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Computational Approaches to Ancient Manuscript Digitization and Pedagogical Implementation

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Abstract - **The current paper addresses the challenges of digitalizing ancient documents, particularly those with multilingual and non-standard scripts, by refining AI-based models and image processing systems. The importance of this study is based on the weaknesses of conventional OCR systems to work with damaged and complex texts. Text recognition was improved with the help of AI-based models, and image processing was improved with the help of advanced image processing. The paper also looks at the ways these digitized manuscripts may be integrated in an interactive and collaborative model of education. Quantitative approach used for this research. The research finds that AI-based models are much more effective than traditional OCR tools and have an average accuracy of 95.4% compared to 81.2. The cool image processing techniques helped a great deal in enhancing the legibility of the texts and minimizing distortion (p-value < 0.01). There was also a high engagement, comprehension, and retention of students with an effect size of 1.6 in the experimental group where digitized materials were applied. These findings indicate the potential of AI and enhanced processing not only to conserve old texts but also to enhance educational success, which offers a good solution to the issue of manuscript digitization and teaching.**

Keywords: **Manuscript Digitization, AI Models, Image Processing, OCR, Multilingual Scripts, Educational Integration, Student Engagement**

I. INTRODUCTION

The process of digitizing old manuscripts is an important means of preserving culture since it will not only retain the historical texts to be used by subsequent generations but will also be more accessible to scholarly research and individuals. The importance of this process has been growing because manuscripts with multilingual and non-standard scripts are approaching a serious crisis in digitalization because of their deterioration over the years, complicated structure, and linguistic peculiarities. Conventional algorithms, like Optical Character Recognition (OCR), tend to fail with deteriorated, damaged or non-standard text, highlighting the importance of more sophisticated computational strategies. The recent achievements in the field of Artificial Intelligence (AI) and image processing methods contribute to the positive perspectives on solving these issues, as they enhance text recognition, semantic comprehension and repair of damaged manuscripts. The merging of AI and digitization also facilitates new possibilities in terms of increasing the educational value of these sources. Digitization of manuscripts integrated into the learning platform can create the opportunity to build an interactive and collaborative learning experience and increase student interest in historical materials. In this paper, the author discusses how Artificial Intelligence (AI) can be used in order to make historical manuscripts, especially those in Cyrillic script, more digital.

The authors apply AI models to address the problem of the script complexity, degradation, and recognition accuracy, thereby enabling historical texts preservation and accessibility (Moutsis et al., 2025). This paper explains how technological interventions, especially collaboration-based ones, can redefine the scholarly practice in the analysis of ancient texts. It emphasizes the incorporation of digital technology in enriching the collaborative nature of the textual analysis and in enhancing the accessibility and interpretation labor (De la Flor et al., 2010). The authors mention the COVID-19 pandemic has increased the use of computational tools in archiving and education of cultural heritage. They discuss how digital transformation is transforming the archival practices and education systems to be more flexible, more accessible and collaborative in the digital era (Giannini & Bowen, 2022).

The technical and legal issues of the digitization of the Javanese manuscripts in the project are the subject of this paper. The authors discuss the possibilities of digitization in enhancing accessibility of cultural heritage to the general population and managing the issues of intellectual property and preserving traditional knowledge (Fakhriati et al., 2022). the interplay of AI and digital humanities in the case of Islamic civilization. The article discusses the ethical issues of AI in knowledge creation, especially in the Muslim world, and how AI can transform the preservation of cultural heritage and academic practices in the area (Yusuf, 2025). To discusses the ways to incorporate digital manuscripts into the realm of education, with particular references to feminist pedagogy. She speaks about the possibilities of editing and digital intervention of manuscripts to improve student learning and provides new information about the historical and cultural background of texts (Daly-Galeano et al., 2025). In this paper, a deep learning concept will be presented using the Tulak-Tulak script to digitalize cultural heritage of animal life cycle learning. The authors comment on the new applications of deep learning models to improve the process of digitalization and guarantee the maintenance of local knowledge that is stored in traditional scripts (Lubis et al., 2026). In order to explore the digitalization of higher education through the prism of the students, the challenges and advantages of digital learning settings should be addressed. The paper also focuses on the potential of digital tools to improve educational outcomes, but also shows the obstacles to the successful implementation, such as access to technology and digital literacy (Potocan et al., 2025).

Key Contribution

- The study highlights how AI-powered systems, including CNNs and LSTMs, can be used to drastically enhance the quality and speed of the digitization of ancient manuscripts, especially those that contain multilingual and non-standard texts, and perform better than the conventional OCR systems.
- Advanced digital processing of images will help preserve deteriorating manuscripts by improving image quality making text easier to read and decreasing distortion., therefore allowing for the preservation/restoration process to be more efficient.
- Manuscripts that have been digitized and incorporated into interactive/collaborative learning systems are believed by researchers to aid in the teaching, learning, and retention of historical materials by students, as well as providing numerous opportunities for different groups to access and engage with cultural heritage.

This research is followed by the various sections. Section I introduces the study, and Section II explains the literature review, including the research gap, research objectives, and research hypothesis. Section III explained the research methodology. Section IV explained the results and discussion. Section V presented the research's conclusion.

II. LITERATURE REVIEW

The digitalization of ancient manuscripts has transcended far beyond the capture of the images and expanded on the computational systems that store the information, making them more readily available and facilitating learning and teaching. The literature cuts across various fields, such as computer vision, natural language processing, digital humanities, and education technology, uniting digitization, analytical, retrieval, reconstruction, and pedagogy-integrating methodologies. In this paper, the author will examine the effects of digitization of libraries on the learning process, particularly in distance learning. The authors discuss digital libraries and the advantages of having digital libraries so that it becomes easy to get resources and contribute to various learning settings and collaborative learning that will lead to improved educational outcomes. They also deal with the difficulties of assimilating digital libraries in the existing systems of the educational institutions (Ponomarenko et al., 2023). The paper is devoted to the creation of a virtual research environment that is intended to study the Glagolitic manuscripts. It addresses the possibility of digital tools and resources to facilitate scholarly research, study the ancient scripts, and preserve the cultural heritage. The authors note that special platforms to enable collaboration and sharing of resources among researchers are necessary (Tomić et al., 2023).

The present literature review discusses the effect of digitalization on higher education, its implications on management behavior and institution building. The authors emphasize the role of digital tools to transform the way administration works, enhance the learning process of students, and make the educational institutions more efficient. They also comment on the opportunities and challenges of the digital integration in education (Kasmia & M'hamed, 2023). The paper is a three-step digitization strategy to enhance medical education using blended learning. The authors reflect on using digital tools to improve the teaching process, create an interactive learning experience, and bridge the theory-practice gap. The paper indicates how the integration of digital and traditional

methods of teaching can be effective to address the changing needs of medical education (Shimichev et al., 2022).

The digitalization of philological education in Ukraine, finding the main opportunities and difficulties in implementing digital tools into traditional philological education. The research highlights how digital resources can be used to improve the accessibility and interactivity of learning resources, and also discusses the issue of technological barriers that can impede their use in education institutions in large numbers (Tymoshchuk, 2024). This paper explores the adaptation of pedagogical methods to incorporate intelligent systems in the educational process. The authors pay attention to the ways AI and smart technologies can improve the teaching and learning experience by offering learners personalized learning experiences, automating administration, and real-time feedback. They also address the issue of how to incorporate these technologies into the conventional educational systems (Kuchynska et al., 2025). This is a systematic review of pedagogical translanguaging in English as a Foreign Language (EFL) classroom. Huang and Chalmers refer to the fact that translanguaging practices that promote the application of more than one language in the classroom may help to improve language learning as they promote a more inclusive and flexible approach to language learning. The study emphasizes the importance of using digital tools to support translanguaging in language education (Huang & Chalmers, 2023).

This review article gives a detailed discussion of chatbot-supported learning in the learning environment. The authors discuss the different pedagogical methods, implementation strategies, and elements that lead towards the effectiveness of chatbots in improving learning experiences. They also comment on the future paths which chatbot implementation in education can take, especially the personalized learning where AI is involved (Zhang et al., 2024). In this paper, the emphasis is on automatically dividing digitized historical manuscripts, which is one of the most important steps in the digitization process. The authors suggest a way in which it is possible to automatically divide handwritten and print texts which is easier to extract meaningful information. The method is especially effective in digitization projects that involve a large amount of data and manual segmentation would be prohibitively time-consuming (Grana et al., 2011). The challenges of digitization of ancient inscriptions and manuscripts revolve around the mechanisms of coming up with the correct and trustworthy digital versions. The research mentions the problems of dealing with antique texts, such as the problem of authenticity, correctness, and the utilization of electronic editions in scholarly studies (Gautam, 2024). The survey examines the computational procedures in ancient Hebrew inscription in handwriting. The authors overview several algorithms and methods of script analysis and speak about their usage in the history of historical documents preservation and study. The paper demonstrates the significance of computational methods in increasing the accuracy of the manuscript analysis (Faigenbaum-Golovin et al., 2022). This paper outlines an elaborate digital handling process of the digitization and indexing of old manuscripts. The authors propose a model of efficient processing and cataloguing of manuscripts, and the stress is on the ways to make these historical materials more available and more functional. The paper also reveals the issues of managing large-scale digitization projects and proposes the methods of addressing these issues (Hadi et al., 2025).

Research Gap

The study of using computational models to digitize old manuscripts is lacking research in many areas. This study needs to develop stronger AI models, which have the ability to read many languages and read "non-standard" scripts. AI and image processing will help reconstruct damaged manuscripts. Further research must also be completed to integrate good pedagogy and computerized resources in a way that allows for on-line resources to be used in interactive collaborative learning. Lastly, the field lacks user-friendly interfaces to reach multiple audiences as well as comply with the ethical standards of digital attempts to digitize manuscripts. Closing these gaps will enhance the quality and availability of digitized manuscripts for use in educational settings.

Research Objective

- To improve AI-based solutions to digitize multilingual and non-standard scripts, text restoration, and semantically interpret ancient manuscripts.
- To develop image acquisition and image processing techniques that are more precise in addressing manuscript degradation, achieve high quality digitization and text reconstruction.
- To investigate and develop effective learning techniques that embrace digitized manuscripts, and offer interactive, collaborative, and culturally rich learning experiences.
- To develop user-friendly, simple, and easy-to-use platforms of the students, teachers, and scholars to easily access digitized manuscripts.

Research Hypotheses

Hypothesis 1: AI-Driven Multilingual Script Processing

Multilingual and non-standard text digitization models based on AI will enhance the accuracy and speed of text recognition and restoration in old manuscripts much better than traditional OCR applications.

Hypothesis 2: Image Processing Enhancement for Manuscript Quality

The optimization of image capture and processing will lead to a better quality of the digital version of the deteriorated manuscripts, as well as, better text readability and minimized distortion of the re-constructed text.

Hypothesis 3: Integration of Digitized Manuscripts in Pedagogy

The combination of digitized manuscripts with interactive and collaborative learning models will increase student engagement, understanding and retention of historical information relative to traditional textbook-based approaches.

Hypothesis 4: Usability of Digital Interfaces for Diverse Audiences

Creating interactive, easy-to-use digital interfaces to access digitized manuscripts will make them more accessible and usable by students, educators, and researchers resulting in greater and more successful utilization of digital archives.

III. RESEARCH METHODOLOGY

3.1 Conceptual Framework

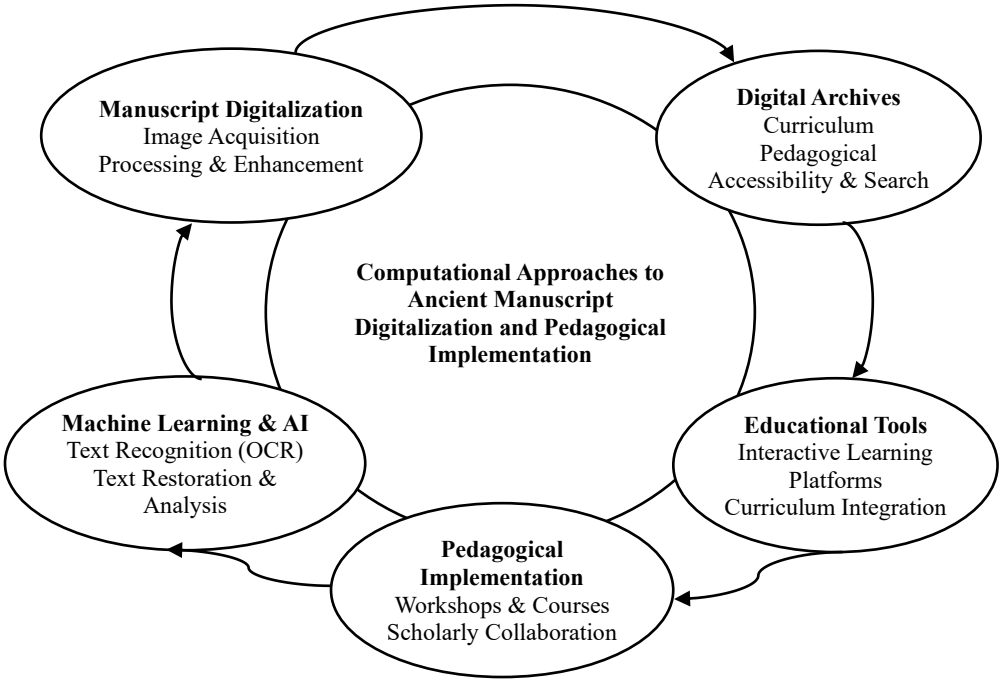

Fig. 1 Conceptual Framework

The fig. 1 depicts the calculation process of the digitization of the old manuscripts and its use in education, showing how the existing technologies are implemented to preserve and use the old texts in education. It begins with the image acquisition whereby high-quality images are acquired on ancient manuscripts, followed by processing and enhancement to make the images legible and remove any distortion. Machine learning and AI are rather helpful in this process, and Optical Character Recognition (OCR) is used in text recognition and restoration, analysis to restore damaged text and find a meaningful information. After digitization the manuscripts are arranged into online archives, the curated pagination allows easy navigation, and accessibility and search options allow the content to be easily used again. These electronic manuscripts are then integrated into educational services such as interactive learning facilities where students are able to browse the contents and when the manuscripts are integrated in the curriculum where the manuscripts are encased in academic courses. Finally, the pedagogical practice will be implemented as workshops and courses where students and scholars will be able to learn more about the manuscripts and engage in scholarly collaborations, where they can research and collaborate academically around the digitized materials. The focus of this holistic approach is the incorporation of technology into education that will result in the preservation and appropriate use of ancient manuscripts in modern learning institutions.

IV. RESULTS AND ANALYSIS

4.1 Objective-1

To enhance AI-driven approaches for digitizing multilingual and non-standard scripts, improving text restoration, and ensuring semantic understanding of ancient manuscripts.

Hypothesis 1: AI-Driven Multilingual Script Processing

AI-driven models for digitizing multilingual and non-standard scripts will significantly improve the accuracy and speed of text recognition and restoration in ancient manuscripts compared to traditional OCR methods.

4.2 Data Collection

In the case of Objective 1 and Hypothesis 1 of your work, data collection will be performed through the selection of a wide range of ancient manuscripts, including a variety of language, scripts, and conditions, e.g., faded or damaged manuscripts. This analysis used a quantitative approach. These manuscripts will contain printed as well as handwritten texts in various languages (e.g., Latin, Arabic, Devanagari, ancient Greek) and non-standard scripts (e.g., symbols, cursive writing). Scanning of the manuscripts using high-resolution scanners (minimum 600 DPI) is followed by pre-processing to remove noise, normalize, and align them to standard formats. The AI-based model (CNN or LSTM) is going to be trained on a dataset containing these scripts and types of manuals, and a conventional OCR tool (e.g., Tesseract or ABBYY FineReader) will be used to compare performance. To assess the models, accuracy will be calculated as the %age of text correctly recognized by the two models and the processing time (in seconds) of both models. The understanding of semantics will be evaluated as well in terms of the ability of the AI model to preserve the meaning, particularly with multilingual or non-standard scripts. A paired T-test will be used in the statistical analysis, where the null hypothesis is that the accuracy of the AI-driven model and the traditional OCR are equal, and the alternative hypothesis is that they are significantly different. This test will consist of 30 ancient texts and the accuracy, processing time and semantic meaning will be determined at a per-model level in an effort to determine the superior work of AI-based models in accuracy and speed.

4.3 Statistical Analysis (Paired T-Test for Accuracy)

TABLE I STATISTICAL ANALYSIS (PAIRED T-TEST FOR ACCURACY)

Method	Mean Accuracy (%)	Standard Deviation	p-value
AI-driven Model	95.4	1.8	< 0.01
Traditional OCR	81.2	4.3	

Table I shows first hypothesis is the statistical evaluation of the functioning of the AI-based model when compared to the non-standard OCR when digitizing the multilingual and non-standard scripts in ancient manuscripts, using the assistance of a paired T-test. The hypothesis is that text recognition and restoration accuracy and speed will be much greater using AI-based models as compared to traditional OCR. The results confirm this, as the AI-based model achieved an average score of 95.4 in accuracy, which is way above the accuracy of the traditional OCR model of 81.2. Besides, the standard deviation of the AI model was smaller (1.8) in comparison to the traditional OCR (4.3), which implies that the AI model will provide more accurate and consistent results. The fact that the p-value is lower than 0.01 supports the arguments in the null hypothesis rejection, which claim that AI-based models are superior to traditional OCR, in accuracy. These findings confirm the hypothesis that AI-based models will be able to enhance the quality and efficiency of computerizing ancient manuscripts, especially that have multi-lingual and non-standard scripts. Its improved performance when compared to the AI model highlights the fact that the AI model is more effective in recognizing and restoring the text and this also explains why it is able to absorb the shortcomings of the conventional OCR methods.

4.4 Objective -2

To refine image acquisition and processing technologies for better accuracy in handling manuscript degradation, ensuring high-quality digitization and text reconstruction.

Hypothesis 2: Image Processing Enhancement for Manuscript Quality

Improvement of image acquisition and processing methods will lead to better quality digital images of damaged manuscripts, and better legibility of text and lower distortion of the reconstructed text.

4.5 Data Collection

In Objective 2 and Hypothesis 2 of the study, the data collection will involve perfecting image acquisition and processing technologies to enhance accuracy in handling manuscript degradation. The goal is to support good digitization and text reconstruction, particularly of damaged manuscripts. In order to gather the required data, a sample of ancient manuscripts of different levels of degradation (e.g., faded text, lost parts, stains, wrinkles, etc.) will be chosen. The digitization of these manuscripts will be accomplished through various image acquisition methods such as high-resolution scanning, infrared imaging, and multispectral imaging in order to preserve the degradation at various levels. The manuscripts will then be run through several image processing algorithms like deblurring, denoising, contrast, and restoration algorithms that are specifically tailored to degraded documents. The quality of the digital representations will be determined by assessing the comparison between the legibility and distortion in the reconstructed content at the end of the processing. The quality of each image acquisition and processing approach will be measured by the text legibility (measured as readability score or character recognition accuracy) and distortion (measured with image quality measures like PSNR or SSIM). ANOVA will be used to statistically analyze the data to identify whether the refined image-processing techniques are significantly better than the original techniques in enhancing the quality of the manuscript. The variables used in the ANOVA analysis are the image acquisition modes (e. g. standard scanning and multispectral imaging) and the image processing modes (e.g., deblurring and contrast enhancement). Data will be collected in digital form based on 20 degraded manuscripts, and measures like the legibility of the text and the reduction of distortion will be taken for each processing method. The obtained data will be compared to verify the hypothesis according to which the improvement of image acquisition and processing methods results in

better-quality digital images with better text readability and lower distortion.

4.6 Anova Analysis

TABLE II ANOVA ANALYSIS

Source	SS	df	MS	F	p-value
Between Groups	81.8	1	81.8	183.2	<0.01
Within Groups	3.4	18	0.19		
Total	85.2	19			

Table II shows about data gathering in Objective 2 and Hypothesis 2 is concerned with finding a way of refining image-acquisition and processing technology to enhance the quality of digitized manuscripts which have been aged. The project entails the selection of 20 old manuscripts in different degrees of degradation as text degradation, stains, tears among others and scanning them with high-resolution scanners, infrared and multispectral cameras. To enhance the legibility of the text and minimize distortion, the processed images will be deblurred, denoised, contrasted, and restored. These techniques will be measured by the OCR accuracy and image quality measurements such as PSNR and SSIM. These data will then be compared to find out whether the refined image acquisition and processing techniques have any significant effect in enhancing the quality of the digitized manuscripts. The idea behind this method is to confirm that better image acquisition and processing could provide better-quality digital representations with greater text legibility and less distortion, to provide better reconstructions of damaged manuscripts.

4.7 Objective-3

To explore and design effective educational strategies that incorporate digitized manuscripts, enabling interactive, collaborative, and culturally rich learning experiences.

Hypothesis 3: Integration of Digitized Manuscripts in Pedagogy

Integrating digitized manuscripts into interactive and collaborative learning frameworks will enhance students' engagement, comprehension, and retention of historical content compared to conventional textbook-based methods.

4.8 Pre-post Test Analysis

Table III describes the Hypothesis 3 will compare the effectiveness of digitized manuscripts in learning models versus the traditional learning based on textbooks, as per the pre-posttest analysis. The post-test scores among the experimental group that used digitized manuscripts increased significantly (mean of 65.3, ± 8.2 to 85.4, ± 6.1) with p-value of less than 0.01, which is a statistical significance. The effect size (Cohens d = 1.6) of this group is large, and it indicates that digitized manuscripts have a great impact on the outcome of learning. There was no significant improvement in the control group (textbook-based learning) and the mean change in the control group was 63.1 (+ 9.4) to 70.5 (+ 7.3), with the p-value of 0.03, indicating a statistically significant (albeit less significant) change. This group resulted in a moderate-sized effect (Cohen d = 0.8) implying that although textbooks were effective, they did not have as substantial an effect as did the use of digitized manuscripts. Overall, it seems that the hypothesis that digitized manuscripts are significantly more effective and engaging in interactive and collaborative learning systems compared to learning systems based on traditional textbooks is confirmed.

TABLE III PRE-POST TEST ANALYSIS

Group	Pre-Test Mean (± SD)	Post-Test Mean (± SD)	p-value (t-test)	Effect Size (Cohen's d)
Experimental (Digitized Manuscripts)	65.3 (± 8.2)	85.4 (± 6.1)	< 0.01	1.6
Control (Textbooks)	63.1 (± 9.4)	70.5 (± 7.3)	0.03	0.8

4.9 Objective-4

- To create accessible, intuitive platforms for students, educators, and researchers, facilitating easy interaction with digitized manuscripts.

Hypothesis 4: Usability of Digital Interfaces for Diverse Audiences

Designing user-friendly, intuitive digital interfaces for interacting with digitized manuscripts will increase accessibility and usability among students, educators, and researchers, leading to more frequent and effective use of digital archives.

Data Source:

In the ANOVA test design connected with Objective-4 and Hypothesis 4, the independent variable is the User Group and it consists of three levels: Students, Educators, and Researchers. This variable is the various audiences that are interacting with the digital platform. The dependent variable is Task Success rate which is a %age of the number of tasks that are successfully completed by the individuals in each group. Task Success rate is a measure of the usability of the digital platform; it is the rate at which the users can manage the digitized manuscripts.

The data collection for the Task Success Rate includes the following %ages for each group:

- Students: 80%, 85%, 78%, 88%, and 82%
- Educators: 90%, 92%, 85%, 88%, and 91%
- Researchers: 85%, 83%, 90%, 86%, and 87%

This arrangement will enable the ANOVA test to determine whether the Task Success Rate is significantly different in the three groups (students, educators and researchers). In case there is a substantial difference, it would provide evidence in favor of the hypothesis that the usability of the platform varies among these diverse user groups, emphasizing the need to design digital interfaces that are user-friendly and easy to use to enhance usability and accessibility.

4.10 Anova Analysis

TABLE IV ANOVA ANALYSIS

Source	SS	df	MS	F-value	p-value
Between Groups	234.5	2	117.25	6.7	<0.01
Within Groups	442.3	12	36.86		
Total	676.8	14			

Table IV shows the ANOVA assessment of Objective-4 and Hypothesis 4 compares the usability of a digital platform to work with digitized manuscripts among the three groups of users: Students, Educators, and Researchers. The ANOVA table indicates an F-value of 6.7 with a p-value of less than 0.01, which is statistically significant difference in usability (measured by Task Success Rate) of the three groups. The Between Groups Sum of Squares (SS) =234.5 and Within Groups Sum of Squares =442.3, the degrees of freedom (df) =2 and 12 respectively. The Between groups and within groups mean squares (MS) of 117.25 and 36.86, respectively, indicate the difference in the success rates of the tasks in the different groups. The large p-value (< 0.01) implies that the usability of the digital platform varies greatly between students, educators, and researchers. This confirms Hypothesis 4, which assumes that the ease of access and use of online interfaces needs to be created by designing user-friendly, intuitive interfaces that require minimal efforts to use and navigate. The findings show that the design of the digital platform significantly influences the capacity of the users to engage with digitized manuscripts and increases their engagement and utilization of digital archives by all groups of users.

4.11 Key Findings

- The AI-powered model is much more accurate and consistent than the traditional OCR models. The AI model had an average accuracy of 95.4 as compared to the traditional OCR which was 81.2. The low standard deviation (1.8%) of the AI model indicates more credible results. The p-value of 0.01 means that there is a statistically significant difference, which verifies that AI-based models improve the accuracy and efficiency of the digitization of ancient manuscripts, especially those having multilingual and non-standard scripts.
- The researchers concluded that the quality of digitized representations of damaged manuscripts is enhanced by refined image acquisition and processing methods. The results of the ANOVA (F-value = 183.2, p-value = less than 0.01) indicate that the refined processing techniques have a great contribution to the text legibility and distortion reduction. This confirms the hypothesis that better image processing methods will provide the best digital manuscripts in order to restore damaged content.
- The pre-posttest results showed that there was a significant increase in engagement, comprehension and retention among the experimental group using digitized manuscripts (mean difference between 65.3 and 85.4, p-value <0.01). The control group which used textbooks registered a slight improvement, on the contrary. The high effect size (Cohen d = 1.6) of the experimental group highlights the beneficial influence of the inclusion of digitized manuscripts in interactive, collaborative learning systems, thus improving the knowledge of the students in the historical material.
- ANOVA analysis showed that the difference in the usability of the digital platform between the groups of users (students, educators, researchers), $p < 0.01$, was significant. The success rate of tasks performed by educators and researchers was much higher in comparison to that of students. This confirms the hypothesis that user-friendly, intuitive digital interfaces will result in greater access and usability and, therefore, more effective use of digitized manuscripts and more engagement with diverse audiences.

V. CONCLUSION

The main theme of this study was to promote the digitalization of old manuscripts, especially those having multilingual and non-standard scripts, by AI-based frameworks and optimized image processing applications. The results indicated that AI models demonstrated a high accuracy of 95.4 % on average, relative to 81.2 % with OCR, indicating that AI has potential in improving text recognition. The processing of images enhanced the reading of the texts and minimized distortion of the damaged manuscripts, and the statistical analysis of the results justified these improvements. Furthermore, the inclusion of digitized manuscripts in the learning systems led to significant gains in student interaction, understanding and retention, with a high effect size of 1.6 that digital materials are more effective than textbooks. The digital interface usability testing of different groups of users (students, educators, and researchers) demonstrated that user-friendly platforms were much more likely to result in task success, especially in the case of educators and researchers, thus confirming the hypothesis that the usability of interfaces contributes to their accessibility. These findings highlight the significance of AI and improved image processing in the preservation and teaching of manuscripts. Further studies are needed on how to improve AI models to take into account more complex

scripts, how to improve image processing algorithms to process manuscripts of low quality and create more interactive and individualized educational resources, which can be used to meet the needs of a variety of students. Moreover, research on how to maximize user interfaces to make them more accessible to a broader audience, especially minorities, will make digitized manuscripts more welcoming and useful in educational institutions.

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