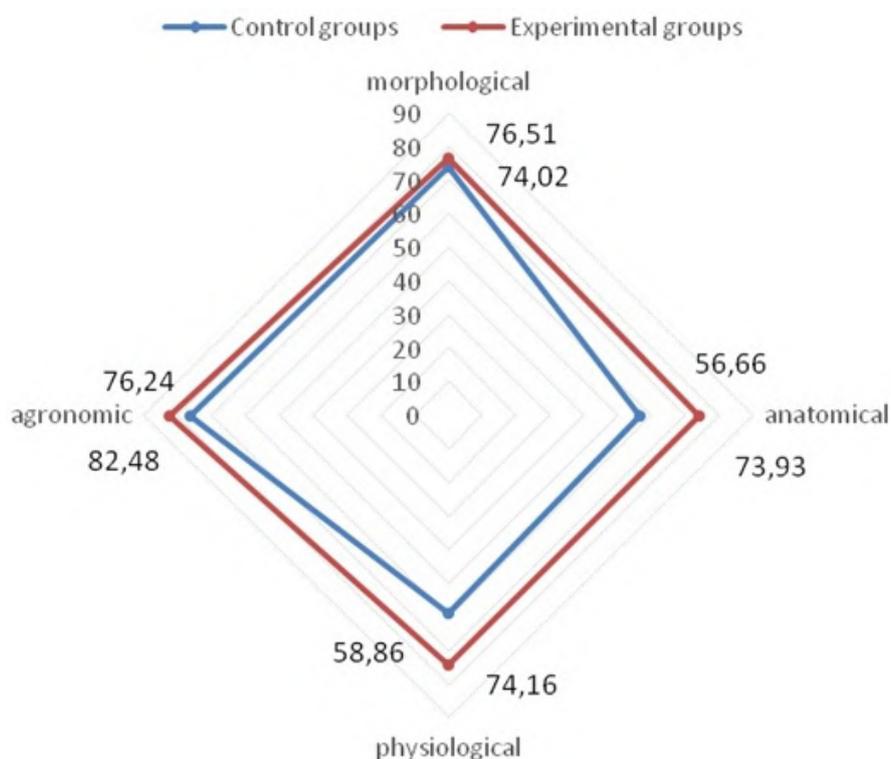


Figure 4: Coefficients of students' acquisition of the elements of botanical knowledge (Stage I of the thematic assessment).

educational material ($K = 74.36\%$ – in CG and $K = 76.51\%$ – in EG).

As it can be seen in figure 4, the coefficient of students' acquisition of the anatomical and physiological notions has considerably increased in EG (from 56.66% and 58.86% to 73.93% and 74.16%, respectively). We believe that the effectiveness of knowledge acquisition is connected with the proposed methodology of teaching students using the LearningApps.org online resource. The formation of such notions as “photosynthesis”, “respiration”, “evaporation”, and “transportation of substances in the plant” is possible only with a rational combination of traditional visual aids (tables, diagrams, experiments) and the use of multimedia fragments, that what the experimental methodology included.

A comparison of the answers to the questions with agronomic content showed that the results of thematic assessments of students' academic achievements from CG and EG did not differ significantly (76.21 and 82.48, respectively).

A comparison of the thematic assessment results on the themes “Plant reproduction: sexual and asexual. Vegetative plant reproduction. Flower. Inflorescence. Pollination. Fertilisation” is shown in figure 5.

The results of students' educational information acquisition proved that the most significant impact the proposed methodology of using the online resource LearningApps.org in combination with information devices has on the formation of anatomical ($K = 76.73\%$) and physiological notions (73.16%). At the same time, the difference in coefficients of knowledge acquisition in CG

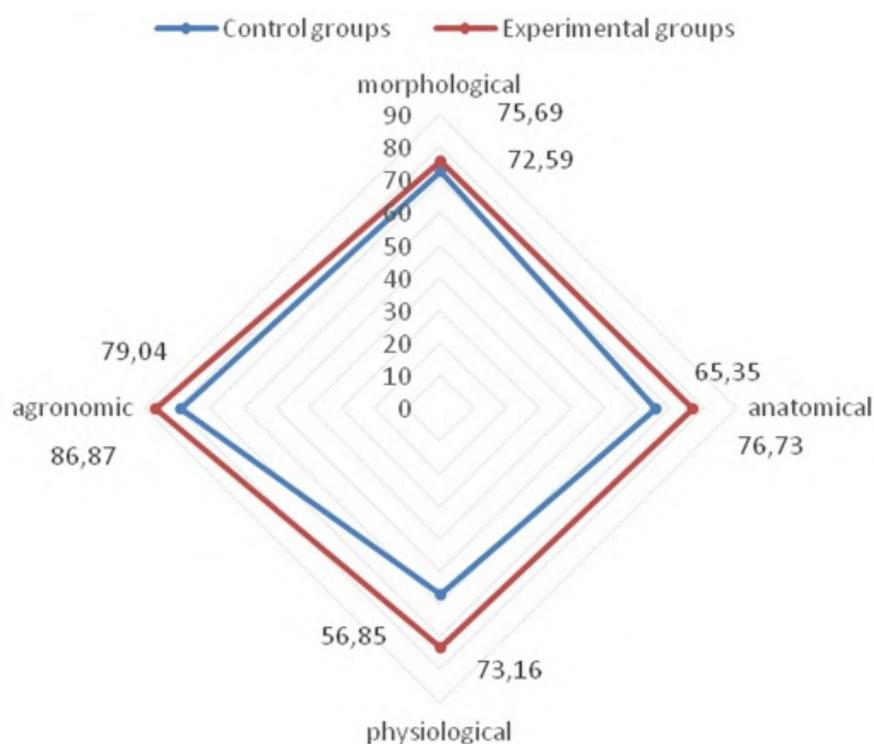


Figure 5: Coefficients of students' acquisition of the elements of botanical knowledge (Stage II of the thematic assessment).

and EG is +11.38% and +16.31%, respectively. It can be explained by the fact that for the students of this age group (12-13 years old), the physiological processes of “pollination”, “fertilisation”, and “plant development” are challenging to understand and remember. It is not easy to show these processes and form a holistic visual representation of the mechanisms of their occurrence with the help of traditional static visualisation.

The results of Stage III of students' thematic assessment on the theme “Algae”. “Mosses”. “Gymnosperms” according to the coefficients of knowledge elements acquisition (morphological, anatomical, physiological, systematic, and ecological) in control and experimental groups are shown in figure 6.

The analysis of the results of tasks on the themes “Algae”, “Mosses”, and “Gymnosperms”, which involved the acquisition of morphological knowledge (figure 6), showed that this knowledge is acquired by students at a sufficient level ($K = 71.07$) using traditional teaching. Undoubtedly, using the LearningApps.org online resource for training, in particular, the demonstration of images of the organs of higher sporophytes and gymnosperms, promotes better memorisation of educational information, as evidenced by the coefficient of knowledge acquisition ($K = 76.08$).

The most significant impact of using the online resource LearningApps.org in the process of studying we observe at those stages where anatomical ($K = 56.49\%$ in CG and $K = 80.18\%$ in EG) and physiological ($K = 48.64\%$ and 70.33% respectively in CG and EG) notions are formed. It is difficult to form these notions using traditional mediums of instruction (tables, microscopes,

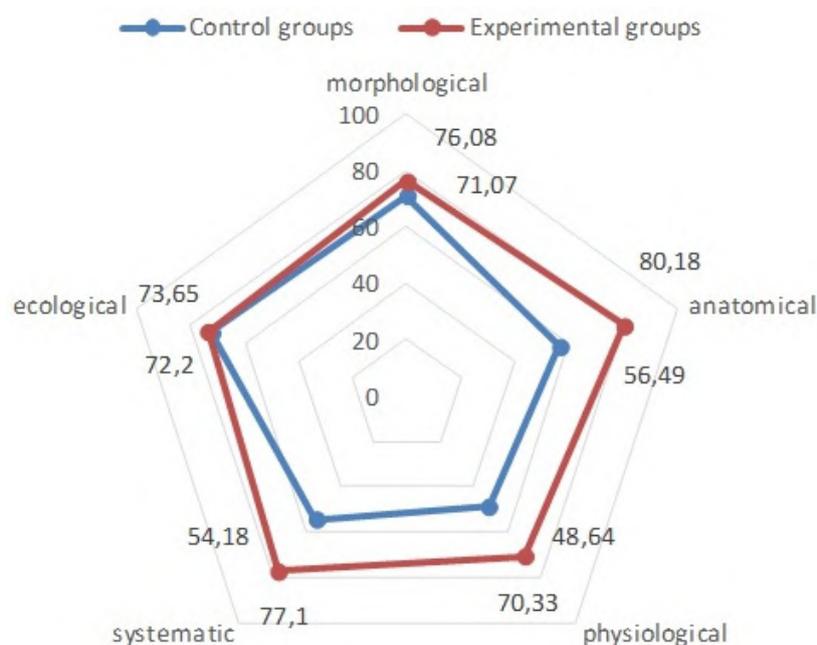


Figure 6: Coefficients of acquisition of the elements of botanical knowledge (Stage III of the thematic assessment).

textbooks). Using pedagogical software with dynamic multimedia fragments helps to illustrate the complex reproduction processes of higher sporophytes and algae and their better visual perception.

In students' systematic notions acquisition, they must possess already formed morphological, anatomical and physiological notions. Since after using the LearningApps.org online resource in EG, the coefficient of these notions acquisition increased, this can explain the increase of the coefficient of systematic notions acquisition ($K = 54.18\%$ in control groups and $K = 77.10\%$ in experimental groups).

Analysis of the answers to the questions with ecological content allows us to confirm that this material can be learned as the coefficient of educational information acquisition in CG and EG is higher than 70%.

Thus, the comprehensive analysis of the results of the forming experiment allowed us to conclude that the proposed methodology of using information devices in the process of Biology school course studying is effective.

4. Conclusions and perspectives of further research

This study demonstrates the effectiveness of integrating the LearningApps.org online resource with information devices like computers, tablets, and interactive whiteboards to enhance biology education in secondary schools. A methodology utilising sequenced LearningApps.org exercises, smartphone apps, websites, and interactive whiteboards was developed and experimentally

validated to improve learning processes and outcomes related to plant morphology, anatomy, physiology and systematics.

Results from over 1000 students in experimental and control groups indicate increased knowledge acquisition for topics involving complex anatomical and physiological concepts when applying the methodology. Learning coefficients rose by 11-16% on assessments covering plant reproduction and algae/mosses/gymnosperms. The interactive and multimedia nature of the online exercises facilitated an understanding of intricate biological phenomena challenging to convey through static traditional mediums.

These outcomes highlight best practices for leveraging educational technologies in biology instruction:

- Align exercise types from LearningApps.org to specific learning stages and objectives.
- Sequence activities to optimise skill development from introduction to evaluation.
- Combine interactive online elements with in-class teaching.
- Focus technology integration on complex concepts requiring visualisation.
- Train teachers on methodology principles and IT tools.

Further research can expand the approach to other biology subjects, age groups and school IT environments. However, the methodology provides a model for modernising science education to develop students' digital competence while improving mastery of curricular concepts through technology-enhanced instruction. Wider adoption will require teacher training and increased access to IT infrastructure.

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