

Digital transformation of the thesis preparation and defence: case of Zhytomyr Polytechnic State University

Andrii V. Morozov¹, Tetiana A. Vakaliuk^{1,2,3,4}, Serhii S. Duniev¹, Yurii O. Kubrak¹ and Mykhailo G. Medvediev⁵

¹Zhytomyr Polytechnic State University, 103 Chudnivsyka Str., Zhytomyr, 10005, Ukraine

²Institute for Digitalisation of Education of the NAES of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine

³Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine

⁴Academy of Cognitive and Natural Sciences, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine

⁵ADA University, School of Information Technologies and Engineering, 61 Ahmadbey Aghaoghlu Str., Baku, AZ1008, Azerbaijan

Abstract. The situation in which Ukraine has found itself since February 2022 has also contributed to the development of digitalisation of all processes in higher education. Thus, higher education institutions have forms of control such as course design, diploma design, various practices, etc. In this context, the issue of digitalising the process of diploma design is the most relevant since explanatory notes to qualification works must be kept at the university upon graduation and go through several stages to be admitted to defence. The article presents the experience of the Zhytomyr Polytechnic State University in digitalising the process of diploma design. The procedure of preparing and defending a qualification work with a detailed description of each step is presented. The article discusses the peculiarities of implementing an electronic digital signature in the Zhytomyr Polytechnic Portal¹.

Keywords: digital transformation, higher education, qualification papers, thesis defence, electronic documents, electronic signatures

1. Introduction

Recent events in Ukraine, including the pandemic and war, have accelerated the digital transformation of all educational sectors, with higher education being no exception. Unlike secondary schools, many processes in higher education were traditionally conducted in person. However, the circumstances that Ukraine has faced since February 2022 have further propelled the digitalisation of all aspects of higher education.

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✉ morozov@ztu.edu.ua (A. V. Morozov); tetianavakaliuk@gmail.com (T. A. Vakaliuk); ssduniev@gmail.com (S. S. Duniev); kubrak79@ukr.net (Y. O. Kubrak); miserablewisdom@ukr.net (M. G. Medvediev)

🌐 <https://ztu.edu.ua/teacher/323.html> (A. V. Morozov); <https://acnsi.org/vakaliuk/> (T. A. Vakaliuk)

📞 0000-0003-3167-0683 (A. V. Morozov); 0000-0001-6825-4697 (T. A. Vakaliuk); 0009-0006-2041-0885 (S. S. Duniev); 0000-0002-1122-7580 (Y. O. Kubrak); 0000-0002-3884-1118 (M. G. Medvediev)



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Higher education institutions employ various assessment forms such as course projects, diploma projects, and diverse internships. Among these, the digital transformation of diploma projects is particularly pertinent. This is because the explanatory notes to qualification works, which must be stored at the university upon graduation, must undergo several stages before they are approved for defence.

Consequently, it was resolved to elevate the preparation for the defence of diploma projects through digital transformation amidst martial law.

Based on the legislation of Ukraine [15, 16], in 2022, Zhytomyr Polytechnic issued an order to experiment with the use of digital documents and electronic signatures during the diploma design and defence of qualification works in the speciality 121 “Software Engineering”. By [15], an original digital document is an electronic copy of a document with mandatory details, including the author’s electronic signature. The legal force of such a document cannot be denied solely because it has a digital form [15].

2. Theoretical background

Sych, Khrykov and Ptakhina [10] have identified trends in the development of higher education due to its digitalisation, among which it is worth paying attention to some of them. Namely, educational digital technologies have great potential in assessing and accounting for educational activities, introducing a mixed form of the educational process, and practical orientation of educational systems. As a result, the authors conclude that the modern digital transformation of education is the primary means of developing higher education and extends to all areas of activity of contemporary universities [10].

Bygstad et al. [4] presented the digital education space in the form of a diagram (figure 1).

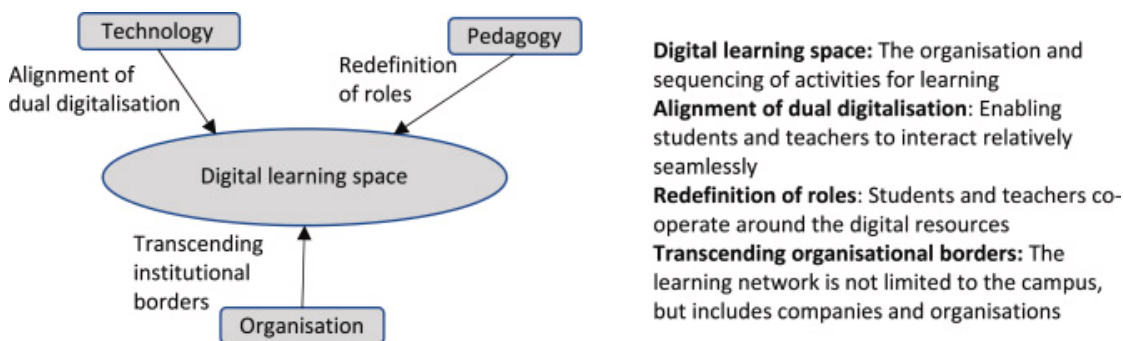


Figure 1: Digital learning space [4].

Scientists define the digital learning space as a set of three components: technical, pedagogical, and organisational. The authors describe the technical component as combining digital education and digital subjects. They see the pedagogical element for the redefinition of roles between participants in the educational process in the digital learning space. The researchers see the organisational component in the interaction of institutions with the broader society through the digital learning space [4].

Vdovychyn, Kohut and Sikora [14] considers the feasibility of using Google's digital tools to organise the educational process in crisis social situations (the authors distinguish between the pre-COVID, COVID-19, and military periods of higher education in Ukraine). The researchers argue that distance learning contributes to the safety of the subjects of the educational process. After all, distance learning provides fast communication, operational planning, re-planning, documentation, and storage, ensures student access to learning materials, and diversifies ways to achieve results.

Belousova, Belousov and Narkevich [2] define the areas of influence (professional, environmental, functional) of the virtual environment on the university and propose their methodology for assessing the level of digitalisation of higher education institutions. To determine the level of university digitalisation, researchers suggest three groups of indicators: digitalisation of the educational process, digital literacy of students, and digital literacy of teachers.

The possibilities of using various digital educational tools and digital learning platforms in the educational process are considered by Ciarko and Paluch-Dybek [5]. The author also cites several problems that may arise in such implementation.

Various scholars have also conducted studies of distance learning [13] and the possibility of using multiple types of digital educational resources about the educational process as part of the digital transformation of the educational process [12], didactic aspects of the digitalisation of university education [1, 11], and the global digitalisation of the academic and scientific space [6].

The article [3] discusses the advantages and efficiency of electronic document management systems (EDMS) and how they can be implemented in companies of different sizes. Burtylev et al. [3] propose a method for implementing EDMS that involves using a system of requirements to ensure the effectiveness of electronic document management.

However, research shows that the issue of digitalisation of the process of admission to the defence of theses has not yet been studied.

3. Results

As part of the digital transformation of all educational processes at Zhytomyr Polytechnic State University, an information system was developed to include a module responsible for the diploma design process, from accepting papers for the defence to the actual reason.

The digitalisation of the diploma design process makes it possible to significantly increase the efficiency of the process of writing a qualification work, switch to electronic documents and eliminate the need to use paper copies of documents, speed up communication between all participants in this process, prevent potential corruption, and organise the practical work of the examination committee during defences. The most important advantage provided by the proposed approach and the developed software product is to offer a real possibility of remote protection of qualification works in conditions when the higher education student, supervisor, reviewer, chairman, and members of the examination committee are in different places and communicate using Internet communication and have the opportunity to familiarise themselves and work with documents (qualification work, review, feedback, certificate of verification of employment for borrowing, etc. All papers are signed with electronic signatures and uploaded

to the information system “Zhytomyr Polytechnic Portal” (from now on – IS). This allows for organising an electronic repository of qualification works and related documents.

By digitalisation of the diploma design process, we mean the complete transition of all stages of diploma design from paper to digital, including submission of the work in digital format, digital signature, review by the supervisor and return for revision, digital signature of the supervisor, generation of supervisor’s feedback and external reviews with digital signatures, etc.

An electronic digital signature is data in electronic form obtained from cryptographic transformation, which is attached to other data or documents and ensures their integrity and author identification [9].

According to the Law of Ukraine “On electronic identification and electronic trust services”, an electronic signature - electronic data attached to or logically linked to other electronic data and used by the signatory as a signature [17].

As stated in [8], the following requirements must be met when storing electronic documents:

1. The information contained in electronic documents must be available for further use.
2. It must be possible to restore an electronic document in the format in which it was created, sent or received.
3. If available, information must be stored to establish the origin and purpose of the electronic document, as well as the date and time of its sending or receiving.

Writing and defending qualification papers is divided into eight steps (figure 2). However, they are preceded by a preparatory stage where the secretary of the examination board enters information into the IS. It involves entering the composition of the examination committee (figure 3) and, for each higher education student, the topic of the qualification work, supervisor, and reviewer.

Figure 4 shows the view of the page for viewing the list of qualification works by the secretary of the examination committee. It is possible to select the speciality and educational program, educational degree, and graduation date of higher education applicants.

After the secretary of the examination board adds the initial information, the relevant higher education student, supervisor, consultant, and reviewer members of the examination board have access to the Qualification Papers module. There are eight stages for each paper:

- Uploading a qualification paper
- Qualification paper for supervisor’s review
- Qualification work for approval by the head of the department
- Qualification work for checking for borrowing
- Preparing a review and review of the work
- Obtaining admission to the defence
- The work is admitted to the defence
- Completed training

At each stage, the following roles of the subjects of the educational process are envisaged:

- Higher education applicant – uploads the qualification work, can withdraw it for revision, can view all documents that will be attached at each stage;

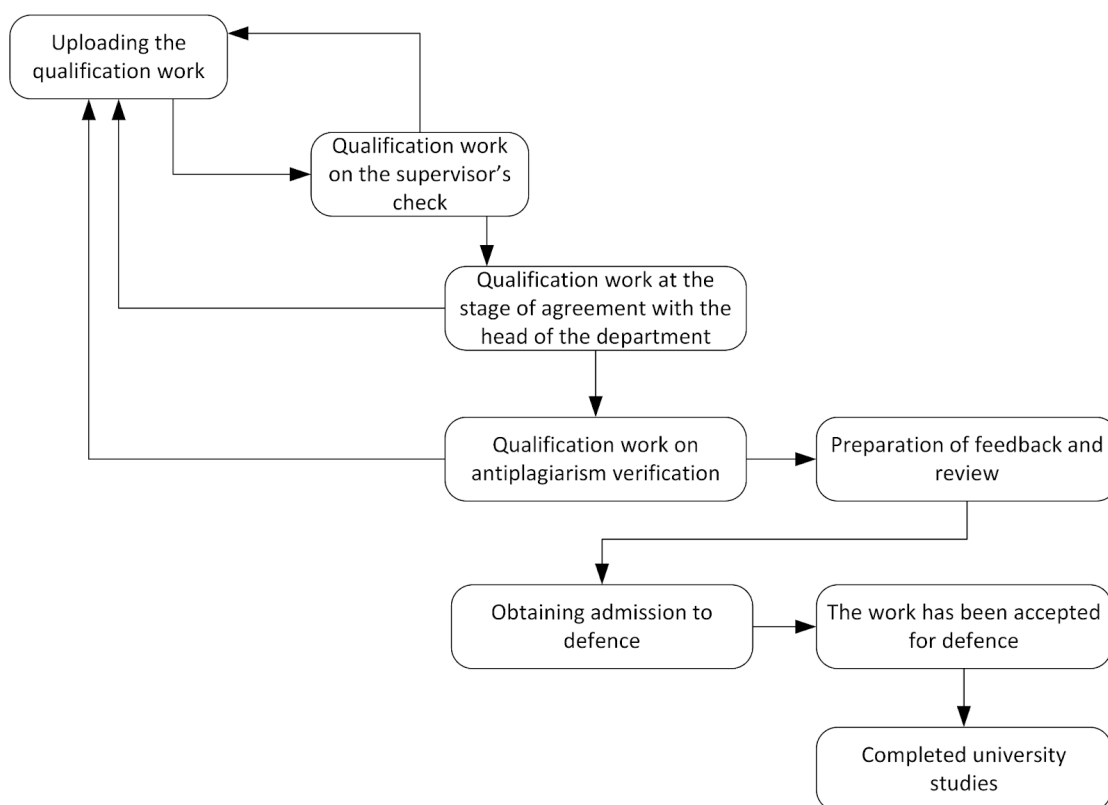


Figure 2: Procedure of the preparation and defence of qualification work.

- Supervisor/consultant – reviews the qualification work, has the opportunity to send it back for revision, noting deficiencies, or sign the work and submit it to the next stage; prepares and signs a review of the qualification work; has the opportunity to review all documents related to the qualification work;
- Head of the department – can view the general list of higher education students and the stages of each qualification work; has access to view all qualification works and accompanying documents; for each work that is approved by the head, can put their electronic signature or send the work for revision, noting the shortcomings;
- The employee responsible for checking the work with anti-plagiarism systems – uploads the qualification work file to the specialised software used by the higher education institution to check qualification works for borrowing; generates and uploads borrowing certificates to the IS; has the opportunity to return the qualification work for revision in case of non-compliance with regulatory documents;
- Reviewer – can review qualification papers and accompanying documents and download the review file;
- Secretary of the Examination Board – has full access to view all documents for each qualification work; enters information about the supervisor, reviewer, and topics of qualification works into the IS; checks documents and admits to the defence; enters

The screenshot shows a web interface for forming the composition of an examination committee. It features a table with the following structure:

#	Id	Member of the EC	Non-voting observer (from stakeholders)	
1		Member 1	Member of the EC	
2		Member 2	Member of the EC	
3		Member 3	Member of the EC	
4		Member 4	Observer	
5		Member 5	Member of the EC	
6		Member 6	Observer	

Below the table is a green button labeled '+Add EC member'. At the bottom of the form are three buttons: 'Save' (blue), 'Save as a copy...' (light blue), and 'Cancel' (red).

Figure 3: Formation of the composition of the examination committee.

information about the date, time and place of the defence into the IS; enters information about the grade received by the applicant at the defence;

- An employee of the examination board – has the opportunity to review qualification works that are allowed for defence and all accompanying documents.

At the first stage of the process, the higher education applicant uploads the qualification work, which is signed with an electronic signature, through a personal electronic account (figure 5).

Next, the qualification work is submitted to the supervisor for consideration. At this stage, the higher education applicant is displayed an informational message about the need to wait for the decision of the work supervisor. The applicant can also withdraw the work and return to the previous stage, "Uploading qualification work".

For the work manager in the IS, the main page and the left menu display the number of tasks waiting for review and feedback. For convenience, the numbers for the supervisor in the left menu are displayed in different colours: the number of tasks pending review is in red, and the number of functions for writing a review is in orange. A list of tasks assigned to the supervisor will be displayed by clicking on the corresponding menu item. If this user has other roles, they will also see information about the number of pending tasks (figure 6).

After selecting the qualification work, you will be taken to a page that displays general information about the work and learning outcomes of the higher education applicant, including grades for the entire period of study and summary statistics of tests and exams. For the convenience of viewing the qualification work and, at further stages, the accompanying documents,

Specialty
121 Software engineering X

Educational program
Choose an educational program ...

Educational degree
All educational degrees X

Release date
2023-06-30 X

Qualification works (the role of EC secretary)

List of students

#	Date	Name of the student	Status	Git Group	Supervisor	Reviewer	The topic of the work
16	2023-06-09 13:14:00	Student 4	Go to Loading qualification work	IPZ-19-3	Supervisor 4	Reviewer 4	Work schedule automation
14	2023-06-08 13:51:24	Student 3	Go to Loading qualification work	IPZ-19-3	Supervisor 3	Reviewer 3	Application for planning entertainment and hotel menus
9	2023-06-08 13:23:19	Student 2	Go to Loading qualification work	IPZ-19-3	Supervisor 2	Reviewer 2	A website for selling online courses
1	2023-06-09 12:13:00	Student 1	Go to Loading qualification work	ZIPZ-19-1	Supervisor 1	Reviewer 1	Service for organizing video online training between the trainer and the participants. Implementation using AWS Serverless approach and PWA technology

Figure 4: Viewing the list of jobs by the secretary.

it is possible to view each document directly in the browser and the ability to download the copy by clicking on the appropriate button (figure 7).

At the bottom of the window, a panel is displayed that allows you to notify the higher education student and record the decision made by the supervisor of the qualification work in the IS. If the work meets all the requirements, the supervisor must sign it with an electronic signature, upload the file to the appropriate form, and click the button to transfer the work to the next stage (figure 8).

If the work contains deficiencies and needs to be revised, the supervisor must describe them appropriately and click the button to return the work to the applicant for revision (figure 9).

After that, the applicant will see a notification in the electronic cabinet and will be able to download a new version of the qualification work.

In many higher education institutions, it is common practice to check qualification papers for compliance with formal requirements, which the relevant authorised persons carry out. We will call this process the stage of standard control of qualification works. In the context of digitalisation of the process of preparation and defence of qualification works, the stage of normative control should be provided after the stage of approval of the qualification work by the supervisor and before the stage of revision of the work by the head of the department.

At the stage of normative control, the authorised person checks the qualification work for the correctness of the work, the presence of all necessary sections and the availability of mandatory supporting documents and materials (for example, for IT specialities - Git repositories with software code). In case of deviations from the approved requirements, the authorised person describes all the identified shortcomings in the text field and returns the work for revision. Next, the student must upload a new version of the qualification work and go through the approval stage by the supervisor. If the work meets all the applicable requirements, the work is transferred to the stage of approval by the head of the department.

Zhytomyr Polytechnic
Exit

Qualification work

Current status of qualifying work

Uploading qualification work >	Qualification work on the supervisor's check >	Qualification work at the stage of agreement with the the head of the department >
Qualification work on antiplagiarism check >	Preparation of feedback and review >	Obtaining admission to defence >
The work has been accepted for defence >	Completed university studies >	

Uploading qualification work

Attach the file with the qualification work in PDF format .

↑ Select a file

Selected file
 File name: **master.pdf**
 Size: **2.078 MB**

In the next step, the work will be signed with an electronic signature.
 To do this, select an electronic signature and follow the instructions that will be displayed.

Reading the private key

Select the type of private key carrier, private key, enter the key protection password and click "Read"

Type of private key carrier:

- File media (flash drive, CD, SD card, etc.)
- Protected media (electronic key Almaz-1K, Crystal-1, Hryada-301, ID card, etc.)
- Carrier included in the service

Qualified e-mail provider. trust services:

КНЕДП "MASTERKEY" ТОВ "АРТ-МАСТЕР"
▼

Private key (Key-6.dat, *.pfx, *.pk8, *.zs2 or *.jks):

Select

Key protection password:

Read

Figure 5: Interface for uploading a qualification work by a higher education student.

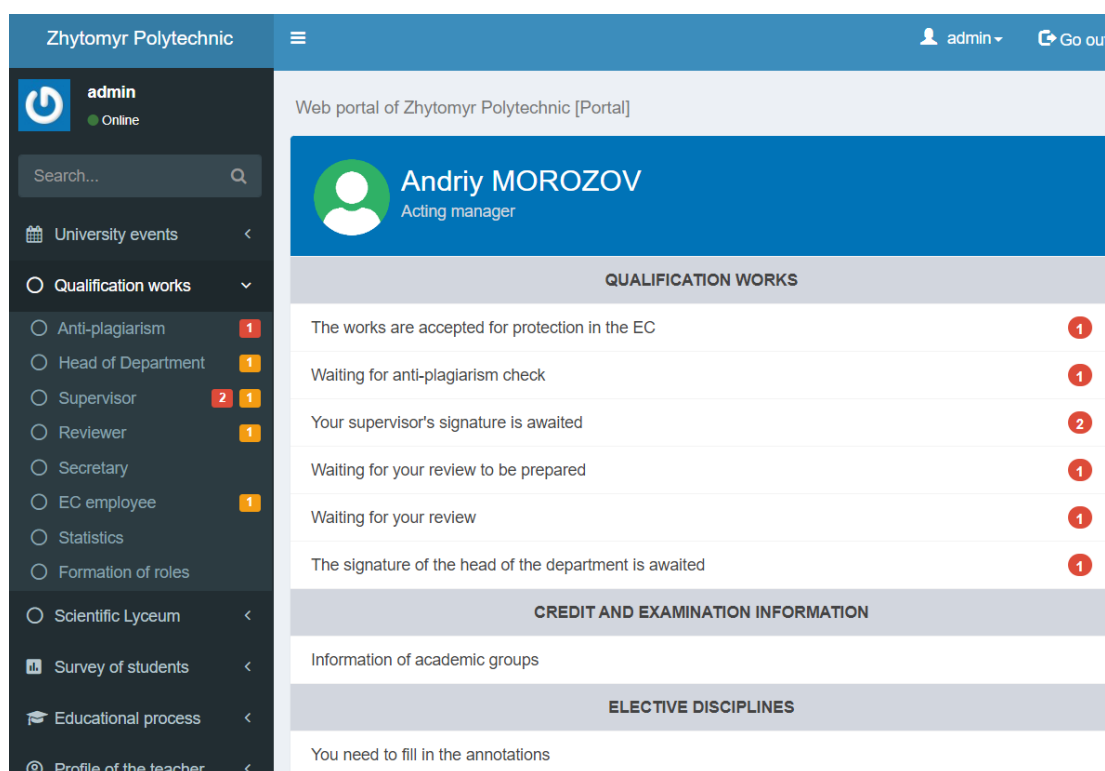


Figure 6: Home page of the information system “Zhytomyr Polytechnic Portal”.

If the supervisor approves the work, it is transferred to the next stage – approval by the head of the graduating department. At this stage, the head of the department has two options. The first option is to approve the work, sign it electronically, and submit it to the next stage. The second option is to return the result for revision to the higher education student with an indication of the shortcomings. The interface for the head of the department is implemented similarly to the interface of the head (figure 8, 9).

If the head of the department has passed the work to the next stage, the result is placed in the queue for checking for borrowings. At this stage, the responsible person uses a particular software product to analyse the content of the qualification work for borrowings from other sources. If borrowings are found, the amount and sources of each borrowing are determined. The information is formalised in the form of two certificates. The first certificate is generated in the software product used for the verification. The second certificate is a conclusion on the compliance of the work with the internal regulations of the higher education institution and the legislation in general. Each document is electronically signed and uploaded to the IS, which allows all participants in preparing and defending a qualification work to work with the documents as official (figure 10).

Suppose the qualification work is inconsistent with the regulatory framework and legislation. In that case, the result is returned to the higher education applicant for revision and must go through all the previous stages, starting with the first. If the work is found to comply, it proceeds

General information | Status history | Learning outcomes 4 | Education statistics

Name of the student Student 1 06/24/2023 20:47

Group IPZ-19-3 Work

Form of education Day

The topic of the work Development of a mobile application for recognizing emotions

Supervisor Supervisor name

Reviewer Reviewer name

Current status Qualification work on the manager's check

Status date 06/24/2023 20:47

Status description

At this stage, the supervisor must review the work, and in case of deficiencies, return the work for revision, notifying the student about existing problems in the work. If the qualifying work meets all the requirements, then the work must be approved and transferred to the next stage (approval by the head of the department).

Viewing documents in the browser:

Work

Downloading documents:

Work

Versions of qualified work with electronic signatures:

06/24/2023 20:47

Work (STUD)

Figure 7: Viewing general information about the work by the supervisor.

Performing an operation on the work

✓ Approval of work

✗ Returning the work for revision

In order to approve the work, you need to perform the following steps:

1. Download the student's work with his electronic signature
2. Sign the work through the Diya portal service
3. Attach the signed file to the following field and click the green button:

Choose file

No file chosen

Transfer the signed work to the next stage

Figure 8: Interface for approval of qualification work by the supervisor.

to the next step – preparation of the supervisor’s feedback and writing a review by the reviewer.

For the supervisor (figure 11, 12) and the reviewer, forms have been implemented that they must fill out in the IS. After filling out the forms, it is possible to generate PDF versions of the feedback and review, which must be downloaded and signed with an electronic signature and uploaded to the IS.

After generating and uploading the signed feedback and review to the IS, the work proceeds

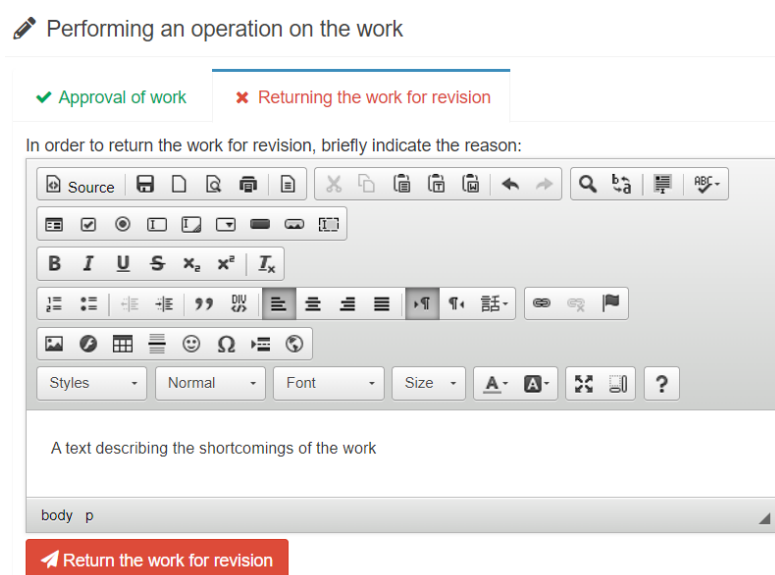


Figure 9: Interface for returning work for revision.

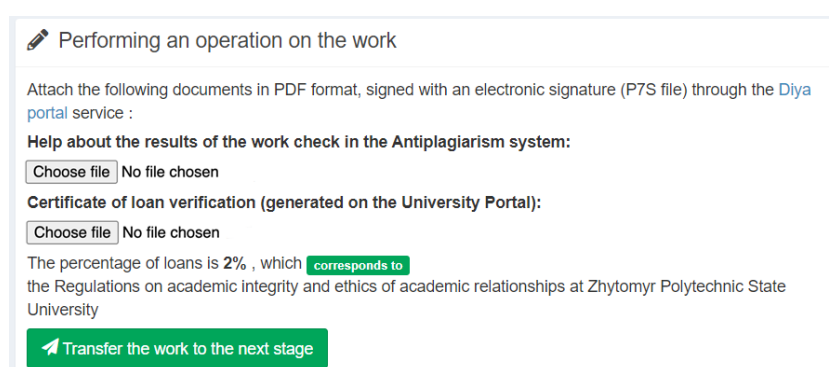



Figure 10: Interface for uploading documents for checking qualification work for borrowing.

to the next stage – obtaining admission to the defence. At this stage, the secretary of the examination committee checks the conditions for securing access to the reason (internal regulations may set these conditions and may differ from one higher education institution to another). If the applicant cannot be admitted to the security, the reason is indicated in the appropriate field of the form (figure 13).

Suppose a higher education student is admitted to the defence. In that case, the secretary must additionally fill in the fields that indicate the date and time of the reason, the link for online connection, or the place of the defence (figure 14).

Upon completion of the defence, the secretary of the examination committee enters the grade received by the higher education student in the appropriate field in the IS.

An essential element of designing the Zhytomyr Polytechnic Portal was selecting and imple-

 Forming feedback on work

Topicality

The number of pages in the work	The number of tables in the work	Number of illustrations in the work	Number of applications in operation	Number of literary sources
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

The content of the sections of the work (indicate for each section which questions are investigated and for what purpose)

Conclusions (reasonableness, theoretical and practical significance)

List of used literary sources (extent and completeness of processing according to the content of the work)

Annexes (list of annexes and completeness of their processing according to the content of the work)

Tables and illustrations (purpose of tables and their use to confirm research in work)

Figure 11: Formation of the supervisor’s feedback (part 1).

Quality of work design

General comments and elaboration of preliminary defense comments

The student's attitude towards the completion of the final qualification work

The student demonstrated the ability to select the necessary literature, information base, analyze them, draw appropriate conclusions and formalize his research in the final qualification paper

The work is written at the level

Can the work be admitted to the defense?

Figure 12: Formation of the supervisor’s feedback (part 2).

menting an approach to storing documents in electronic form.

For storing qualification papers and accompanying documents on the server, the CADES format (CMS Advanced Electronic Signatures, CMS – Cryptographic Message Syntax) with the DSTU 4145 signature algorithm with signature and data storage in one file (enveloped) and the CADES-X Long signature format was chosen. The advantage of this approach is storing the original content and the overlaid signature (or several overlaid signatures) in one P7S file.

Several superimposed signatures are used when writing a qualification work. The file signed

Performing an operation on the work

Link to the Git repository: **Has the Git repository passed validation?**

Has an application for the protection of qualified work (percentage) been issued?

To admit a higher education student to the defense of a qualifying work

If there are other reasons for non-admission, they must be entered in the following field:

Source 🗑️ 📄 🔍 📁 📁 📁 📁 📁 📁 📁 🔍 🔍 🔍 🔍

B I U S x₂ x² I_x ☰ ☰ ☰ ☰ ☰ ☰ ☰ ☰ ☰ ☰ ☰ ☰ ☰

📧 📧 📧 📧 📧 📧 📧 📧 📧 📧 📧 📧 📧 📧 📧 📧 📧 📧 📧

Styles Format Font Size A- A+ 🔄 📄 ?

Figure 13: Form of admission of a higher education student to the defence.

Date of assigned defence

📅 ✖

Time of assigned defence

🕒

Links for remote defence:

Audience for face defence:

Defense score (on a 100-point scale):

Figure 14: Entering information about the date, time, and place of defence.

by the student, provided there are no comments from the supervisor, is downloaded from the portal and signed by the supervisor. At the stage of approval by the head of the department, similar actions are performed. The result is one file with three P7S electronic signatures.

The borrowing certificate, review and feedback are generated as a PDF file downloaded from the portal and signed with a CADES electronic signature with the “enveloped” type and CADES-X Long format.

At the same time, this approach has its advantages and disadvantages. The disadvantages include downloading a file from the portal and transferring it to an external service for signature application. At this stage, the user may accidentally (or even intentionally) take another file (or another version of the same file), sign it and upload it to the portal. Therefore, each subsequent stage requires manual control of file signatures.

Another disadvantage is the need to store three copies of the qualification work with different sets of signatures:

- The work signed by the student.
- The student and the supervisor sign the work.
- The student signs the work, the supervisor and the head of the department.

This is necessary to ensure the work can be returned to the previous stage when the signature added at the current stage is cancelled.

To improve the procedure for signing files and eliminate the above shortcomings, the signature type was changed to “detached”, and a widget for signing files directly on the portal was introduced. This ensures that the original file and the file with the signature data are stored separately. Using detached signatures to sign qualification papers will increase the number of files on the server for each qualification paper from one to four. The following will be stored separately: the original qualification work file, the student’s signature, the supervisor’s signature, and the head of the department’s signature. The review, feedback, borrowing check certificate, and associated signature files will also be kept separately. Separate storage of the original file and signatures will allow for the “removal” of electronic signatures when the work is returned to the previous stage by deleting the files with the relevant signatures.

Implementing the signature widget directly on the portal eliminates the need to download the file and transfer it to an external service.

4. Discussion

Using the proposed IS module, during 2022-2023, 148 bachelor’s degrees and 31 master’s degree qualification works were defended in the speciality 121 “Software Engineering”. All participants in preparing and supporting qualification works could obtain electronic signatures through Internet banking systems or the State Tax Service to sign documents.

At the same time, in the process of implementing this module of the information system, some problematic issues were identified:

- the need to conduct training and consultations on the use of electronic signatures for students and teaching staff;
- the difficulty of obtaining electronic signatures in Ukraine for foreign applicants;
- dependence on the Internet connection (in case of loss of connection, it is impossible to access electronic documents).

5. Conclusions

Zhytomyr Polytechnic State University has implemented a digital approach to creating and defending qualification papers. This method, tested between 2022 and 2023, has enhanced the quality of the papers and related documents. The shift in focus from generating physical copies to concentrating on the quality and content of the documents is the primary reason for this improvement. If there are any shortcomings, reprinting the entire document is unnecessary; a new version can be created and signed digitally. This eliminates the necessity for in-person collection of signatures from the supervisor, reviewer, and department head, significantly reducing the time spent on document preparation and signing. Future research will involve an external expert assessment of the portal and its modules.

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