Harnessing online services for creating augmented reality enhanced comics in primary education

Dmytro M. Bodnenko, Oleksandra V. Lokaziuk, Lesya A. Poryadchenko and Volodymyr V. Proshkin

Borys Grinchenko Kyiv Metropolitan University, 18/2 Bulvarno-Kudriavska Str., Kyiv, 04053, Ukraine

Abstract

This article explores the current state and practical solutions for addressing the readiness of primary school students and teachers to utilise cloud services for creating augmented reality (AR) enhanced comics. The didactic potential of comics as an educational tool is clarified, and a comparative analysis of modern cloud services, programs, and applications for comic creation is presented, highlighting their advantages and disadvantages. The functionality of AR programs for creating comic-based content (Vuforia, EasyAR, Maxst, ARCore, AR.js, 8th Wall) is analysed. A survey of teachers reveals the most popular cloud services, including Pixton, Marvel HD, and Comica. Algorithms for developing educational materials using these cloud services to create AR-enhanced comics are presented. Readiness levels for using cloud services to create AR-enhanced comics (elementary, basic, and creative) are developed, and the current state of readiness among teachers and students is characterised. Educational and methodological support has been developed for implementation in university education and teacher professional development. Prospects for further research, including monitoring the readiness of students and teachers to use cloud services for creating AR-enhanced comics following the introduction of the authors' educational and methodological support, are discussed.

Keywords

cloud services, augmented reality, comics, educational technology, primary education, teacher training

1. Introduction

In the rapidly evolving landscape of primary education, modern teaching methods are increasingly focused on employing non-traditional, interactive, and playful approaches to engage young learners. As traditional lessons often prove less effective, teachers are compelled to seek innovative means and forms of instruction. The role of the teacher is transforming, necessitating the ability to organise captivating lesson-plays, lesson-journeys, and lesson-quests. Among these emerging educational tools, comics stand out for their potential to simplify, visualise, and virtualise complex information through a blend of forgiveness and visual playfulness. The visual nature of comics enhances the level of learning, offering advantages over time-limited media such as movies and animation, which present language and actions at a rapid pace. In contrast, the progression of time in comics is determined by the reader's pace of eye movement across the page, allowing for a personalised speed of information processing. As Chykalova [1] note, comics serve as a tool for developing imagination, fantasy, and the skills to clearly and concisely formulate and express opinions, as well as to distinguish the main ideas from the text. Engaging with comics contributes to the development of 21st-century skills among younger schoolchildren, such as emphasising the essential and collaborating in a team.

The effectiveness and productivity of educational technologies incorporating comics have been demonstrated in recent years, with materials containing or based on AR technology proving particularly popular, as evidenced by the authors' pedagogical experience. However, an analysis of the actual practice of the educational process in primary schools reveals a lack of high readiness among teachers to apply comics in pedagogical activities, particularly those enhanced with AR. This can be attributed

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d.bodnenko@kubg.edu.ua (D. M. Bodnenko); o.lokaziuk@kubg.edu.ua (O. V. Lokaziuk); l.poriadchenko@kubg.edu.ua (L. A. Poryadchenko); v.proshkin@kubg.edu.ua (V. V. Proshkin)

0000-0001-9303-6587 (D. M. Bodnenko); 0000-0001-9663-251X (O. V. Lokaziuk); 0000-0001-8596-8907 (L. A. Poryadchenko); 0000-0002-9785-0612 (V. V. Proshkin)

to a shortage of methodological developments on the use of AR-enhanced comics in training and the limited capacity of teachers to develop and utilise such materials using cloud services. Consequently, this highlights another significant problem: the preparation of future primary education teachers to use cloud services for creating AR-enhanced comics in their professional practice.

In today's digital age, the integration of innovative technologies such as AR-enhanced comics into primary education has the potential to revolutionise the way young learners engage with and absorb complex information. By harnessing the power of visual storytelling and immersive experiences, educators can create captivating learning environments that foster creativity, critical thinking, and collaboration. However, the successful implementation of these technologies hinges on the readiness and competence of teachers to effectively utilise cloud services for developing and deploying AR-enhanced comics in their classrooms.

1.1. Related work

The importance of comics as a learning tool has been highlighted in several studies [2, 3, 4, 5, 6, 7, 8, 9]. Of particular relevance to this work are studies focusing on the use of digital technologies as a means of effective visualisation in the creation and application of comics. The works of [10, 11] analyse modern software such as Bitstrips, Comic Life, Pixton, MakeBeliefsComix, Cartoon Maker, and Graphix Comic Builder, examining their functions, characteristics, capabilities, and limitations. Fragments of the use of these software in the implementation of the educational process are presented. Zerkina et al. [12] explored the possibilities of using Pixton to form the ICT competence of engineering students using a project approach. Different didactic possibilities of the specified cloud service are given in the studies [13, 14, 15]. Weber [16] considered the use of cloud-based graphic narrative software in medical ethics teaching. In addition, the theoretical and practical aspects of data visualisation and the use of digital technologies for this purpose are presented in the works [17, 18, 19, 20]. The use of augmented reality to work with comic book-based teaching material is the subject of research in [21, 22, 23].

1.2. The objective of the research

The purpose of this article is to explore the possibilities of using online services to create AR-enhanced comics in the educational process of primary school.

The study aims to address the following objectives: to identify the most popular cloud services for creating comics among teachers and characterise them; to reveal the algorithms for developing educational materials in cloud services for creating AR-enhanced comics; to investigate the current state of readiness of future teachers and students to use cloud services for creating AR-enhanced comics; and to develop educational and methodological support for the use of these cloud services in the educational process.

2. Research methodology

To conduct this study, the following methods were employed: theoretical (analysis and synthesis of psychological, pedagogical, and methodological sources, programs, handbooks, systematisation and generalisation of theoretical material; study of experience with the research problems; clarification of the basic knowledge of the studied problem), empirical (pedagogical observation, interviews with teachers and questionnaires, writing methodological recommendations, formulating conclusions and determining the sequence of research), and statistical (Pearson's criteria for identifying the real state of readiness of students and teachers for the use of cloud services).

The study was conducted at Borys Grinchenko Kyiv Metropolitan University and 11 schools in Kyiv, Ukraine. The study involved 28 primary school teachers and 84 students specialising in "Primary Education" from years 1-4 of study.

3. Results and discussion

3.1. Analysis of cloud services for creating comics

Comics serve as a new, effective, and democratic tool for primary school teachers in the formation and comprehensive development of initiative and creative personalities among schoolchildren. Combining visual and playful qualities, comics can satisfy the interests and meet the peculiarities of the course of mental processes in modern junior schoolchildren, representatives of the generation, to prevent the occurrence of stress during the study [1]. There are numerous online services and apps available for creating comics. However, not all of them are suitable for teachers to organise work in class. Most services are paid, too complex, require special knowledge and skills, or their content is not designed for a children's audience. Finding the right program, service, or app is difficult and time-consuming, which teachers often lack.

Lack of time for training is also a problem because the service must not only be found but also learned to work with and know how and when to use the developed materials.

In this study, we focused on functional, free, and most importantly, simple services that provide easy access to programs for both teachers and students (table 1).

Each of these online services contains a certain number of templates grouped by types:

- People (children, teens, young men, adults, elderly people);
- Animals;
- Things;
- Transport;
- Special characters;
- Backgrounds (school, forest, city, houses, historical and mythological views, nature, etc.).

Table 1
Modern online services, standalone and mobile applications for creating comics.

Online services		*Need to be uploaded*	
StoryboardThat	Price: Free basic version; Language: English.	Comic Life	SW: Windows/macOS; Price: Free version – 30 days; Language: choice.
Pixton	Price: Free; Language: Italian.	Krita	SW: Windows; Price: Free; Language: choice.
Make Beliefs Comix	Price: Free; Language: choice.	MediBang Paint Pro	SW: Windows/macOS; Price: Free; Language: choice.
Debate365	Price: Free; Language: English.	*Mobile apps*	
Canva	Price: Free; Language: Ukrainian.	Comica	SW: Android/iOS; Price: Free; Language: choice.
Write Comics	Price: Free; Language: English.	Comic and cartoon maker	SW: Android/iOS; Price: Free; Language: choice.
Marvel HD	Price: Free; Language: English.	MomentCam	SW: Android/iOS; Price: Free; Language: choice.

When creating a plot, you can choose the expression of the face, the position of the body, the mood of the hero, change his appearance, clothes, etc.

It should be noted that in table 1 you can also get acquainted in detail with the main characteristics of modern online services, programs, and applications for creating educational comics, which can be used not only for working online but also for working in the classroom with the ability to print material.

All offered by us online services, programs, and applications for creating comics can use instant translation in Ukrainian and maintain it in the services themselves. Using these services, the teacher can diversify the form of educational material presentation, will be able to convey complex ideas and concepts using minimal artistic means, and will be able to organise not only face-to-face but also distance learning qualitatively and interestingly. It is also possible to organise work with services not only individually but also in a group format.

The services are quite simple, so schoolchildren will be able to work with them. Most of them do not require users to register, and they can start working with them right away. Talking about the advantages of using these services, we can note the following:

- Availability of services in material terms (most are free or have the possibility of using the trial/free version);
- Simple interface (intuitive);
- Use of templates (each service has its template database for use);
- The ability to create a completely new product (the ability to download own resources is provided);
- Dissemination of materials (it is possible to disseminate or embed the created materials of the author);
- Versatility (materials can be used to work in any lesson for individual or frontal work, both online and printouts). It is also worth highlighting the disadvantages:
- Other-language interface (most programs are foreign, but there is a possibility of using Google instant translation);
- Preliminary training of teachers and students;
- Conversion (not all file formats are supported; their size is limited).

The creation of training materials such as comics using the specified software can be supplemented with AR elements. The experience of implementing the educational process using AR also allows us to highlight programs for developing and working with AR.

- Vuforia can easily create marker-based AR, markerless-based AR, and cloud-based AR. Provides sufficient support to create an application for minor tasks. In particular, it allows you to recognise 2D and 3D objects, English text (the vocabulary contains over 100,000 words, or you can use your dictionary) and allows you to play videos.
- EasyAR offers its next-generation SDK, which has some features such as SLAM, 2D–3D screen tracking and recording, cloud-based object recognition, and unlimited recognition requests. In addition, the free version can store up to 1000 tags on the device.
- Maxst offers two types of augmented reality software: Maxst AR SDK 2D and Maxst AR SDK 3D. The first tool can only recognise 2D images, and the other is much more powerful and can track 3D objects. The Maxst AR 3D SDK has features such as SLAM, physical engine effect, and occlusion effect. The Maxst AR SDK 2D features multiple image recognition (up to 200 images per channel), video zoom, instant object tracking, image and marker tracking, and a QR/barcode scanner.
- ARCore is not only supported on Android, but also on iOS devices, allowing you to develop cross-platform AR applications. Features of the application include: in addition to identifying key points, ARCore can detect flat surfaces, and can also estimate the average illumination around them; determining the size and location of vertical, horizontal, and inclined surfaces; tracking movement according to the position of the phone, accurate placement of virtual objects; assessing light and understanding depth.
- AR.js is an open-source AR SDK based on JavaScript. Can create AR scenes based on markers. The tool comes with an A-Frame and three.js extension that works with any smartphone, regardless of its OS version, including Android, iOS, and other. Markers are stable but limited in shape, colour, and size.

- 8th Wall provides support for markers (Image Target), World Effects, Face Effects, SLAM. Video recording, light evaluation, and relative zoom function are available. Can be used in combination with Unity and Unreal engines.

When choosing modern online services, programs, and applications for creating comics, as well as AR, which a teacher can use in his educational activities to study in primary school, we were guided by three main criteria:

- Service availability;
- Ease of use;
- Functionality.

As a result of a survey of primary education teachers, it was found that all services meet such requirements, but separately, for working with primary school students, the following services are most often distinguished: for teachers – Pixton; for schoolchildren's work – Marvel HD, and the app installed on the gadget – Comica.

3.2. Algorithms of development of educational materials in cloud services for the creation of comics

Let's start with Pixton comic book designer that allows you to create your stories almost from scratch. Allows you to customise models, background images, people's postures and emotions, and other image details, allowing you to create interactive comics. We start working at Pixton by choosing the type of user (teacher, pupil, parent, or business). We are interested in the user-teacher. A sign-up window appears, indicating that you can sign up for free. After registration, the user is flipped to the configuration panel. Suggested three steps to set up the service.

Step 1 – Watch an introductory video where pupils who work with this service share their impressions. After watching the video, click the "Next Step" button.

Step 2 – Familiarise yourself with the process of creating comics in the Pixton service. Press the button "Create a comic book" and go to the Pixton work field. The work field contains a page panel, four comic creation toolbars, a search bar, and a comic display area. In the first toolbar, select the background of the comics (for example, the pupil's room) and the main characters (the girl). Use the search bar to enter the name of the desired background or character (in English) or use the suggested groups (under the search bar). You can also upload your own materials – the camera icon under the comic book display area. Go to the toolbar to focus the image. Select the desired type of drawing (for example, "to the right"). Next, go to the text panel and enter the lines of the characters. This can be direct language (round dialog window), thoughts (window-cloud), shout (orange window), and whisper (dotted window). In the face setting panel, choose the desired emotion, for example, a thoughtful look. There is also the option to choose the character's look. The last panel is the position setting of the hero's body. Here you can choose the posture, the direction of movement and the possibility of holding objects in the left or right hand. In the upper-right corner, click the "Finish" button and go to the third step of the settings.

Step 3 – Enter the name of the comic book and choose a class. Next, the service offers to make a teacher's avatar, which is created similarly to the comic, following the instructions offered by Pixton. Then the user is moved to the personal account, where the existing 4 sections (created classes, student comics, class photos and printed versions of comics) are also displayed on the right-hand side, where the "Link for pupils" button is displayed, from which the teacher can invite students to the virtual classroom.

A fragment of work with the program is shown in figure 1.

Figure 1: Example of a comic created using the Pixton online service.

The following program, which was chosen by us, is excellent for both individual and group work of junior school students. It is not required to register and fill out various forms here. There is an opportunity to create the simplest comic with ready-made templates.

Write Comics – is the easiest service to create comics and stories. After all, this is just one page where you can set all the parameters of your plot: characters, background; text box.

We start by entering the name of the comic. Scroll the cursor further and select the characters in

our story, dragging them to the desired location in the comic book image area. Next, we choose the background, the place where the events of the story take place and enter the lines of the characters. Press the "Finish" button, the comic book is ready (figure 2).

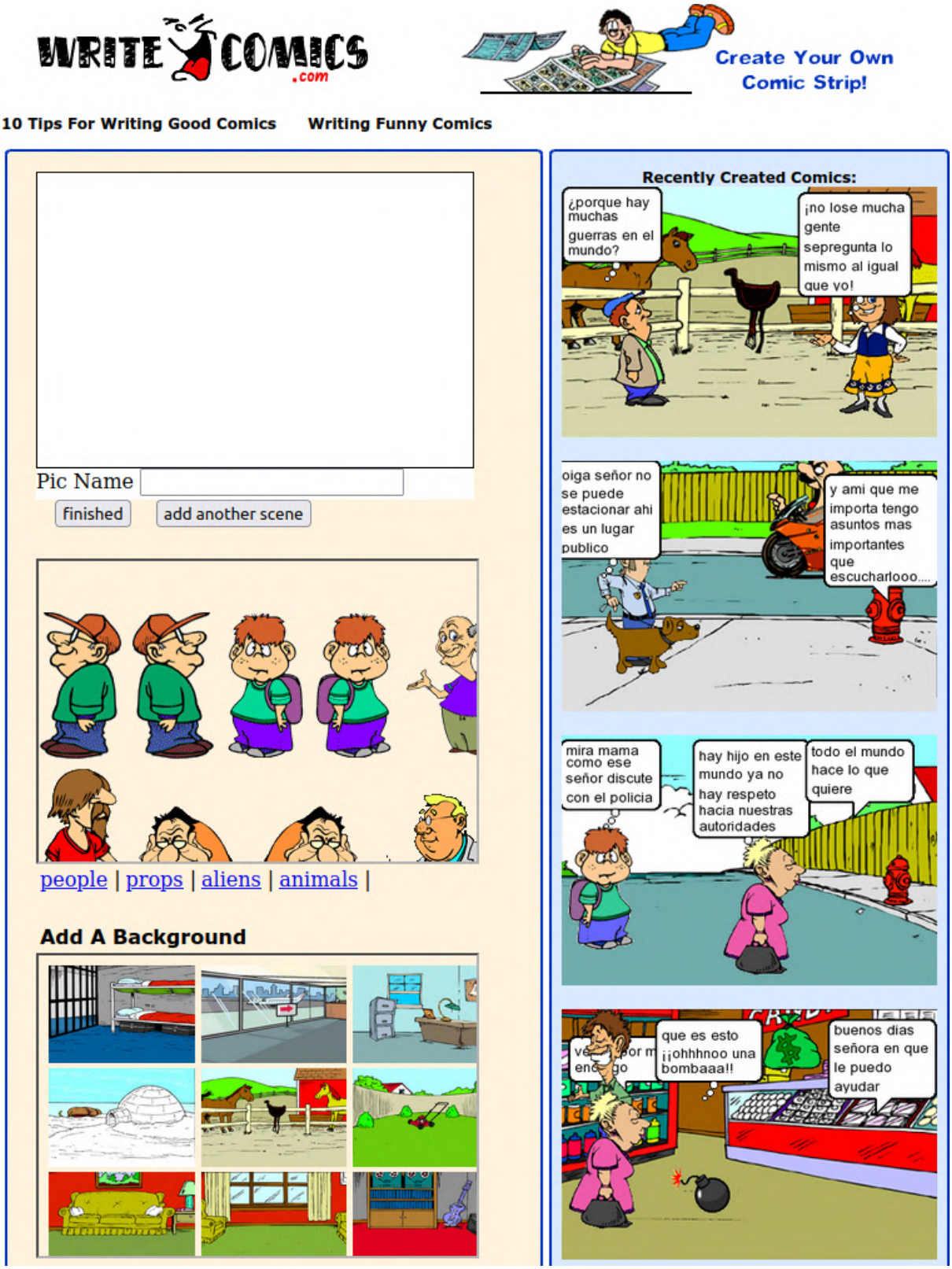

Figure 2: Fragment of work with the Write Comics service.

The next program that can be used to create comics in primary school is Comica. This is an app that

you can use to create a comic from your own photos. First, you need to download the app and install it on your gadget. It can be done in any user-friendly service (for example, in the Play Market).

Open the app and view the menu: Gallery – processing of one photo in the comic book editor; Camera – instant photo creation; Multi is the comic book editor.

Select "Multi", set the number of episodes in the picture (for example, 3 pictures), click on the field and select a photo from the gallery. We process the photo in the photo editor and choose the comic style. We individually adjust brightness and contrast, if needed. Next, we select the stickers and the comic book elements that the user needs. We do the same thing with the other two photos and create an episode of the comic. Download the comic book or share it (figure 3).

These services are quite convenient and understandable. The key value of resources is that in each program there is an opportunity to use ready-made templates of drawings, characters, backgrounds, signs, objects, etc., and to adjust them as needed. Working with these applications does not require special knowledge and skills, which is why it is an immense advantage. After all, even junior school students will be able to work in the service.

However, a significant disadvantage is that the developers of these online services and applications do not provide any instructions on how to work with them, so users have to deal with the way applications work by themselves.

3.3. Determination of the real state of readiness of teachers and pupils to use cloud services to create comics with AR elements

As a result of a survey of teachers, it was found that many people "do not know where to start" or consider it an impossible mission to create comics on their own. Many teachers know about cloud services, where you can find ready-made developments, but cannot select the appropriate comic for a particular learning situation or lesson. Most teachers do not know how to create comics, including with AR elements, using cloud services. These and some other circumstances keep many teachers from introducing this kind of teaching activity into teaching practice.

The analysis of the student survey also shows that within the informatics disciplines at the university, the use of cloud services for creating comics is not given due attention (table 2).

Table 2
Levels of readiness of teachers and students to use cloud services to create comics with AR elements.

Level	Characteristics of the level	Teacher skill level requirements
Elementary	Lower awareness of cloud services use, in particular AR. The teacher knows fragmentarily about the peculiarities of working with these cloud tools, but does not have a goal to learn how to create comics, cannot relate to the pedagogical expediency of their use.	Using the pedagogical capabilities of comics at the starting level, for example, conducting a lesson with a multimedia presentation or a ready-made animated resource already developed by a bulk product with AR elements. Using didactic materials with the help of cloud services, already developed and ready for the lesson comics.
Basic	Uses cloud services to create comics and AR at the demonstration level (presentations, pictures, slides). Formulates the request in relation to the specific topic of the upcoming lesson. Can associate with the pedagogical feasibility of their use. Can create his own comic book by analogy, including with AR elements, using step-by-step instructions.	Designing tasks for pupils using cloud services that involve the use of comics, including with AR elements in class and outside classroom hours, for example, for homework tasks related to search and selection of information, including on the Internet.
Creative	Actively uses cloud services to create new and use ready-made comics with AR elements. Disseminates its developments and participates in network communities.	Integrated use of cloud services and modern educational technologies: integrated lessons, project activities of pupils using comics with AR elements. Advise colleagues on using and working with resources to create comics with AR elements.

Figure 3: Comic Book Editor Comica.

As a result of the experiment, we found the willingness of teachers and students to use cloud services to create and use comics in educational practice. Appropriate criteria and levels of readiness have been identified and developed.

Level 1 – elementary, characterised by superficial knowledge of working with cloud services to create comics with AR elements;
Level 2 – basic, characterised by a focus on the use of cloud services at the demonstration level;
Level 3 – creative, characterised by the active use of cloud services to create comics with AR elements.

As a result of the questionnaires developed by us on the theoretical principles of using cloud services, tasks on working with cloud services and the results of self-assessment, the real state of readiness of teachers and students to use cloud services for creating comics with AR elements was revealed (table 3).

Table 3
The state of teachers and students readiness to use cloud services to create comics with AR elements.

Level	Students (84 persons), %	Teachers (28 persons), %
Elementary	63.1	67.9
Basic	26.2	25.0
Creative	10.7	7.1

According to the results of the study, students and teachers showed approximately the same ability to use cloud services. Most students (63.1% of the total number of respondents) and teachers (67.9%) have an elementary level of readiness. Only 10.7% of students and 8% of teachers reached the creative level.

The results confirmed the problem of the preparation of future primary education teachers for the use of cloud services for creating comics with AR elements in professional activities.

To compare the results obtained, we used the Pearson criterion χ^2. For this purpose, statistical hypotheses are formulated:

H0 – the level of students' readiness to use cloud services does not exceed the level of teachers' readiness;
H1 – the level of students' readiness to use cloud services exceeds the level of teachers' readiness.

The obtained empirical value of the Pearson's criterion $\chi^2 = 0,932$ we compared with the tabular values (for the number of degrees of freedom 2 (table 4).

Table 4
Critical value of the Pearson criterion χ^2.

χ^2 $(p = 0.05)$	χ^2 $(p = 0.01)$
5.991	9.21

Thus, we accept the hypothesis H0 that the level of students' readiness to use cloud services does not exceed the level of teachers' readiness.

Note that given the insufficiently large sample size, we certainly do not claim a strong scientific justification for the state of this readiness in the context of the activities of all teachers and students of primary education. The data obtained, rather, indicate an overall trend regarding the research problem and require finding ways to improve it.

3.4. Educational and methodological support for teachers

As a result of a survey of teachers, we identified fundamental problems with the use of cloud services. Among them, we can note the lack of time for self-education and learning.

Taking into account this problem, Iryna R. Chopyk have developed a website, where the necessary information was collected and methodological recommendations were prepared on the organisation of the teacher's work using cloud services for creating comics in classes in primary school (https://blogger090.wixsite.com/comics).

This educational website helps primary school students and teachers improve their own competencies in using cloud services to create comics.

Thus, the work of the website is aimed at helping the primary school teacher to create their own development of interactive educational content, as well as using them in lessons in primary school. The website contains 4 sections:

1. Homepage;
2. “About the project”;
3. “For teacher”;
4. Feedback.

The homepage provides a brief description of the project, links to articles, and a contact window where anyone can contact the author of the website if needed. At the top, the site menu is presented, which is intuitive and allows the user to go to the following categories (figure 4).

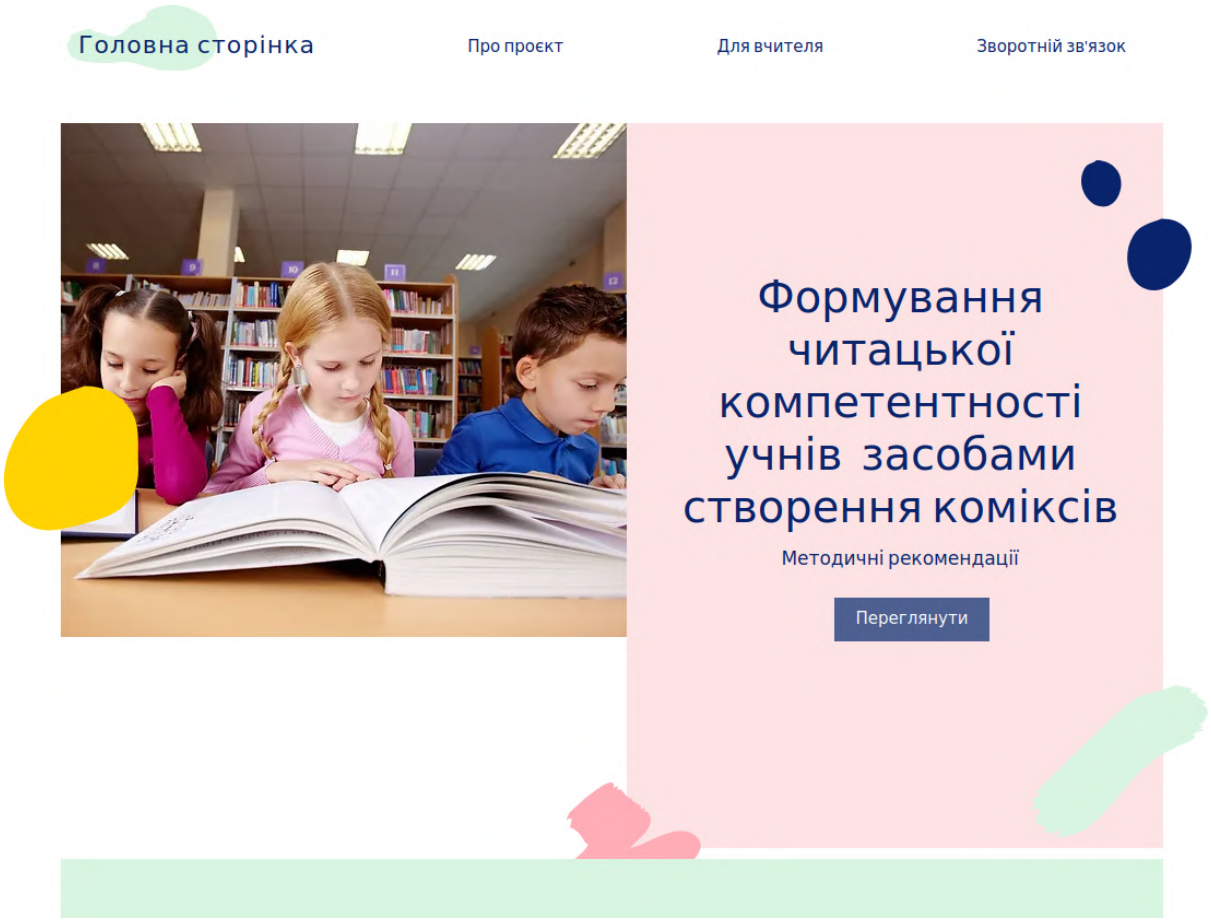

Figure 4: The main page of the developed website.

The section “About the project” provides basic information about the master’s study, the purpose of creating the site, what its work is aimed at, and short theses “Here you will learn”:

- What is a tutorial comic?
- How to work with online services to create comics?
- How to organise work in the classroom using the comic book technique?

The category “For the teacher” contains three subdivisions:

- “Theoretical information”, which provides information about what is the process of reading and its importance in human life, reveals the essence of basic concepts, describes the reasons for the popularity of educational comics, and identifies the strengths of their application in education;

- "Services", where the user can find a list of free and available online services for creating their educational comics. Separately, in the section, there are links to instructions for the described services.
- "Methodological recommendations", which provides practical advice and methodological recommendations for working with the technology of using comics in primary school. The unit provides a step-by-step description of the technology of working with comics, describes the preparatory work with pupils, defines the rules for selecting the subject of comics, provides examples of building educational tasks for working with comics and links to online resources for creating educational comics.

Looking at the "Services" section in more detail, users can see the rating from the TOP-3 online services for creating educational comics. This rating of tools was formed based on three key criteria: functionality, affordability (all services are free) and ease of use of the service for both teachers and pupils.

Each presented service contains instructions for use, which the user will be able not only to view but also to download to himself on a PC as a MS Word document.

Each service title contains a link to its main page, which the user of the site will be able to start working on creating his own educational comic, using the downloaded instructions and methodological recommendations presented on the educational website.

Thus, the work of the educational website is aimed at helping teachers of primary education in the development of relevant educational comics using online services Pixton, Write Comics and Comica for conducting lessons in primary school, as well as for methodological support of educators.

4. Conclusions

1. It has been established that the use of AR-enhanced comics in primary school is one of the effective didactic means that increases children's interest in learning and allows for the simplification, visualisation, and virtualisation of complex information. As a result of the analysis of modern cloud services, programs and applications for creating comics, their advantages are highlighted: the availability of services in material terms; a simple interface; the use of templates; the possibility of creating a completely new product and distributing materials; versatility. The major disadvantages have been clarified: a foreign language interface, the need for preliminary preparation for working with them; conversion. The functionality of AR programs for creating content based on comics (Vuforia, EasyAR, Maxst, ARCore, AR.js, 8th Wall) is analysed. As a result of a survey of 28 primary school teachers, considering availability, ease of use and functionality, the most popular cloud services are highlighted: for teachers – Pixton; for pupils – Marvel HD and the app installed on the gadget – Comica. Algorithms for the development of educational materials in these cloud services for the creation of comics are presented.
2. The levels of readiness for the use of cloud services for creating AR-enhanced comics (elementary, basic, creative) are highlighted. It is established that most teachers and students have an elementary level of readiness. To improve the real state of readiness of teachers and students to use cloud services, an educational website has been developed. Its goal is to help primary school students and teachers improve their competencies in using cloud services to create comics. Methodological recommendations on the use of comics in primary school using digital technologies have also been developed.
3. The next step of the study will be the implementation of the developed methodological recommendations in the practice of university education, in the system of teachers' certification training, as well as further monitoring of the readiness of students and teachers to use cloud services to create AR-enhanced comics in primary school.

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