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An Impact Analysis Framework for Digital Libraries: A Case Study

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***Abstract*: This research article explores the diverse effects of digital libraries on learning in higher education environments. By conducting an extensive review of existing literature, the study examines how digital libraries improve accessibility, encourage collaboration, enhance information literacy, and support innovative teaching practices. It introduces a generalized research methodology that integrates data collection and analytical pipelines for processing and interpreting data. Using a mixed-methods approach, the research gathers data through questionnaires and analyzes it to draw meaningful conclusions. Focusing on the Saudi Arabian context, the study addresses key questions about the influence of digital libraries on learning outcomes. By analyzing usage patterns, user perceptions, and academic performance metrics, it investigates the connections between digital library utilization and educational success. The paper defines its objectives, formulates hypotheses, and confirms them through data analysis. It also presents a general framework and a dashboard for data visualization. The findings reveal that digital library usage significantly impacts academic performance, information literacy, global awareness, and interdisciplinary research among users.**

***Keywords*: Digital library, Data analytics, Dashboard design, Impact analysis, Framework, t-statistic, Data, Visualization, Case study.**

1. Introduction

A digital library (DL) is an electronic information retrieval system. It has an organized collection of digital content such as electronic books, and e-journals, and a wide range of digital resources, such as multimedia collections, and archival materials resources. Digital libraries use digital technologies to enable ubiquitous access to resources. Contents of digital libraries can be accessed anywhere and anytime using the internet and intranet technologies. This is in contrast to traditional libraries, which are limited to physical spaces and printed materials.

DLs have become an integral part of the modern information ecosystem. DLs contain many resources besides the collection of pedagogic and academic literature. They contain databases, search and retrieval tools, digital lending features, Interactive interfaces, Learning Management systems (LMS), Content Management Systems (CMS), and Security tools. The DL landscape is evolving [1].

While rapid technological advancements are adding more capabilities to deep learning, are they also helping users achieve their ultimate goals of learning and academic excellence? The answer to this question is crucial.

In this paper, a factual study is conducted to inquire about the impact of DL on learning in higher education. The paper proposes a framework to set the objectives of such a study and collect data based on the questionnaire generated. The framework is designed to address multiple aspects of impact, including academic performance, impact on research, learning experience, user satisfaction, and overall service benefits. By conducting a detailed case study, this research will illustrate the practical application of the framework and highlight key findings. The research methodology is that of hypotheses testing by empirical data analysis. Initially, the "Null" hypotheses are defined and then they are either rejected or accepted based on the computed metrics [2].

To provide concrete insights, the paper focuses on a case study of a prominent digital library in Saudi Arabia. In Saudi Arabia, the pursuit of knowledge is deeply embedded in the cultural ethos and proliferation of digital transformations. As educational institutions strive to adapt to the evolving needs and aspirations of learners in the digital age, digital libraries are emerging as indispensable tools for facilitating access to information, fostering critical thinking skills, and nurturing a culture of lifelong learning. This case study will allow us to explore the framework's effectiveness in a real-world context, examining how various impact metrics are collected, analyzed, and interpreted. The chosen digital library represents a diverse user base and a broad range of digital content, making it an ideal candidate for this analysis.

The paper is organized as follows. Section 2 details the research methodology employed in the study, including the definition of research objectives and hypotheses. This section also includes sample questions corresponding to each hypothesis. Section 3 reviews the existing literature on digital libraries and their impact. Section 4 describes the proposed framework and its associated software components. The analytical methods used, and their importance are discussed in Section 5. Section 6 presents the experiments conducted and their results, featuring statistical findings for each hypothesis

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test accompanied by a graphical representation. The outcomes are interpreted, and inferences are presented. Section 7 is about conclusions.

2. Research Methodology

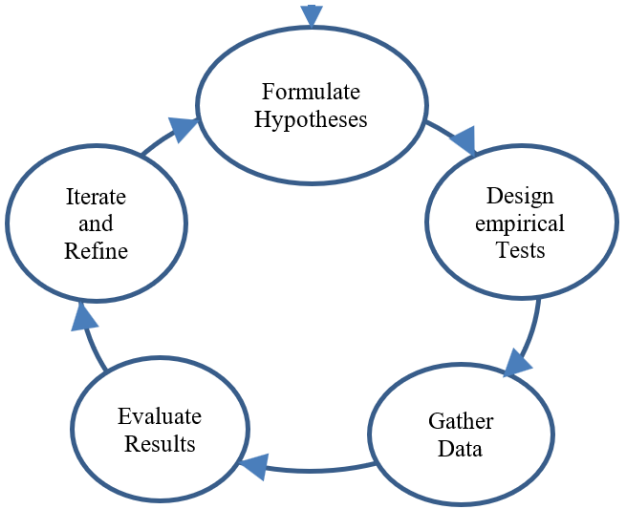

Fig. 1. The research design flow

This study in this paper adopts a mixed-method research approach [2], utilizing online surveys, focused group discussions, and interviews to collect a combination of qualitative and quantitative data. Fig. 1 illustrates the research design that was used.

The process begins with defining the study objectives. Once the objectives are established, a set of theories aligned with these goals is developed. The study employs a "design by falsification" approach, characterized by skepticism, transparency, and critical analysis in its initial stages. Empirical data is collected to support the formulation of "null hypotheses." The gathered evidence undergoes rigorous and iterative examination before any conclusions are drawn.

Defining the study objectives is the first step in the process.

A. *Objectives*

i) To examine the utilization patterns of DL resources among users in higher education institutions.

ii) To assess the impact of DL usage on users' information literacy skills, academic performance, and overall learning outcomes.

iii) To assess the impact of DL usage on users' pedagogical practices, research productivity, and interdisciplinary collaborations.

iv) To evaluate the effectiveness of DL platforms and support services in meeting the information needs and academic requirements of users.

v) To take an account of the direction of DL services to be offered in promoting quality education.

Based on these objectives, the following hypotheses were developed, all intentionally framed as "null hypotheses.".

The hypotheses are:

B. *The Targeted Hypotheses*

- *Hypothesis 01*: There is no significant relationship between using digital libraries and academic achievement.
- *Hypothesis 02*: The use of DL resources does not impact users' information literacy skills.
- *Hypothesis 03*: There is no significant relationship between user satisfaction and using digital libraries.
- *Hypothesis 04*: The use of DL resources has no bearing on users learning abilities and pedagogical activities.
- *Hypothesis 05*: The availability of DL materials has no impact on the output of research.
- *Hypothesis 06*: The use of digital libraries does not affect research's interdisciplinary research.
- *Hypothesis 07*: There is no difference in critical thinking skills between the users who use DL and those who do not use DL
- *Hypothesis 08*: The diversity of academic research is unaffected by the accessibility of DL materials.
- *Hypothesis 09*: The degree of users' training in digital literacy does not affect how they use DL resources.
- *Hypothesis 10*: There is no relationship between the use of digital libraries and users' engagement or retention rates.

According to the first hypothesis (H01), there may be no direct correlation between the usage of DLs and academic achievement. According to the second hypothesis, (H02), users' capacity to use information efficiently is not always improved by just having access to digital content. The third hypothesis, or H03, suggests that using DL resources may not have a major impact on user happiness. According to the fourth hypothesis (H04), teaching strategies and learning processes are not greatly impacted by the use of DL resources. The fifth hypothesis (H05) posits that there is no evidence to suggest that access to digital libraries improves the quantity or quality of research outputs. According to the sixth hypothesis (06), According to seventh hypothesis (H07), DLs might not make cross-disciplinary research easier. The eighth hypothesis (H08) proposes that having access to a wide range of digital content does not diversify research topics or approaches. The ninth hypothesis (H09) asserts that users' use of digital library resources is not influenced by their digital literacy training. According to the tenth hypothesis (H10), once a user utilizes DL, they do not continue using it for longer periods.

The hypotheses are intentionally framed as negativist, starting as "null hypotheses." Empirical evidence is subsequently gathered to determine whether to accept or reject these null hypotheses. The next step in the proposed framework is to frame appropriate questions that inquire about the stated hypothesis. A sample list of the classification of questions with the targeted domain of inquiry and their mapping with the hypothesis are displayed in the following table (Table 1) advantages of these resources for improving learning outcomes in higher education.

[9] investigates how digital libraries may improve scholarly communication, encourage cooperation and innovation, and democratize access to knowledge. Pavani also covers the potential problems that come with digital libraries, such as

Table 1
Questionnaire classes and samples

S.No.	Query class	Target Hypothesis	Sample question	Type of Answer
1	DL usage vs Academic performance	H01	Rate your academic performance relative to your utilization of the digital library resources and services	MCQ
2	DL usage vs Users' information literacy	H02	Which of the search strategies or techniques you used for finding and accessing scholarly information through digital library resources?	MCQ
3	DL use vs DL GUI (happiness)	H03	Rate your navigation and usage experience of DL	Likert
4	DL Usage vs Learning Abilities	H04	"Digital library resources have enhanced my learning experience" Give your rating	Likert
5	DL vs Research output	H05	How many research papers did you publish during the couple of years since you started using	MCQ
6	DL vs interdisciplinary research	H06	Did you refer DL resources which are outside of your academic discipline?	MCQ
7	DL vs Critical thinking abilities	H07	Did you use DL resources to solve any complex problem/ to propose a project?	Yes/No
8	DL vs Diversity of academic research	H08	To what extent has access to digital library resources expanded your awareness of global research trends, challenges, or innovations across different regions or countries?	Likert
9	Training vs DL usage and search skills	H09	Do you agree that searching in DL resources saves your time and effort in referencing?	Likert
10	DL usage vs Retentions	H10	Since how long have you been using DL resources	MCQ

copyright, sustainability, digital preservation, and information literacy.

[10] explores how digital libraries might improve e-learning experiences, including the provision of tailored learning routes,

C. Questionnaire Design and Classification

The table 1 shows questionnaire design and classification.

3. Literature Review

Several studies have investigated the impact of digital libraries on learning outcomes in higher education settings.

In [3], authors have constructed a behavioral model and found that users who utilized DL resources demonstrated higher academic achievement and information literacy skills compared to those who relied solely on traditional library materials. Similarly,[4] reported that access to DL collections improved users' critical thinking abilities and research competencies. Furthermore, [5] emphasized the importance of integrating cultural perspectives into the design and implementation of DL services to ensure relevance and accessibility for Saudi Arabian users

In [6], user satisfaction and loyalty to digital libraries is studied. They have found that the perceived ease of use and DLs' affinity impacted perceived usefulness.

The work in [7] emphasizes the importance of strategic planning, investment, and collaboration in harnessing the full potential of digital libraries to enhance the quality and accessibility of higher education in India

Research in [8] investigates how digital libraries affect users' academic achievement in Coimbatore City's colleges. The study's conclusions shed light on the connection between users' use of digital libraries and their academic achievement, underscoring the advantages. Directed learning. Overall, this article offers insightful information about how digital libraries can enhance and support e-learning projects. It also offers advice to stakeholders, legislators, and educators who want to maximize the advantages of digital resources in online learning environments.

In [11], authors undertook a study that looks at how users view DL resources, how they use them, and how these resources affect their academic performance and overall growth. The study's conclusions provide light on how DL resources benefit user learning outcomes.

In [12], observe the potential of digital libraries to enhance research productivity, promote information literacy skills, and facilitate lifelong learning opportunities. [13] investigates how digital libraries are essential for satisfying the information needs of researchers, educators, and users in the context of pedagogical shifts and technological breakthroughs. The author talks about the many uses and advantages of digital libraries, such as enabling access to a large number of digital resources, fostering collaborative learning environments, and promoting cutting-edge teaching techniques. The article by [14] investigates the role of the National DL of India (NDLI) provides access to open access resources (OARs), focusing specifically on the COVID-19 research repository.

[15] investigates how users interact with digital libraries and evaluates their experiences based on perceived usability and usefulness. It provides insights into user experiences.

In [16] researchers, explore how digital archives can enhance the effectiveness of PBL by providing users with access to historical documents and primary sources relevant to their learning objectives. The case study focuses on the implementation of a PBL approach in two courses at a Taiwanese university, where users utilized digital archives to investigate historical events and develop critical thinking skills.

[17] explores the significance of digital libraries in education. The article highlights the benefits of digital libraries in facilitating access to a wide range of digital resources, promoting collaboration and innovation, and fostering lifelong learning habits among users and educators. [18] investigates university users' perceptions of the use of digital technologies in formal learning environments, focusing on a developing country perspective. The authors discuss the challenges and opportunities associated with integrating digital technologies into formal learning contexts, highlighting the importance of addressing infrastructure issues, digital literacy skills, and pedagogical approaches to enhance the effectiveness of digital learning initiatives. [19] examine the various services offered by digital libraries.

In [20] analyze the utilization of digital resources in university libraries. The article examines the trends and patterns of digital resource usage among university library users, focusing on factors such as user demographics, types of resources accessed, and frequency of use.

The paper [21] assesses how DL database resources affect academic research output. The paper looks at how academic information discovery, access, and utilization are affected by researchers' access to DL databases. In [22] authors have studied the impact of the Saudi Digital Library on research in the kingdom. They find that digital libraries have greatly boosted research in the kingdom. The authors express concern about privacy, and security issues due to the digital content and current web access mechanisms. However, the paper doesn't provide a technical methodology used to arrive at these conclusions.

The article [23] examines the factors contributing to the success of e-libraries in higher education, utilizing the Social Learning Theory as a framework. In [24], the study examines how well e-learning technologies are accepted and how satisfied users are with them in Saudi higher education. The paper examines various elements, including usability, convenience of use, perceived utility, and technological assistance, that impact users' attitudes and perceptions toward e-learning. [25] investigates what makes users engaged and devoted to digital libraries in Chinese institutions. The impact of perceived value, system quality, information quality, and service quality on users' happiness and loyalty to DL services is examined in this article.

Researchers in [26] investigate factors influencing users' intentions to adopt and use mobile DL applications, such as perceived usefulness, ease of use, compatibility, and perceived risk.

In [27] they discuss how designing digital libraries with user views in mind might help to foster academic research. The essay examines user-centered design theories and approaches, including iterative design, usability testing, and user requirements assessment, that include incorporating users into the design process.

The integration of artificial intelligence, machine learning, and data analytics holds promise for enhancing personalized learning experiences, predictive analytics, and content recommendation systems within DL platforms provided in [28]. Furthermore, the COVID-19 pandemic has accelerated the adoption of online and hybrid learning modalities, underscoring the importance of digital libraries as essential resources for remote education and distance learning initiatives.

4. Design of the Framework

An automation software was designed to frame objectives, map hypotheses and generate questionnaires. An analytic tool (Power BI) [29] was integrated to analyze and visualize the outcomes. SQL was used as a backend database to store the collected data. The following figures, Fig 2 and Fig 3 show the screenshots of the implemented framework.

The framework has secured login. Successful login will lead to a page, where the user is allowed to set the objectives in the context of "Digital Library". The framework then guides to selection of the hypothesis based on the objective. Embedded intelligence then will guide to selection of specific question/s for each hypothesis. The user makes a list of questions and dispatches to the target users. The collected data is analyzed by using the analytic tool.

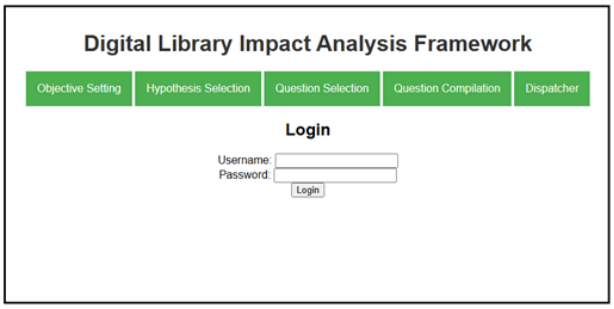

Fig. 2. User Interface of the framework

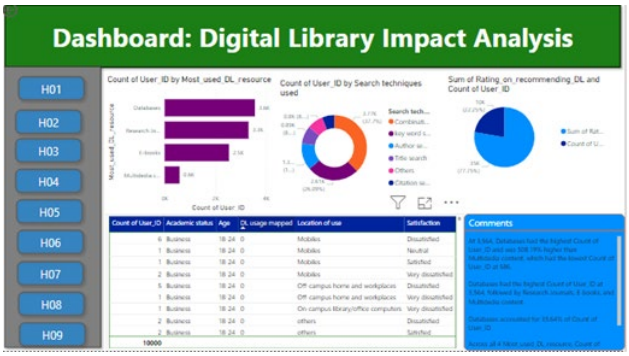

Fig. 3. Analytic output visualizations: The dashboard

5. About the Analytics

The questionnaire form was made available to all the users of the DL and the input was stored in the backend servers. The database schema contained columns representing each question field in the questionnaire along with a few additional metadata fields. Over 10,000 responses were collected amounting to the same number of records.

Fundamental statistical measures were explored to analyze and conclude the hypotheses [30][31]. To understand the correlation, the Pearson correlation coefficient r was evaluated.

To negate or accept the hypothesis t-tests were conducted and p-values were reported. The z-score was evaluated wherever there was proportionality in the data involved. The following equations were explored as per the parameter mapping in each case of the hypothesis.

A. Analytic Equations

- Correlation

$$r = \frac{N(\sum xy) - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}} \quad (1)$$

Where,

x and y are independent variables (Columns) of selected analysis.

Example: while analyzing the correlation between academic performance and DL usage, the x values could be academic performance ratings and y values could be the frequency of DL usage.

N is the total number of records

r is the correlation coefficient

If $r > 0$, then the two variables are positively correlated, meaning, one variable grows when the other variable grows.

If $r < 0$, then the two variables are negatively correlated, meaning that when one of the variables grows the other variable decreases.

And finally, if $r == 0$, then it is concluded that there is no relation between the two variables.

- T-statistics

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{{S_1}^2}{n_1} + \frac{{S_2}^2}{n_2}}} \quad (2)$$

where,

$\bar{X}_1$ is the mean value of the first variable (Column)

$\bar{X}_2$ is the mean of the second variable (Column)

S_1 and S_2 are standard deviations of the respective variables

n_1 and n_1 are the number of records for each variable

t is the test score

Once the test score is computed, it is compared with a predefined $p\text{-}value$, and conclusions are drawn based on this comparison.

If $p\text{-}value < 0.05$:

The null hypothesis is rejected and there is a significant difference between the two variables.

If $p\text{-}value > 0.05$:

The null hypothesis is Accepted and there is no significant difference between the two variables. Examples for t-statistic and p-value computation are as follows:

Example 1 (t-statistic and p-value):

Data values:

Sample1=[87, 48, 223, 466, 90]

Sample2=[19, 20, 14, 14, 17]

Computed values:

T-statistic: 2.1628815956333898

P-value: 0.06250809933625925

Inferences:

Based on P-value:

a. Fail to reject the null hypothesis: There is no significant difference between the two groups.
b. The Pearson coefficient is:

-0.8223151636417011 (negative), They are negatively correlated.

Example 2:(t-statistic and p-value):

Data values:

Sample3= [23, 49, 16, 38, 31, 11, 49, 16]

Sample4= [14, 16, 18, 12, 14, 14, 20, 13]

Computed values:

T-statistic: 2.59196569257619

P-value: 0.021307836943434525

Inferences:

Based on P-value:

a. Reject the null hypothesis: There is a significant difference between the two groups.
b. The Pearson coefficient is: 0.35899805917518096, They are positively correlated.

Z-Score

It is computed where proportionality in data is involved.

$$z = \frac{p_1 - p_2}{\left(\sqrt{\frac{p_{1(1-p_1)}}{n_1} + \frac{p_{2(1-p_2)}}{n_2}}\right)} \quad (3)$$

Where,

z is the z-score value

p_1 and p_2 are sample proportions of the two groups under comparison.

n_1 and n_2 are the sample sizes of the two groups being compared.

This score is useful when conducting hypothesis testing involving two proportions.

Example (z-score):

In a survey, if out of 50 male respondents 10 say they are satisfied with the DL services, and out of 20

female respondents 5 say they are satisfied, and the null hypothesis is stated as below:

H0: "*There is No significant difference between the male and female users about the level of satisfaction of using DL*"

Then this is tested by computing the z-score value and compare it with the p-value

$$p_1 = \frac{10}{50} = \frac{1}{5} = 0.2 \text{ and } p_2 = \frac{5}{20} = \frac{1}{4} = 0.25$$

$$n_1 = 50 \text{ and } n_2 = 20$$

Enter n1: 50

Enter n2: 20

Enter respondents from the population of n1: 10

Enter respondents from the population of n2: 5

Computed p1 and p2 values are 0.2,0.25:
Z-score: -0.46056618647183817
p_value 0.322554937892386
Result: Fail to reject the null hypothesis
Example 2:(z-score)
Enter n1: 50
Enter n2: 20
Enter respondents from the population of n1: 3
Enter respondents from the population of n2: 20
Computed p1 and p2 values are 0.06,1.0:
Z-score: -7.564217825019836
p_value 1.9510269449941073e-14
Result: Reject the null hypothesis

6. Experiments and Results

A. Hypothesis Testing & Results

In this section, the results of t-statistic and p-value runs on the digital library dataset are presented. Each value computed targets a specific hypothesis. The outcomes are presented in the table (Table 2). The raw data set is suitably transformed during analytic evaluation. The categorical values are converted into numeric equivalents before subjecting them to statistical evaluation. For a question related to the frequency of use of DL, the raw response options are a) Daily b) Weekly c) Once a month d) Occasionally e) Never. These are categorical values. Such columnar values are programmatically transformed using weight mapping such as by giving weight scores such as,

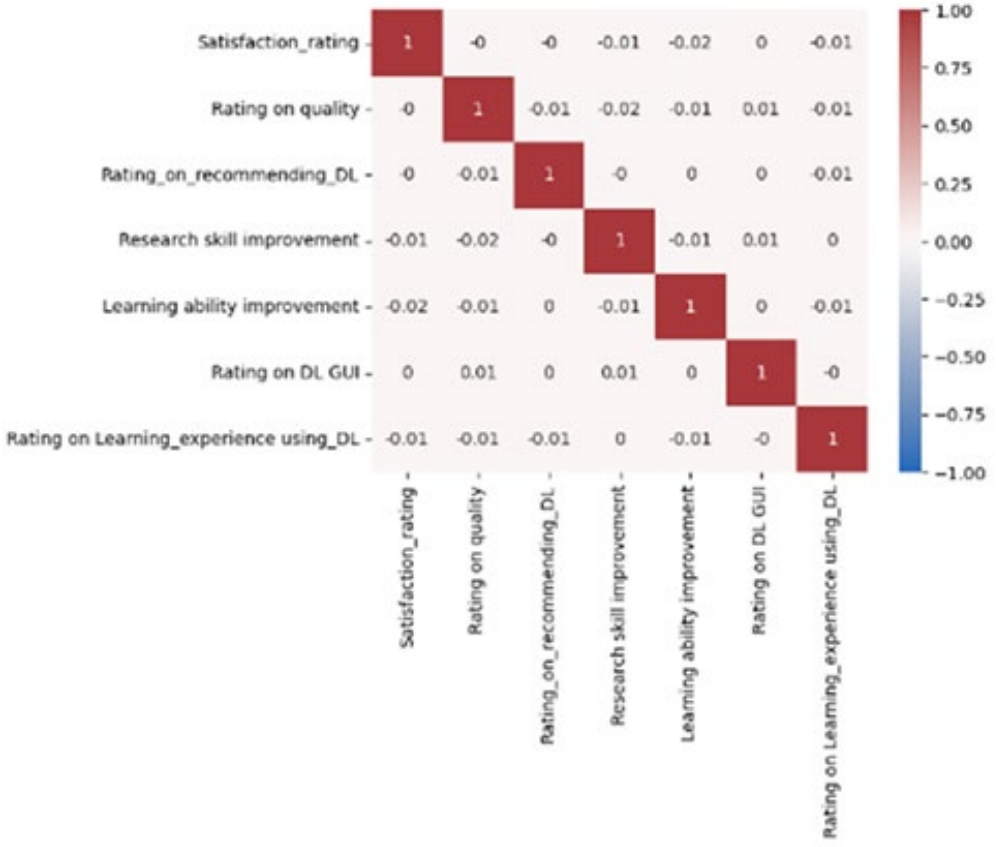

Fig. 4. The heat matrix showing the correlation coefficients

Table 2
Results of test scores

S.No.	Domain of inquiry	Target Hypothesis	t-statistic	p-score	Comments
1	DL usage vs Academic performance	H01	-45.73	0.0	There is a significant and strong relationship between DL usage and Academic performance.
2	DL usage vs Users' information literacy	H02	3.8	0.000145	There is strong evidence to reject the null hypothesis and there is a significant relation between the two.
3	DL use DL GUI (happiness)	H03	-19.70	$1.4e^{-85}$	Users are happy to use the DL GUI and the relation has a strong significance.
4	DL Usage vs Learning Abilities	H04	-28.66	$7.98e^{-178}$	
5	Interdisciplinary research	H05	48.33	$2.8e^{-31}$	The p-values near zero or miniscule values suggest that in all such observations, the null hypothesis can be rejected.
6	Critical thinking abilities	H06	-54.22	0.00032	
7	Diversity of academic research	H07	-38.76	$16.98e^{-76}$	
8	DL usage vs rating on Quality	H08	-51.20	0.0	Therefore, in all these relations there is a strong significance between the two values.
9	DL usage vs Research skill improvement	H09	-42.065	0.0	
10	DL usage vs Retentions	H10	23.86	$3.4e^{-22}$	

```
frequency_weight_map={‘Daily’:4
‘Weekly’:3
‘Once in a month’:2
‘Occaisionally:1
‘Never’:0
}
```

A heatmap of correlation coefficients in the context of digital library impact analysis provides a visual representation of the relationships between various factors.

B. Visuals and graphs

1) Inferences

The visual graphs (a) through (i) in Figure 5 clearly highlight the trends among the selected variables. In particular, the pie chart in (a) reveals that 85.71% of respondents (65.26% and 15.45% combined) agree that the use of digital libraries has enhanced their academic performance.

In graph (b), it is evident that digital library (DL) users employ various search methods to navigate and explore DL resources. A notable 37.1% use a combination of keyword, author, and title searches, indicating a strong correlation between DL usage and enhanced information literacy skills.

Graph (c) reveals that 77.21% of DL users are willing to recommend the platform to their friends, which serves as an indicator of their satisfaction and happiness with the service.

Graph (d) highlights the diversity in resource utilization, showing that users primarily explore DL databases more than other resources. This further underscores the information literacy of DL users.

In graph (e), skill improvement ratings are depicted, with the majority of respondents assigning ratings of "4" and "2," signifying agreement on the role of DLs in enhancing skills.

Graph (f) illustrates the impact of DL usage on research output, with 38.59% of users having not published any research papers, while 60% have published one or more, and 40.31% have published more than two papers. This indicates a positive relationship between DL usage and research productivity.

Graph (g) categorizes research publications by academic disciplines, showing the highest number in the Humanities, followed by Engineering. This demonstrates the influence of

Fig. 5. Visuals of selected variables of the data

DL usage on research across different fields.

Graph (h) indicates that Arabic is the most preferred language among DL users.

Graph (i) presents user expectations and suggestions for DL improvements. Only 15.65% of users are satisfied with current resources and services, while 85% express expectations, including the integration of chatbots, virtual assistants for augmented reading, and more training materials. The majority, 25.59% and 25.09%, prioritize virtual assistant integration and expanded training resources. This graph provides valuable insights for policymaking in DL development.

In addition to the visual interpretations, statistical analysis supports the findings. The t-statistics, p-values, and correlation coefficient heatmap collectively demonstrate that hypotheses H01 to H10 are rejected, effectively disproving the null hypotheses. This indicates that...

which means that the,

i) Use of DL has a strong bearing on academic performance.
ii) Use of digital libraries improves the information skills of the user.
iii) The use of Digital libraries has a strong bearing on individual domain research outputs as well as on interdisciplinary research.
iv) The users of DL appear to be happy and satisfied.
v) There are strong indicators in the direction of exploring and providing extended services of DL to the users.

However, it is to be noted that the statistical significance does not necessarily suggest a causal relationship between the variables, even when it does show a substantial link between them. To determine the causal explanations for the underlying relationships and causes, more investigation is necessary.

7. Conclusions

This study introduces a framework for analyzing the impact of digital libraries, focusing on a specific case study with a defined user base. The research employs a mixed-method approach, utilizing online surveys, in-person interviews, and targeted discussions to collect data. A systematic methodology is proposed for crafting focused questions to gather relevant information. The study emphasizes the importance of defining objectives, formulating questions, and establishing hypotheses. An automated process is suggested to streamline these tasks. Data analysis is conducted with the defined objectives and hypotheses in mind, incorporating statistical parameters such as p-values and t-statistics to derive conclusions. The integrated analytical tool aids the process by providing parameter visualizations to support the findings.

The analytic outputs show that there is enough evidence to conclude

- Digital library usage has a strong association with academic performance. It improves the performance of the user.
- Learning experience and research work of the DL user are benefitted by the DL.
- The user finds it convenient to use DL resources and is satisfied with the existing services
- Arabic is the preferred language in Dl usage, considering the context of the study
- The user expects extended tools/facilities to be included in the DL.

The analytical results recommend that policymakers, educational institutions, and other stakeholders prioritize integrating digital library infrastructure into their academic initiatives.

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