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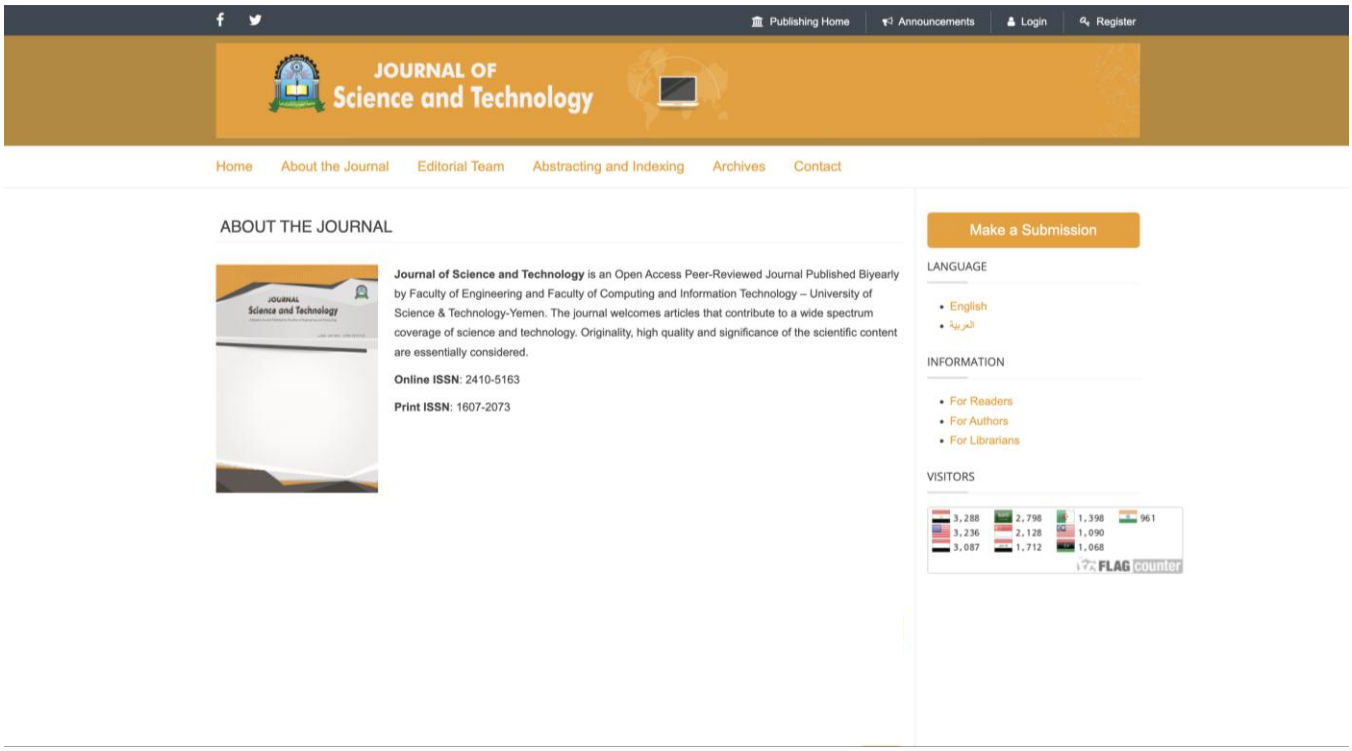

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TOTAL QUALITY AS AN APPROACH TO DEVELOPING ARCHITECTURAL EDUCATION

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Total Quality as an Approach to Developing Architectural Education

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Abstract— Total Quality Management (TQM) – the third revolutionary wave following the Industrial Revolution and the Computer Revolution – is a modern concept that emerged at the end of the last century as a result of intense global competition among economic, industrial, technological, and commercial organizations in developed countries. This was particularly evident between Japanese institutions on one side and European and American institutions on the other, aiming to achieve customer satisfaction. In the past few decades, the term "TQM" began to enter the field of education. This research paper seeks to shed light on what this approach can offer in higher education in general and in architectural education in particular.

Keyword Total Quality Management (TQM), Architectural Education, Customer Satisfaction, Educational Reform.

I. Introduction

At the beginning of this century, there has been a growing interest among numerous educational institutions in implementing Total Quality Management (TQM) in both general and higher education. The aim is to achieve a better quality of learning and to graduate students who are more capable of effectively serving their communities.

Total Quality in education has become a prominent concept worldwide, proving its success over time. In fact, the era we live in is often referred to as the “Era of Quality”. The number of educational institutions adopting Total Quality Management systems is continuously increasing, whether in the United States[1], European countries, Japan, and other advanced nations, or in many developing countries such as India, Malaysia, Pakistan, and others. Some Arab countries, including Gulf countries, Jordan, Egypt, Palestine, and others, have also begun implementing this approach in some of their educational institutions.

In education total Quality is closely linked to the processes of teaching and learning, as well as the management of the educational process. It involves connecting education to the needs of society and the labor market, bringing about purposeful educational change, and fostering creativity among learners. Learning occurs when there is interaction between the learner and his environment, leading to a modification in the learner's behavior. Our role is to provide the opportunity for this interaction to take place so that learning can occur. This means creating all the necessary conditions and a suitable environment for learning, which requires setting standards for processes, including a specific system to ensure the quality of education. Therefore, this research seeks to answer the following question:

What role can the concept of Total Quality play in university architectural education?

II. Research Objectives

This research aims to achieve several objectives, which are:

1. To explore the concept of Total Quality in its broad sense, its application in the field of education, and the modern trends in this area.
2. To identify the justifications and benefits of implementing Total Quality in university education.
3. To examine the extent to which the current university education system is suitable for applying the principles and foundations of Total Quality.
4. To identify the requirements for implementing Total Quality in the university education system.
5. To explore how the concept of Total Quality can be applied in architectural education and the expected benefits.

A. First: Defining the Concept of Total Quality and its Modern Trends:

1. *The Concept of Quality from an Islamic Perspective:*

The concept of quality is not new in our Islamic culture. A discerning observer of the sources of Islamic legislation—the Holy Quran and the Prophetic Sunnah—can describe Islam as the foundation of quality and excellence in worship, transactions, and all aspects of life daily. [2]

Islam is the religion of excellence, mastery, and skill. It calls for righteous and collective work, emphasizing conformity and monitoring—two measures of good deeds and standards for performance quality and mastery. Mastery is broader and more comprehensive than the term "quality" or merely doing a good job.

The Prophet Muhammad (peace be upon him) said: "Allah loves that when one of you does a job, he does it with excellence[2]."

“**Ihsan**” (excellence) means doing what is good and avoiding what is bad, performing good deeds that elevate humanity and improve their interactions.

Allah Almighty says: "Indeed, those who have believed and done righteous deeds—indeed, we will not allow to

[1]The number of higher education institutions adopting the concept of total quality in America increased from 78 institutions in 1980 to 220 in 1991, and then to 2,196 institutions in 2001. [1]

[2]Narrator: Aisha, may Allah be pleased with her. The Hadith Scholar: Ibn Adi. Source: Al-Kamil fi al-Du'afa; page 84.

be lost the reward of any who did well in deeds." (Quran 18:30)

The Prophet Muhammad (peace be upon him) said: "Allah loves the worker who perfects his work[3]."

2. *The Conceptual Definition of Total Quality:*

Total Quality is primarily an economic term that emerged due to industrial and technological competition among advanced industrial nations. There are numerous definitions of Total Quality, and the meanings of the words that constitute this concept are as follows:

Quality:

- Complete customer satisfaction– Armand V. Feigenbaum, 1956. [3]
- Conformance to requirements– Philip B. Crosby, 1979. [4]
- Fitness for use as perceived by the user– Joseph Juran, 1989. [5]
- A predictable degree of uniformity and dependability at low cost, suited to the market, W. Edwards Deming[4],2001. [6]
- Performing the right task correctly from the first time, relying on customer feedback to assess performance improvement. The American Federal Quality Institute, 2016. [7]

Total:

- It involves applying the principle of seeking quality in every aspect of work, from identifying customer needs to evaluating whether the customer is satisfied with the services or products provided. [8]
- It is a cooperative form of performing work, relying on the shared abilities of both management and employees, aiming for continuous improvement in quality and productivity through teamwork. [9]
- It is a strong and consistent focus on customer needs and satisfaction, achieved through the continuous development of process outcomes to meet customer requirements. [10]

All these definitions, despite differences in wording and meaning carry a single concept: **"Gaining customer satisfaction."**

Moreover, these definitions share an emphasis on the following:

a. Continuous improvement in development to achieve long-term results.
b. Teamwork involving individuals with diverse expertise.
c. Reviewing and responding to customer requirements.

As for the concept of Total Quality (TQ) in education:

It pertains to all the features and characteristics related to the educational field that reflect the quality of the desired outcomes. It translates the needs and expectations of the primary beneficiary—the student—into specific characteristics that form the foundation of their education and training. It also involves generalizing the educational service and formulating it into goals that align with their aspirations [11].

Consequently, (TQ) in this field aims to prepare students with specific attributes that enable them to cope with the abundance of information, ongoing changes, and tremendous technological advancements. Their role is not limited to merely transferring knowledge or listening but extends to engaging with this information and utilizing it sufficiently to serve the learning process [12].

This requires individuals with specific qualities who can comprehend everything new and rapidly evolving and deal with it effectively. It also necessitates a significant shift in the role of educational institutions and their staff—faculty members, administrators, and technicians—so that everyone works to provide an educational environment that allows freedom of expression and discussion and helps students achieve self-directed and collaborative learning [13].

In the educational sector, Total Quality Management (TQM) is defined as:

"A strategic management process based on a set of values and driven by information that enables the utilization of student' talents and the investment of their intellectual capabilities at various organizational levels in a creative manner to achieve continuous improvement in the educational institution" [14].

This definition focuses on the concept of systems management, which links the "inputs - processes - outputs" of the educational process [15].

Consequently, this concept requires considering both the students, who are the direct beneficiaries of this approach, and how the educational institution prepares them to meet their current and future needs. It also includes faculty members, administrators, and technicians, who need training and development to enhance their skills and competencies to grasp the philosophy, concepts, and applications of (TQ) [16].

Based on these definitions, we can say that (TQ) within the framework of an educational institution encompasses a set of key elements, the most important of which are:

- Adopting a collaborative teamwork approach and leveraging the capabilities, talents, and expertise of the human element within the educational institution.
- Ensuring continuous improvement and development to enhance quality.
- Minimizing errors by performing tasks correctly from the first time and every time, which leads to reducing costs to a minimum while achieving satisfaction among both internal and external beneficiaries of the educational process.
- Calculating the cost of quality within the educational institution to include all activities related to the services

[3]Narrator: Kulayb al-Juhani. The Hadith Scholar: Al-Albani. Source: Sahih al-Jami'; page 1891

[4] He is an American engineer considered the father of quality, with a philosophy and ideas in this field that he initially presented in America in the mid-20th century, but they were ignored. Later, Ishikawa (the president of the Japanese Federation of Economic Organizations) invited him to deliver a series of lectures there. He then taught Japanese producers how to transform cheap and inferior goods into high-quality products. Indeed, Japanese goods gained a competitive edge over American products. When asked about the reason for the greater success of Total Quality Management in Japan compared to the United States, he said the difference lies in the implementation process, that is, the embodiment and application of Total Quality Management [2].

provided, such as: costs of missed opportunities, costs of errors, evaluation processes, and the institution's reputation [17].

- A holistic approach to all areas of the educational (TQ) system, including objectives, organizational structure, work methods, motivation, incentives, and procedures.

The "Deming" program for improving and implementing is one of the most important modern trends incorporated into the design of any (TQ) curriculum applied in educational institutions. This program consists of 14 points:

1. Create a constant need for education and improvement in production and service.
2. Adopt a new philosophy for development.
3. Implement the philosophy of continuous improvement.
4. Avoid making decisions based solely on costs.
5. Eliminate the need for inspection.
6. Focus on continuous training.
7. Provide effective and conscious leadership that embraces the philosophy of Total Quality, implements it, and supports it.
8. Eliminate fear among leadership.
9. Remove barriers in communication.
10. Avoid slogans that rely on achievements and facts.
11. Avoid using performance limits.
12. Encourage expressing feelings of comfort and pride in confidence.
13. Implement a continuous improvement program.
14. Understand aspects of work through the “Deming cycle” [11]:
    - Plan
    - Do
    - Check
    - Act.

See Fig. No. (1)

Fig. 1. Deming Cycle /
Source – Researcher

B. Secondly - Justifications and Benefits of Total Quality (TQ) in University Education:

The topic of (TQ) in educational institutions has garnered significant attention, leading to the organization of workshops and seminars in many countries. This comes after the successes achieved in economic, industrial, and technological fields. This does not merely mean striving to increase profits by improving the product but rather leveraging it to develop methods of the educational process to achieve the quality of the educational product. Among the justifications for applying this new approach in education are the following [18]:

- The quality system's connection to comprehensiveness in all fields.
- The universality of the system, as it is a characteristic of the current era we live in.
- The success of its application in many educational institutions, whether in the public or private sector, in many countries around the world[5].
- The connection of total quality with the comprehensive evaluation of education in educational institutions [20].

These justifications and others confirm that the application of (TQ) in the educational system requires continuous efforts that go beyond improving performance. Instead, they aim to enhance educational inputs, processes, and outputs.

The (TQ) system in education can achieve numerous benefits, including [15]:

1. Regulating and developing the administrative system in any educational institution due to the clarity of roles and precise definition of responsibilities.
2. Elevating students' levels in all aspects: physical, mental, social, psychological, and spiritual.
3. Raising the standards of faculty members, administrators, technicians, and staff in educational institutions.
4. Developing methods of measurement and evaluation.
5. Improving the use of modern educational technologies.
6. Increasing trust and cooperation between educational institutions and the community.
7. Providing an atmosphere of understanding, cooperation, and healthy human relationships among all staff in the educational institution, regardless of its size or type.
8. Increasing awareness and a sense of belonging toward the educational institution among internal beneficiaries (students, faculty members, administrators, and staff).
9. Granting the educational institution greater respect, local appreciation, and global recognition [14].

C. Third: The Suitability of the Current University Education System for Applying Total Quality (TQ) Principles and Foundations:

To begin with, it is essential to distinguish between applying Total Quality principles in the educational field and other fields—whether industrial, commercial, technological, etc.—as the difference is clear and evident. This is due to the following reasons:

[5]A recent study has shown that 80% of educational institutions that failed to implement a Total Quality Management (TQM) system did so due to problems encountered at the upper and middle management levels, as well as their lack of commitment to applying it within their institutions [19].

a. Industrial inputs, etc., can be controlled, whereas this is difficult in education because students are human beings whose performance may vary.
b. It is easy to define processes in industrial fields, etc., and it is easy to control the specifications of the manufacturing process. However, in education, the process is interactive, occurring between the teacher and the learner, and depends on relationships between humans with different behaviours and reactions. Therefore, it is difficult to define specific specifications in the educational process.
c. In industry and other fields, it is easy to control outputs that lead to customer satisfaction. In education, however, there are multiple beneficiaries who are difficult to satisfy all of them [11].

Therefore, Total Quality in the educational and pedagogical field generally refers to "A set of standards and procedures aimed at achieving continuous improvement in the educational product. It refers to the expected specifications and characteristics, as well as the processes and activities through which these specifications are achieved" [21].

The application of the Total Quality system in some universities around the world has led to a qualitative shift in the level of higher education programs [15]. In a previous comparative study to monitor the changes that occurred in a university educational institution that transitioned from a traditional system to adopting the (TQ) system— Table No. (1)—the following was observed:

1. The principles and foundations of Total Quality significantly contributed to elevating the level of performance within universities—both academically and administratively.
2. It provided integrated tools and methods that helped achieve satisfactory results.
3. It fostered close relationships among staff within the university institution.
4. It developed methods of communication, decision-making, and problem-solving, among others.
5. It established new principles within the university system, such as the necessity of continuous improvement, the rejection of errors, and the goal of satisfying beneficiaries (both internal and external), etc [22].

D. Fourth: Requirements for Implementing Total Quality Management in University Education:

Total Quality Management (TQM) requires educational institutions to establish fundamental prerequisites to properly adopt and implement TQM concepts, moving beyond theoretical ideas to practical application. The goal is to achieve satisfaction for both internal (students, faculty, administrators, staff) and external (local community and labor market) beneficiaries. Among these requirements are [18]:

1. Support and endorsement from top management for the Total Quality Management system.
2. Embedding a culture of Total Quality Management among all individuals, which is a key step in serving the new directions for development and quality improvement in educational institutions.
3. Developing human resources—for faculty, administrators, technicians, and staff—and updating curricula, adopting advanced evaluation methods, and modernizing organizational structures to achieve the desired educational quality.
4. Involving all employees in efforts to improve performance levels.
5. Continuous education and training for all individuals.
6. Identifying the needs of internal beneficiaries (students, faculty, administrators, staff) and external beneficiaries (local community and labor market), and subjecting these needs to performance and quality measurement standards.
7. Encouraging the educational institution to effectively practice self-evaluation of performance.
8. Developing information systems to gather facts for making sound decisions regarding any occurring issues.
9. Delegating authority and decentralizing decision-making.
10. Genuine participation of all beneficiaries in the educational institution in formulating plans and objectives necessary for the institution's quality of work. This includes defining everyone's roles, unifying efforts, and boosting morale in the work environment at all stages and levels.
11. Using quantitative methods in decision-making to increase objectivity and reduce subjectivity.

E. Fifth: Applying Total Quality Management in University Architectural Education and Its Expected Benefits:

Jablonski has developed an applied methodology—for any educational field—in the form of fourth stages where participants learn essential skills that enable them to work effectively. These stages are as follows [23]:

1. *Decision-Making Stage*: In this stage, managers—whether top, middle, or direct management—decide whether they will benefit from applying Total Quality Management or not.
2. *Planning and Formulation Stage*: This stage involves formulating a vision for the educational system within the educational institution—or department—along with its desired goals, proposed strategies, and policies. This stage requires disseminating the spirit and concepts of Total Quality (TQ) at all levels and selecting some members to participate in the development process.
3. *Evaluation and Assessment Stage*: This stage includes self-assessment of individual performance and organizational evaluation of the system, along with conducting a comprehensive survey to ensure the satisfaction of internal and external stakeholders.
4. *Implementation Stage*: This is the stage where the philosophy of (TQM) is put into practice.

Table No. (1)- A comparison table to monitor the changes occurring in a university educational institution that transitioned from the traditional system to adopting the Total Quality Management system - Source: Journal of the Association of Arab Universities, Amman, Issue (4), April 2007

No.	Comparison Area	Changes	
		Before	After
		Traditional University	University Operating with Total Quality Concept
1	Vision and Values	Responsibility of Top Management	Shared by Everyone
2	Management's View of Employees	Workforce	Human Resources
3	Management Style	Management by Control	Management by Participation
4	Focus on Efforts	Effort for Daily Wage	Focus on Rationalizing Efforts
5	Scope of Application	Narrow Scope	Integrated Process
6	Accountability	Individual Responsibility	Team Responsibility
7	Performance Reinforcement	Negative Reinforcement (Punishment for Mistakes)	Positive Reinforcement (Reward for Improvement)
8	Communication	Top-Down	Mutual
9	Decision-Making	Mandatory Orders	Consultation Before Decision-Making
10	Individual Skills	Narrow Specialization	Diverse Skill Sets
11	Work Development	Responsibility of Supervisors	Responsibility of Everyone
12	Delegation of Responsibility	Assignment (Only for Supervisors)	Honor (For All Employees)
13	Employee Training	Developmental Duty	Developmental Right
14	Improvement	As Needed	Continuous Improvement
15	View of Work Quality	Higher Quality Means Higher Cost	Higher Quality Means Lower Cost
16	Problem-Solving	Focus on Problems Related to Results	Focus on Problems Related to Processes, Then Addressing Them to Prevent Recurrence
17	Errors	Errors are Detected and Corrected	Assumption that Errors Will Not Occur, and Planning to Avoid Them
18	Tolerance for Errors	Errors are Acceptable	Errors are Unacceptable
19	Goal	Satisfy the Manager	Satisfy the Customer (Internal and External) Above All
20	Quality Department	Responsible for Quality	Quality is Everyone's Responsibility in the University

Therefore, applying the concept of (TQM) in architectural education goes through several steps—after fulfilling the previous requirements—which include:

1. Having a clear vision for the future and a defined mission to serve society.
2. Establishing goals to be achieved in the long, medium, or short term.
3. Developing implementation plans to achieve these goals, along with programs and timelines for execution.
4. Evaluating performance considering the set goals, objectives, and plans, considering the surrounding circumstances.
5. Improving and enhancing performance.

Applying the concept of (TQM) in university architectural education will yield numerous benefits that will undoubtedly enhance the quality of the output—the primary beneficiary being the student of architecture. These benefits include:

1. *In the Academic Field*:
   a. It will help in continuously developing the curriculum and identifying new theoretical and practical knowledge areas that align with labor market requirements.
   b. It will help provide a healthy and correct educational environment for both students and faculty members.
   c. It will significantly contribute to improving the teaching process—in terms of performance style or evaluation methods—in this field.
   d. It will help develop scientific research in architecture to align with local and global societal needs.
   e. It will provide indicators to ensure the quality of education in this field, including:
      - The number of credit hours for each course (if following a credit-hour system).
      - The number and types of courses required at each academic level.
      - The number of faculty members per specialization.
      - The types and titles of books and references required for each course.
      - Educational resources and methods of their use in the educational process to contribute to achieving goals.

- Methods of evaluating and measuring each student's performance during and at the end of each semester or academic year.

f. It will grant departments that implement it a level of distinction, local recognition, and international accreditation.

2. *In the Administrative Field*:
   a. It will help establish standards for evaluating the performance levels of all administrative elements within the system.
   b. It will assist in restructuring jobs and activities according to these standards and performance levels.
   c. It will help reduce wasted costs—in terms of time and money—resulting from poor administrative performance in some tasks.
   d. It will contribute to the flexibility of administrative procedures necessary for the educational process.
   e. It will help define roles and unify efforts across all stages and levels [18].

III. RESULTS

From the above, we can conclude the following points:

1. Islamic legislation has addressed total quality in its most complete form by emphasizing **Ihsan** (excellence) and **Itqan** (mastery). **Itqan** pertains to the skills acquired by individuals, while **Ihsan** is broader and more comprehensive than **Itqan**. It represents an internal force nurtured within a Muslim's being, tied to their conscience, and translated into manual skills as well. These two elements are among the most important principles and foundations of total quality.
2. Total quality in education has become a hallmark and requirement of the era we live in, often referred to as the "Era of Quality."
3. Total quality represents global standards for measuring educational outcomes and outputs and a shift from a culture of minimum standards to a culture of mastery and excellence.
4. It is an integrated approach that seeks to develop methods for managing the educational process year after year, aiming to improve the quality of educational product.
5. It is a comprehensive system that encompasses all fields, linked to productivity, its continuity, and improvement.
6. The application of total quality systems in many higher education institutions worldwide has led to a qualitative leap in the level of programs offered and in their outcomes satisfaction by both internal and external beneficiaries.
7. To apply this concept in any educational institution, two conditions must be met, including:
   a. Support, endorsement, and conviction of top management in its value and benefits.
   b. Genuine participation of all stakeholders in formulating plans and objectives necessary to improve performance (academically and administratively) to enhance the quality of educational products.
8. The application of total quality in architectural education goes through five consecutive stages: starting with a vision and mission, followed by long-term, medium-term, and short-term goals, then implementation plans, evaluation of what has been achieved, and finally performance development and improvement to satisfy the primary beneficiary—the student (see Fig. 2).
9. Applying the concept of total quality in architectural education will help us answer the following logical questions:
   a. Where are we now, and what is our current status?
   b. Where do we want to go, and what are the goals we aim to achieve?
   c. How do we achieve what we want, and what are the standards for measuring our progress toward these goals?

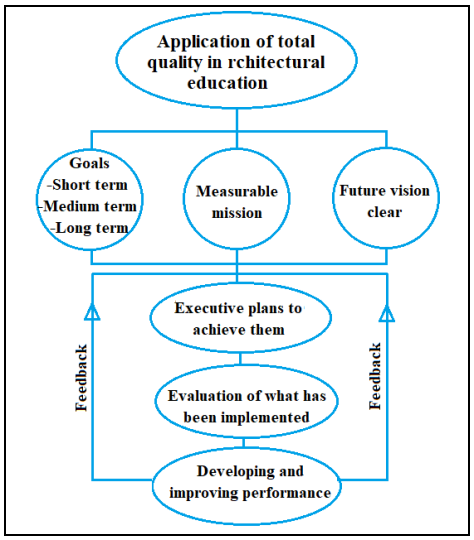

Fig. 2. Application of total quality in architectural education /Source – Researcher

IV. Recommendations

Based on the above, we recommend the following:

1. Total quality (TQ) should not be viewed as a separate program or an isolated endeavor from the other goals and projects of the educational institution. Instead, it should be seen as a shared philosophy that forms an essential part of the institution's mission and culture, explaining its purpose, objectives, and how it performs its tasks—a necessity dictated by contemporary life.
2. Each educational institution must define its mission and work to achieve it by overcoming obstacles to realize the primary and secondary objectives of total quality.
3. Universities should focus their efforts—through the concept of total quality—on developing academic and administrative aspects to bring about comprehensive change that enhances overall efficiency and meets the real needs of the society they serve.
4. Shifting from a culture of memorization and regurgitation to a culture of mastery, and from focusing on teaching to learning.

References

[1] A. R. I. Al-Mudaris, "Quality Management in Education," *Journal of Education*, no. 12, Amman, Jordan, 2016.
[2] Y. M. Al-Kahloot, "Standards of an Effective Educational Institution: Education for Excellence and Excellence for All," in *The Third Technical and Administrative Training Forum*, Jeddah, Saudi Arabia, Nov. 2008.
[3] H. M. Al-Alawi, *Total Quality Management in Higher Education Institutions*, King Abdulaziz University, Scientific Publishing Center, Jeddah, Saudi Arabia, 2008.
[4] J. E. Freed, M. Robson, and J. Ross, "Implementing the Quality Principles in Higher Education Research," *J. Organizational Change Management*, vol. 38, no. 2, pp. 107–119, 1997.
[5] J. R. Jablonski, *Implementers Total Quality Management*, Santiago, USA, p. 70, 2001.
[6] A. Badah, "Total Quality Management: A Proposed Model for Administrative Development and Its Applicability in Jordanian Universities," *Journal of the Association of Arab Universities*, no. 46, Amman, Jordan, 2016.
[7] B. F. Mahjoub, *Management of Arab Universities in Light of International Standards*, Arab Administrative Development Organization, Cairo, 2013.
[8] R. R. Al-Banna, "Total Quality Management: Its Concept and Methodology for Implementation," in *21st Annual Education Conference*, Kingdom of Bahrain, Jan. 2007.
[9] Y. Z. Younis, "Total Quality Management and Higher Education: Is the Marketing Concept Suitable for the Learning Process in Higher Education Institutions," in *Third Technical and Administrative Training Forum*, Jeddah, Saudi Arabia, Nov. 2008.
[10] M. S. Al-Tarawneh, "Total Quality Standards in Higher Education Institutions," in *Third Technical and Administrative Training Forum*, Jeddah, Saudi Arabia, Nov. 2008.
[11] M. A. R. Ibrahim, *Teacher Training System in Light of Total Quality Standards*, Dar Al-Fikr for Printing, Publishing, and Distribution, Jordan, 2003.
[12] R. Middlehurst, "Quality Assurance Implications of New Forms of Higher Education," *European Network for Quality Assurance in Higher Education*, Helsinki, Finland, 2001.
[13] M. S. Al-Dradkeh et al., Total Quality Management, 1st ed. Amman, Jordan: Dar Al-Safa for Publishing and Distribution, 2001.
[14] A. Khouja, "The Culture of Quality and Its Role in Transitioning from Traditional Craft Economy to Industrial Economy Traditions," in The Third Forum for Technical and Administrative Training, Jeddah, Saudi Arabia, Nov. 2008.
[15] F. Al-Najjar, University Management through Total Quality, Cairo, Egypt: Itrak Publishing, 2010.
[16] M. M. Ziad, Total Quality Management in Educational Institutions, Amman, Jordan: Safa for Publishing and Distribution, 2008.
[17] A.E.-S. Mostafa, Total Quality Management and ISO 9000, Cairo, Egypt: Anglo Egyptian Library, 1998.
[18] A. B. E. Aichouni, "A Systematic Literature Review of the Integration of Total Quality Management and Industry 4.0: Enhancing Sustainability Performance Through Dynamic Capabilities," University of Coimbra, Portugal, 2024.
[19] Z. M. Abboudi, Total Quality Management, Jeddah, Saudi Arabia: Dar Kunuz Al-Ma'rifa for Publishing and Distribution, 2006.
[20] FOCUS 2005-2010, Strategies for Success, Bluegrass Community and Technical College.
[21] Q. N. Al-Mahiawi, "University Management in Light of Total Quality Standards," Journal of the Association of Arab Universities, no. 4, Apr. 2007.
[22] K. A. Al-Sarayrah and L. Al-Asaf, "Total Quality Management in Higher Education Institutions: Between Theory and Practice," Scientific Journal for Quality Assurance in Higher Education, vol. 1, no. 1, pp. 1–36, 2007.
[23] J. Jablonski, Implementing Total Quality Management: An Overview, Part Two, trans. A. F. A.-S. Al-Numani, Giza, Egypt: Professional Management Expertise Center "BIMAC", 2010.

UTILIZING AN OPEN IMPELLER OF A CENTRIFUGAL PUMP IN REVERSE MODE TO GENERATE ELECTRICITY

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Utilizing an Open Impeller of a Centrifugal Pump in Reverse Mode to Generate Electricity

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Abstract— The increasing demand for electricity, particularly in remote and off-grid regions, has highlighted the need for cost-effective and environmentally sustainable energy solutions. This study investigates the feasibility of utilizing a centrifugal pump, operated in reverse mode with an open impeller, as a turbine for micro-hydro power generation. Small hydropower (SHP) systems, characterized by their affordability and minimal ecological impact, represent a promising alternative to large-scale energy projects. Experimental tests were conducted to evaluate the operational parameters of the open impeller, focusing on the Best Efficiency Point (BEP), power output, and efficiency at varying discharge rates and inlet heads. Results revealed a peak efficiency of 77% at a power output of 3447 W, a rotational speed of 1990 rpm at a head of 13 m, and a flow rate of 14.58 m³/s. The findings demonstrate that the open impeller effectively functions as a micro-turbine, offering a viable solution for electricity generation in isolated rural communities or standalone urban homes with adequate water resources. This study underscores the potential of centrifugal pumps in reverse mode as a cost-efficient and scalable alternative for micro-hydro power systems, fostering energy accessibility in underserved areas.

Keywords— Centrifugal Pump, Open Impeller, Electricity Generation, Pump as Turbine, Power Output.

I. INTRODUCTION

The global demand for sustainable and renewable energy solutions has intensified over the past two decades, with small hydropower systems emerging as significant contributors to electricity generation from renewable sources [1]. The advancement of technology, coupled with the push for industrialization, has created an urgent need for reliable energy sources in both urban and remote areas. This surge in electricity demand has sparked renewed interest in developing small hydroelectric power (SHP) projects, primarily due to their economic viability and lower environmental impact compared to large-scale hydropower projects [2].

Electrical energy is fundamentally linked to improved living conditions, yet many rural areas remain unconnected to the national grid, particularly in developing countries like Nigeria [3]. This lack of access to electricity presents a unique opportunity to explore innovative solutions, such as utilizing centrifugal pump impellers in a reverse operation as turbines for electricity generation in these underserved regions.

Traditional methods of establishing large-scale power generation facilities—be it thermal, nuclear, or conventional hydroelectric sources—are often prohibitive in terms of cost, time, and environmental disruption. In contrast, micro-hydroelectric power generation using centrifugal pumps offers a simpler, cost-effective, and less intrusive approach to providing electricity, especially in remote locations. Several countries, including Belgium and Nepal, have already implemented "pump-as-turbine" technology in their micro-hydro schemes to address local energy needs [4, 5].

For low-capacity hydroelectric plants (less than 100 kW), the potential of employing centrifugal pump impellers as turbines warrants thorough exploration [6]. The reverse operation of centrifugal pumps has surfaced as an innovative solution for power generation. Advances in electrical machinery control technologies that enable variable speed and torque regulation have further facilitated the practicality of utilizing centrifugal pumps in reverse for energy generation [7].

Existing conventional turbines typically feature inlet guide vanes, which are absent in centrifugal pumps used in reverse mode. This distinction leads to variations in discharge characteristics relative to standard turbines. However, centrifugal pumps operating as turbines' inherent simplicity, durability, and efficiency present a compelling alternative [8].

The performance of a centrifugal pump, particularly its impeller design, plays a critical role in its operational efficacy. The dimensions and configurations of the impeller are instrumental in defining the pump's overall performance, influencing its capacity and total dynamic head (TDH). This study focuses on the open impeller type, posited as an effective alternative to traditional turbines for generating electrical power. This research aims to examine the operational parameters of an open impeller centrifugal pump functioning as a turbine for electricity generation. Key objectives include:

- Determining the centrifugal pump's Best Efficiency Point (BEP) in turbine mode.
- Evaluating the operational power of the pump as a turbine (PAT).
- Assessing the pump's performance across varying discharge rates.

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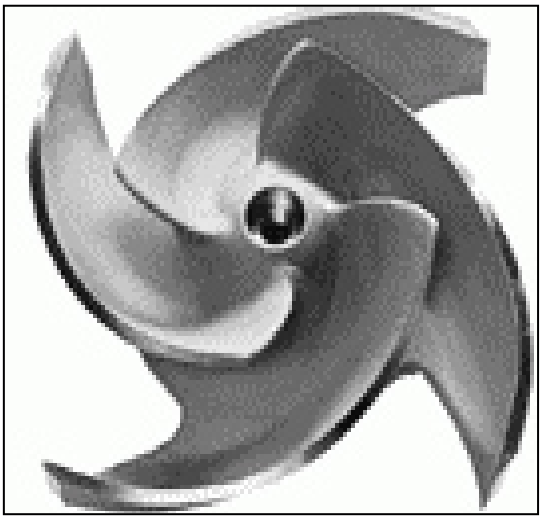

Figure 1. Open Impeller [9]

II. Literature Review

[10] explored the use of an end suction centrifugal pump operating in turbine mode for micro-hydro applications coupled with an induction generator. Their investigation encompassed both experimental and simulation approaches on a single-stage, low-specific-speed pump (<10 kW). Notably, their findings demonstrated that centrifugal pumps could function effectively in turbine mode without mechanical modifications. The study highlighted that achieving the Best Efficiency Point (BEP) required higher flow rates and heads than the pump's rated conditions. Efficiency improvements were linked to geometric modifications of hydraulic characteristics, and coupling the pump with a modified induction motor and electric control systems successfully regulated output voltage and frequency.

[11] evaluated the feasibility of pump-as-turbine (PAT) systems for addressing energy challenges in rural and hilly regions. Using computational fluid dynamics (CFD) simulations, they analyzed a mixed-flow centrifugal pump with a specific speed of 1850 rpm. Their experiments revealed a maximum efficiency of 83.10% at a flow rate of 0.127 m^3/s and a head of 12.48 m, operating at 1450 rpm in turbine mode. The numerical and experimental findings showed satisfactory agreement, underscoring the reliability of PAT systems.

[12] focused on PAT systems' mechanical energy generation capabilities. Experimental performance curves for the "Etanorm pump 150-315" demonstrated up to 80% efficiencies under varying flow rates and rotational speeds. For instance, at a small head of 11.5 m and a speed of 760 rpm with a flow rate of 300 m^3/head, the PAT system generated 7.5 kW on the impeller shaft. These results underscored the adaptability of PAT systems for diverse operational conditions.

[8] conducted a functional characterization of centrifugal pumps in turbine mode, analyzing the influence of rotational speed on efficiency and operational parameters. Their findings demonstrated that turbine characteristics could be partially predicted from pump characteristics, with water exiting the runner free of swirl flow at BEP. Additionally, they observed lower radial stresses in turbine mode compared to pump operation.

Using an experimental rig, [13] experimentally investigated a centrifugal pump operating as a turbine (PAT). Their results confirmed that centrifugal pumps could operate efficiently in turbine mode without mechanical complications, achieving higher heads and discharge values compared to pump operation. However, the BEP in turbine mode was observed to be lower than in pump mode, aligning with previous research findings.

[14] developed a novel approach for predicting the inverse characteristics of industrial centrifugal pumps using three-dimensional CFD simulations. Their method, validated in pumping mode and compared with experimental data for reverse mode operation, provided insights into the best efficiency point and inverse characteristics. Testing on three pumps with varying specific speeds highlighted the accuracy of their predictive model, demonstrating its utility for PAT applications.

III. Materials

A. Materials Used for the Experiment of the Open Impeller for the Turbine Test

The following are the materials and instruments used for the experiment:

Table 1. List of Materials and Instrument used for both Pump and Turbine Test

S/N	Material/Instruments	Pump Descriptions	Turbine Descriptions
1	Centrifugal Pump	3.8 hp	3.8 hp
2	Gauge Valve	51 mm	79 mm
3	Intake Pipe	Diameter 51 mm	Diameter 79 mm
4	Out Pipe	Diameter 65 mm	Diameter 68
5	Ground Tank	As Adequate	As Adequate
6	Tachometer	Cyber Tech. (NUSPSC 25174406)	Cyber Tech. (NUSPSC 25174406)
7	Manometer	Canstock (csp 14719981)	Canstock (csp 14719981)
8	Stop Watch	Digital	Digital
9	Impeller	Open Type	Pelton Type

IV. METHODS

A. Performance Test on the Centrifugal Pump Using an Open Impeller as a Turbine

The performance testing of the centrifugal pump operated in turbine mode utilized the methodology proposed by [15]. The experimental setup, depicted in Figure 2, comprised a PVC pipe connected from the bottom of an overhead tank to the turbine. A manometer and gauge valve were installed along the pipe to facilitate accurate measurement of flow rates.

An underground tank was incorporated into the system to regulate the discharge from the turbine tailrace. A second gauge valve was situated on the pipeline discharging water from the turbine's tailrace to the underground tank, allowing for enhanced control of water flow between the turbine tailrace and the underground reservoir.

The water discharged from the turbine's tailrace flows into an underground tank, which is equipped with a gauge valve on the discharge pipe. This setup facilitates enhanced control over the water flow between the turbine's tailrace and the underground tank.

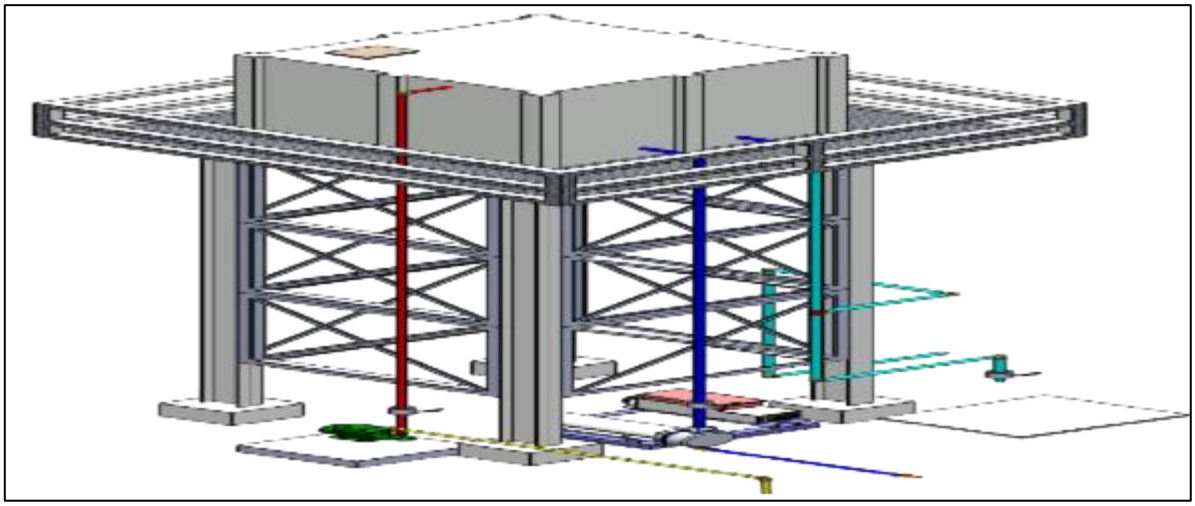

Fig. 2. Turbine Test Schematic Diagram

To ensure a continuous supply of water to the turbine, the water exiting the turbine is recycled back to the overhead tank using an auxiliary pump. A second gauge valve is installed between the underground tank and the auxiliary pump to optimize the control of water flow in this section of the system. Figure 3 illustrates the side view of the schematic diagram representing the turbine test setup.

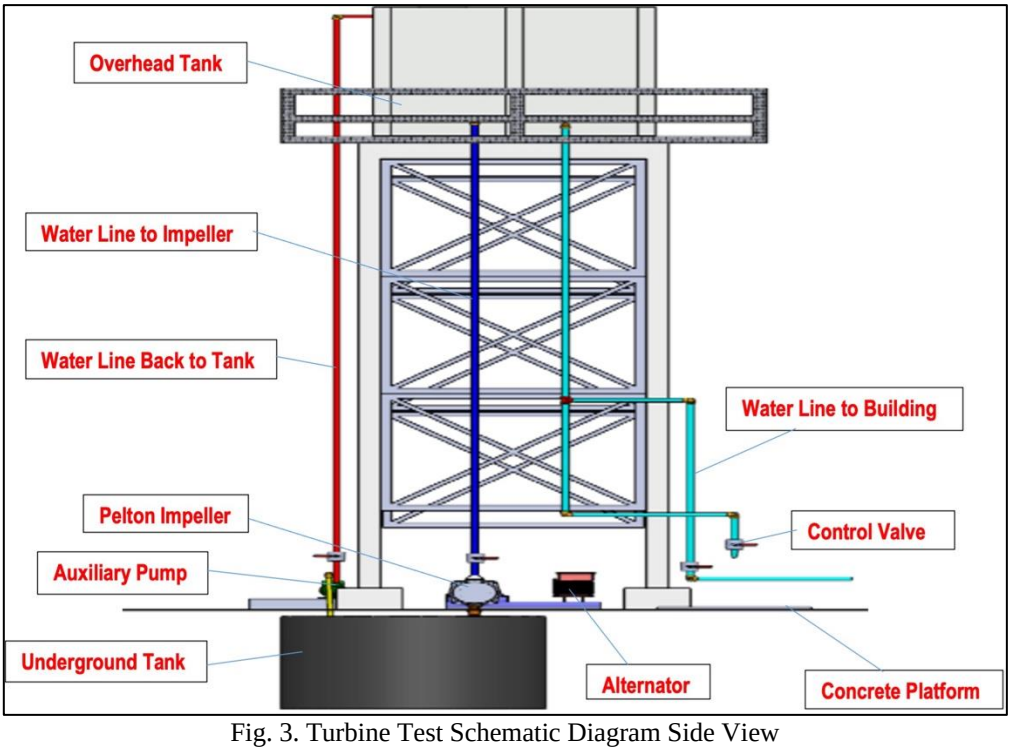

Fig. 3. Turbine Test Schematic Diagram Side View

The experimental procedure was conducted at five distinct heads using an open impeller type centrifugal pump, allowing for the free gravitational flow of water from the overhead tank to the turbine impeller. The impeller speed was monitored using a tachometer placed in close proximity to it. The five test heads used in the experiment were 7.60 m, 9.10 m, 10.70 m, 12.20 m, and 13.70 m, as detailed by [16]. The centrifugal pump was thoroughly primed prior to testing, and all valves were opened to prevent any choking in the system during low flow conditions. This was managed by carefully adjusting the bypass valve as needed. The desired turbine head was accurately achieved through height measurements, followed by the necessary adjustments to the positioning and setup of the entire centrifugal pump system for each specific head.

Once the centrifugal pump system was fixed and readjusted at the desired head the valves and the by-pass valves were reopened for water to flow so as to take the next set of readings at different flow rates. At each step, the water was allowed to flow with the valves constantly adjusted so as to maintain accurate measurements of the readings. This procedure was repeated for all the experiments.

B. Data Collection and Analysis

1. *Measurement of Flow Rates:* Flow rates were recorded using the installed manometer and gauge valve and collected over various operational conditions.
2. *Evaluation of Power Output:* The operational power of the pump as turbine (PAT) was calculated based on the measured flow rates and head developed by the pumping system.
3. *Performance Metrics:* Key performance metrics, including the efficiency, flow characteristic curves, and operational limits of the centrifugal pump, were derived through empirical testing and analysis.

This methodology provides a robust framework for assessing the feasibility of centrifugal pump impellers as viable alternatives to traditional turbine methodologies in micro-hydroelectric power generation.

C. Determination of Flow Rate

Using the process adopted by [17, 3], the flow rate Q was calculated from equation (1).

$$Q = 1 \cdot 73\sqrt{\Delta h}\ l/s \quad (1)$$

D. Determination of Power Output

The process used by [18] was adopted in calculating the power output (P_{out}) of the turbine, which is Bernoulli's Equation. (2 – 6)

$$P_{out} = w_s \times \dot{m} \quad (2)$$

where,

$$Work\ Shaft\ (w_s) = \left(gh - \frac{V^2}{2}\right) \quad (3)$$

$$\dot{m} = \rho AV \quad (4)$$

$$Velocity\ (V) = \frac{\pi DN}{60} \quad (5)$$

$$Cross\ Sectional\ Area\ (A) = \frac{\pi}{4}D^2 \quad (6)$$

E. Determination of Power Input

The process by [19] was adopted to calculate the power input of the Pelton type impeller. According to equation (7) The power input is the power giver to turn the impeller blade.

$$P_{in} = \frac{\rho QH}{75 \times \eta} \quad (7)$$

where, η is the manufacture's pump efficiency (0.55) that is 55%.

F. Determination of Efficiency

The process used by [18] was adopted to calculate the pump efficiency (η). See equation (8).

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \quad (8)$$

G. Determination of Specific Speed of Turbine

The Process adopted by [20] was used to calculate the Specific Speed of the turbine. According to equation (9).

$$N_{ST} = \frac{N\sqrt{P_{out}}}{H^{5/4}} \quad (9)$$

where, $N =$ kinematic speed in rpm.

V. Result and Discussion

A. Experimental Findings

The results of the experiments conducted on the centrifugal pump performance in turbine mode using an open impeller are detailed in standard units compliant with micro hydropower standards. Measurements were taken across five different inlet heads, providing a comprehensive dataset for analysis. The polynomial correlation equation derived from regression analysis serves as the model for generating predictions in this study.

B. Effect of Power Output on Efficiency

The relationship between power output and efficiency was observed to be curvilinear. As power output increased, efficiency correspondingly improved until reaching a peak, after which efficiency declined across all five inlet heads (Figure 4). The maximum efficiency achieved was measured at a specific power output, aligning with the findings of [15, 14]. However, it was noted that the efficiencies reported by these studies were generally lower. The coefficients of variation for efficiency concerning power output ranged from 73% to 98%, indicating that the models reliably forecast the efficiency trends across different power outputs.

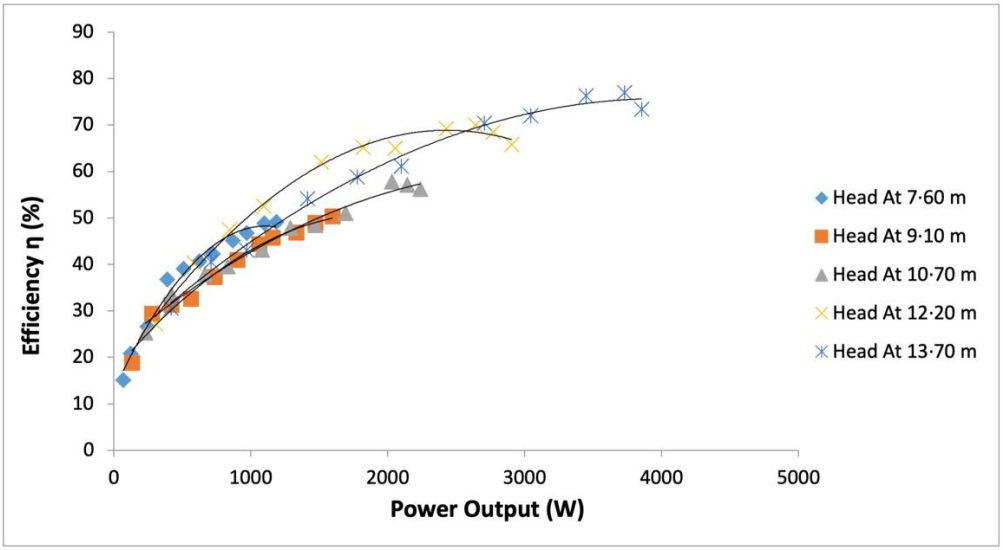

Fig. 4. Effect of Power Output on the Efficiency of the Turbine for Open Impeller

C. Effect of Power Input on Efficiency

Similarly, the data demonstrated a strong correlation between power input and efficiency, revealing a consistent curvilinear trend. Efficiency increased with power input, peaked, and subsequently fell, a pattern consistently observed across all tested heads (Figure 5). This behavior suggests that exceeding the best efficiency point (BEP) leads to reduced efficiency, aligning with previous studies by [14, 1], with the latter reporting lower maximum input power and efficiency ratings 4·17kW and 58%, respectively. The variation coefficients for this relationship ranged from 76% to 98%, further supporting the model's fit across the observed trends.

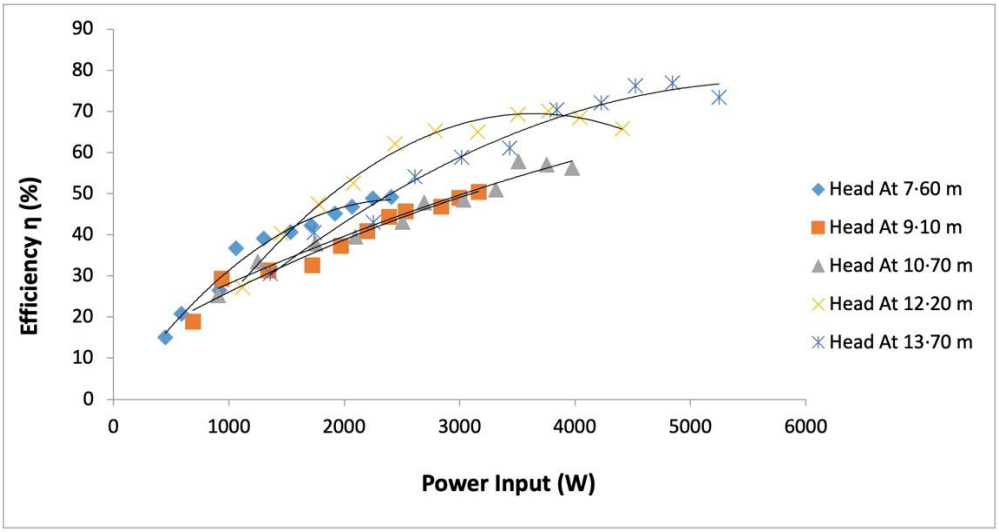

Fig. 5. Effect of Power Input on the Efficiency of the Turbine for Open Impeller

D. Effect of Flow Rate on Efficiency

The flow rate was also examined for its influence on efficiency, revealing a curvilinear relationship where increased flow rates resulted in higher efficiencies until a peak was reached, after which efficiency declined. (Figure 6). The highest efficiency recorded for the open impeller occurred at 76·28%, whereas the best efficiency point of the flow rate occurred at 13·61 m^3⁄s. This finding corroborates the results from [21, 22], with a notable observation that [22] reported a shift toward higher flow rates for maximum efficiency. The coefficients of variation for this relationship ranged from 75% to 99%, showcasing the model's validity in depicting the efficiency trends.

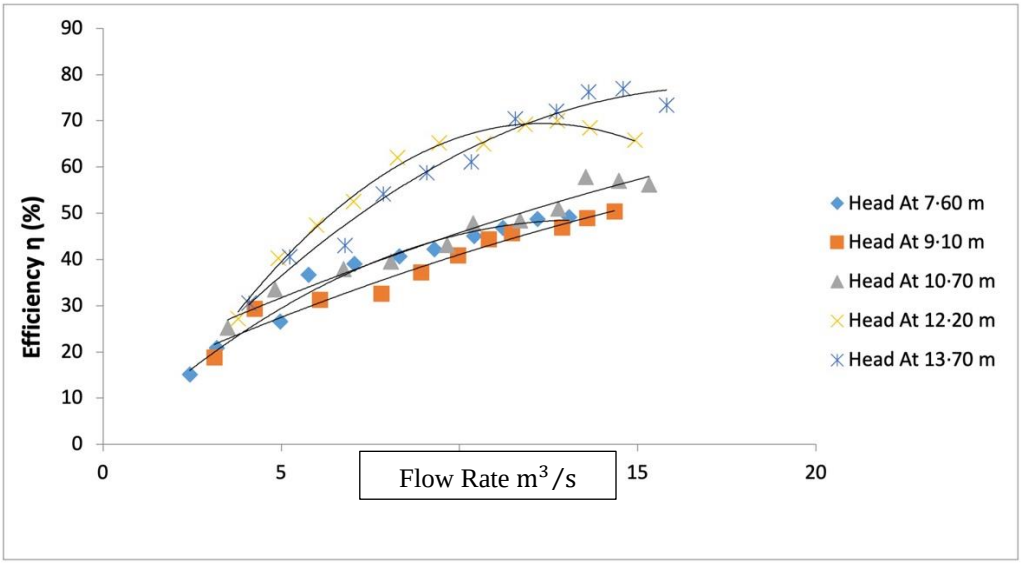

Fig. 6. Effect of Flow Rate on the Efficiency of the Turbine for Open Impeller

E. Effect of Impeller Speed on Flow Rate

Additional observations indicated that impeller speed increased with flow rate. Specifically, for higher inlet heads, impeller speed showed pronounced increases, particularly at elevated head levels due to the gravitational forces acting on the water. The trends observed were consistent with previous studies by [23, 13, 24], illustrating commonalities in hydraulic performance insights across the literature. The coefficients of variation concerning the effects of flow rate on speed ranged from 96% to 99% (Figure 7), affirming the model's applicability in these findings.

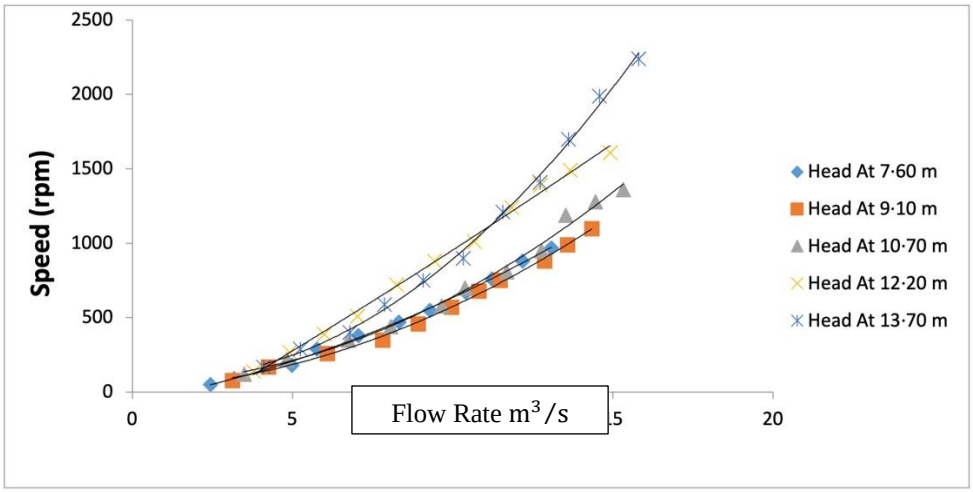

Fig. 7. Effect of Flow Rate on the Speed of Open Impeller

VI. Conclusion

The primary objective of this study was to investigate the operational parameters of a centrifugal pump utilizing an open impeller in turbine mode for micro-hydro power generation. The findings suggest that the open impeller configuration effectively harnesses energy from water resources, making it suitable for applications in isolated rural areas or standalone urban homes, provided there is adequate access to water reservoirs year-round.

Key conclusions drawn from the experimental results include:

- The open impeller reached its best efficiency point at 77%, indicating optimal performance at specific operating conditions.
- The operational power output derived from the centrifugal pump was established, affirming the potential of the open impeller to produce commendable power outputs of 3447W under varying conditions.
- The correlation of speed variations with flow rate across different heads was successfully characterized, highlighting the influence of gravitational forces on performance efficiency.

These findings contribute valuable insights into the design and implementation of micro-hydropower systems, emphasizing the viability of centrifugal pumps as turbines in renewable energy applications. Future research may extend these findings by exploring longer-term operational

efficiency and integrating environmental considerations for sustainable energy solutions.

REFERENCES

[1] H. Zhang, "Optimal Sizing and Operation of Pumping Systems to Achieve Energy Efficiency and Load Shifting," Ph.D. dissertation, Univ. of Pretoria, South Africa, 2011, p. 205.

[2] P. Singh, "Optimization of the Internal Hydraulic and of System Design in Pumps as Turbines with Field Implementation and Evaluation," Ph.D. dissertation, Univ. of Karlsruhe, Germany, 2005, p. 214.

[3] J. D. Lawrence, "Small Scale Hydro: The Use of Pumps and Turbines," in Proc. Waterpower '79, Int. Conf. Small Scale Hydropower, Washington, D.C., USA, Jul. 5-7, 1979.

[4] A. Morabito, J. Steimes, O. G. Bontems, G. Al Zohbi, and P. Hendrick, "Set-up of a pump as turbine use in micro-pumped hydro energy storage: a case study in Froyennes, Belgium," IOP Conf. Ser.: J. Phys., vol. 10, pp. 362–369, 2017.

[5] M. Niroj, C. Sailesh, and K. Ravi, "Design of reversible pump turbine for its prospective application in Nepal," Int. J. Sci. Res. Publ., vol. 4, no. 7, pp. 50–54, 2014.

[6] P. Robinson, "Microhydro in Papua New Guinea—the experiences of an electrical engineer," Power Eng. J., vol. 8, pp. 273-280, 2012.

[7] O. K. Olaore, D. B. Gwadangwaji, M. A. Bayawa, and M. Muazu, "Investigating the Operational Parameters of a Centrifugal Pump Used in Reverse Mode as Turbine for Electricity Generation," Global J. Sci. Frontier Res.: A Phys. Space Sci., vol. 21, no. 6, 2021.

[8] J. Fernandez, E. Blanco, J. Parrondo, M. T. Stickland, and T. J. Scanlon, "Performance of a centrifugal pump running in inverse mode," J. Power Energy, vol. 4, pp. 265-271, 2004.

[9] Goulds Pumps, "Centrifugal Pump Fundamentals," 2009. [Online]. Available: http://www.gouldspumps.com/pdf_fullindex.stm [Accessed: Oct. 4, 2014].

[10] A. I. Mohd, O. Al Khalid, S. I. Shahidul, and Z. Hushairi, "End suction centrifugal pump operating in turbine mode for microhydro applications," Adv. Mech. Eng., vol. 8, Art. ID 139868, 7 pp., 2014. [Online]. Available: http://dx.doi.org/10.1155/2014/139868

[11] S. Rawal and J. T. Kshirsagar, "Numerical simulation on a pump operating in turbine mode," in Proc. 23rd Int. Pump Users Symp., Jun. 4–8, 2007.

[12] D. Rusovs, "Pump Application as Hydraulic Turbine – Pump as Turbine (PaT)," Mech. Sci., vol. 31, no. 1, pp. 158-161, 2009.

[13] N. Raman, I. Hussein, G. Palanisamy, and B. Foo, "An experimental Investigation of Pump as Turbine for Micro Hydro Application," in IOP Conf. Ser.: Earth Environ. Sci., vol. 16, pp. 1-6, Sep. 2013.

[14] E. Frosina, D. Buono, and A. Senatore, "A Performance Prediction Method for Pump as Turbines (PAT) Using a Computational Fluid Dynamics (CFD) Modeling Approach," Energies, vol. 10, pp. 83-89, 2017. [Online]. Available: https://www.mdpi.com/journal/energies.

[15] H. Nautiyal, K. Varun, and S. Yadav, "Experimental investigation of centrifugal pump working as turbine for small hydropower system," Energy Sci. Technol., vol. 1, no. 2, pp. 79-86, 2011.

[16] R. Holland, "Appropriate Technology—Rural electrification in developing countries," IEE Rev., vol. 45, no. 7, pp. 251–254, 2013.

[17] M. Sahdev, "Centrifugal Pumps: Basics Concepts of Operation, Maintenance, and Troubleshooting, Part," [Online]. Available: http://www.maintenanceworld.com/Articles/engresource. [Accessed: Jun. 16, 2009].

[18] V. K. Shankar, S. Umashankar, S. Paramasivam, and N. Hanigovszki, "A Comprehensive Review on Energy Efficiency Enhancement Initiatives in Centrifugal Pumping System," Appl. Energy, vol. 181, pp. 495-513, 2016.

[19] P. N. Modi and S. M. Seth, Hydraulics and Fluid Mechanics, 20th ed. Delhi, India: Standard Book House, 2016, pp. 1606.

[20] W. Arthur, Pump as Turbine: A User's Guide, 2nd ed. Rugby, UK: Practical Action Publishing, 2003, p. 240.

[21] M. Sadral, J. Soukal, and M. Komaurek, "CFD Analysis of Middle Stage of Multistage Pump Operating in Turbine Regime," Eng. Mech., vol. 16, no. 6, pp. 413-421, 2009.

[22] R. Barrio, J. Fernandez, J. Parrondo, and E. Blanco, "Performance Prediction of a Centrifugal Pump Working in Direct and Reverse Mode Using Computational Fluid Dynamics," in Proc. Int. Conf. Renewable Energies and Power Quality (ICREPQ'10), Granada, Spain, Mar. 23-25, 2010.

[23] S. Kumar, S. K. Mohapatra, and B. K. Gandhi, "Investigation on Centrifugal Slurry Pump Performance with Variation of Operation Speed," Int. J. Mech. Mater. Eng., vol. 8, pp. 40-47, 2013.

[24] S. Derakhshan and A. Nourbakhsh, "Experimental Study of Characteristic Curves of Centrifugal Pumps Working as Turbines in Different Specific Speeds," Exp. Therm. Fluid Sci., vol. 40, pp. 400-407, 2016.

ENHANCED GRAPH BASED WORD REPRESENTATION FOR BIOMEDICAL NAMED ENTITY RECOGNITION

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Enhanced Graph Based Word Representation for Biomedical Named Entity Recognition

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Abstract— As the biomedical literature continues to expand rapidly, the significance of extracting biomedical-named entities from this extensive body of work is steadily increasing. Bio-NER presents a greater challenge compared to general entity recognition due to the non-standard use of abbreviations, synonyms, homonyms, ambiguities, and the continual creation of new biomedical entity names. These factors combine to create a significant hurdle in the accurate identification and classification of biomedical entities. The underperformance of machine learning models in biomedical text analysis is primarily attributed to the inadequate representation of these texts through manually created features. In addressing this challenge, this study aims to create enhanced word representation methods to improve biomedical named entity recognition and are based on enhanced graph-based word representation techniques, utilizing machine learning approaches: CRF, SVM, and ensemble learning. These methods are assessed using the well-known GENIA corpus. The results show that SVM, CRF and ensemble learning with morphological, orthographic and context features achieves good results with overall F-measure of (54.6%), (81.87%) and (85.64) respectively. In addition, experimental results also show that enhanced graph-based word representation techniques achieve higher performance with overall F-measures (85.62%), (89.69%) and (91.17) respectively. Results show that proposed graph-based word representations significantly improve the overall performance of CRF, SVM, and ensemble learning over traditional feature representation techniques. In general, results show that word representation is a key factor in constructing a suitable recognition method.

Keywords— Biomedical, Named Entity Recognition, Word Representation, Supervised Machine Learning.

I. INTRODUCTION

The continuous expansion of biomedical texts has unleashed an extensive corpus of freely available, yet largely unstructured, biomedical literature. The challenge of keeping up with new discoveries has become more and more difficult as this amount of data continues to grow. Extracting valuable insights from this huge amount of data to locate relevant literature for research in the biomedical field has become a hard task for researchers. As a result, biomedical text mining and knowledge extraction tools can play a vital role in facilitating the extraction of valuable information from biomedical texts. Biomedical-named entity recognition stands as a pivotal component within biomedical mining tools. Its primary objective is the automatic identification and categorization of biomedical-named entities such as genes, proteins, SNPs, chemicals, and drug names from unstructured textual data in the biomedical domain [1]. The extraction and identification of biomedical entities present a greater level of complexity compared to traditional entities. This heightened complexity arises due to the non-standard use of abbreviations, synonyms, homonyms, ambiguities, and the continual creation of new biomedical entity names. [2].

Several approaches have been employed to tackle the challenge of biomedical named entity recognition. These approaches can be broadly classified into rule-based, dictionary-based, and supervised methods. In the early stages of Named Entity Recognition (NER), systems were built using manually crafted rules, lexicons, orthographic features, and ontologies [3, 4]. While these methods offer certain advantages, such as they do not need annotated training data, they also come with notable drawbacks. For instance, lexicons and handcrafted rules must be comprehensive, and the associated dictionaries require continuous updates by domain experts to remain relevant. In contrast, supervised learning methods rely on annotated training data, typically represented with morphological, orthographic, and contextual features that have been carefully chosen by domain experts. The primary challenge with these approaches lies in the manual feature engineering required for each specific dataset [5]. In addition, a crucial concern within these supervised techniques pertains to the selection of data representations. Creating robust word representations that are domain and datasets independent and can capture useful recognition information is a major issue to enhance the performance of these techniques.

Existing literature highlights the pivotal role of crafting effective data representation techniques when developing named entity recognition systems. Thus, Hence, the creation of enhanced graph-based word representation techniques, capable of capturing valuable information for recognition and classification while remaining independent of specific domains and datasets, is essential for substantially improving the performance of machine learning methods in biomedical named entity recognition. To tackle this issue, this study seeks to design effective dataset- and entity-independent graph-based word representation methods to enhance the performance of supervised machine learning methods for biomedical named entity recognition.

The main contributions can be summarized as follows:

- This work evaluates baseline feature extraction and representation with supervised machine learning methods namely Conditional Random Fields (CRF), Support Vector Machines (SVM), and ensemble learning for biomedical named entity recognition.

- This work introduces enhanced graph-based word representation methods for biomedical named entity recognition.

The rest of the paper is organized as follows. Section 2 reviews related work. Section 3 introduces the materials and methods used in this work. The experimental setting and experimental results are discussed in Section 5. Finally, Section 6 offers some conclusions and suggestions for future work.

II. Literature Review

Several approaches have been used to address biomedical named entity recognition problems which can be categorized as Rule-based approach: In rule-based systems, a set of hand-crafted rules the experts can be built to identify and extract the named entities [6, 17, 18], namely, matches names with a strongly defined morphological and orthographic structure. Dictionary-based approaches: where string-matching methods are used to identify entities in text, are common [4, 6]. Machine learning approaches: When the annotated corpora on biomedical is available. Machine learning approaches are based on statistical models to make predictions about named entities in a given text. These models have their mathematical approaches and techniques for training the corpus, determining the probabilistic values and have their methodologies of working to get the desired result [6]. State-of-the-art Bio-NER approaches use various machine learning algorithms. Each modelling technique uses the feature matrix to create a probabilistic description of the entity name boundaries. Different supervised models have been developed on Bio-NER systems, namely Conditional Random Fields (CRFs) [7], Support Vector Machines (SVMs) [8, 9], Hidden Markov Models (HMMs) [10] and Maximum Entropy Markov Models (MEMMs) [11]. CRFs have been actively used during the last years, since they present several advantages over other methods. Firstly, CRFs avoid the label bias problem, a weakness of MEMMs. In addition, CRFs also have advantages over HMMs, a consequence of their conditional nature that results in the relaxation of the independence assumptions. Finally, although SVMs can provide comparable results, more time is required to train complex models. Semi-supervised solutions use both annotated and unannotated data, in order to solve the data sparseness problem. Thus, the main goal is to collect features of the unannotated data that are not present in the annotated data, which may contribute to a better identification of the entity name boundaries. There are various approaches to implementing semi-supervised solutions [12, 13]. Song, Yu [14] proposed a hybrid dictionary-based entity extraction technique. The proposed technique consists of 1) an approximate string matching technique, 2) a shortest path edit distance technique, and 3) context-enabled text mining techniques. Kuo and Lin [15] achieved F-measures of 80.6%, and 79.7% on the GENIA corpus and the YAPEX corpus respectively for extraction of protein names from biological literature. They used rule-based method to improve protein name prediction rate and N-gram language model to determine the boundary of protein names. In order to enhance the recognition performance of proteins, they used a dictionary to strengthen recognition of abbreviations and words beginning with uppercase. Pilehvar et al. [16] introduced ELMo which generate contextual embeddings by considering the contexts and morphological structures of individual words at each state in text. This way, the embeddings of the same word can vary depending on their syntactical contexts and morphological structures in text.

III. Research Ethodology

The section outlines the methodology for enhancing biomedical named entity recognition through enhanced graph-based word representation. To begin, this work evaluates baseline techniques that involve training and testing machine learning models with datasets structured around traditional features. This phase encompasses a feature engineering task aimed at identifying the traditional features. Subsequently dataset was prepared accordingly. Subsequently, this work explores the development and evaluation of multiple enhanced Biomedical Named Entity Recognition models utilizing the newly proposed graph-based word representation techniques.

A. Baseline Method For Biomedical Named Entity Recognition

In this section, a brief overview is provided of the state-of-the-art in Biomedical Named Entity Recognition models. These models are executed through a series of steps:

1. *Feature Extraction Step*: Each word in both the training and test datasets is transformed into a vector of values using a predefined set of manually crafted features. These features are selected based on existing literature and encompass morphological, orthographic, and contextual characteristics, as detailed in Table 1.
2. *Recognition Step*: In this phase, a range of supervised machine learning models, specifically Conditional Random Fields and Support Vector Machines, are trained and evaluated using the datasets prepared in the previous feature extraction step.

Table 1. Used Features Set

Feature set	Actual features in the feature set
Surrounding words	Four words in the surrounding context: two words before and two words after the current word
Dynamic feature	Dynamic feature denotes the output tag of previous words (tags of two words)
Orthographic features	Orthographic features: Several binary features are defined: initial capital, all capital, includes caps, has slash, has punctuation, has a digit, Start with a dash.
Word affixes	Hyphen suffix, word prefix and suffix character sequences of length up to 4.

B. Enhanced Biomedical Named Entity Recognition Methods

This section provides a detailed description of the enhanced Biomedical Named Entity Recognition models that are being

proposed. These models undergo a sequence of steps. Initially, every word in both the training and test datasets is encoded using one of the proposed graph-based representations. Subsequently, supervised machine learning models are trained and evaluated using these datasets.

C. Co-occurrence graph-based representation method

The main idea of this representation is to generate a graph representation where entities are only connected and have the same class if they co-occur with similar words. The following describe the main steps of this algorithm:

1. *Step 1*: Category Words Extraction: A set of representative words is extracted for each biomedical named entity class c from the training corpus based on the correlation between the word and its class c. The point-wise mutual information (PMI) was used by the following equation:

$$\mathrm{PMI}(\mathrm{class}, \mathrm{word}) = \log_2 \frac{\mathrm{p}(\mathrm{class}, \mathrm{word})}{\mathrm{p}(\mathrm{class}).\mathrm{p}(\mathrm{word})} \quad (1)$$

The top z words for each class are selected as category words for each biomedical entity class.

2. *Step 2*: Co-occurrence Matrix Construction: To measure the association between the word w_i and word w_j, this work uses the co-occurrence relation value by the following equation:

$$\mathrm{crv}(w_i, w_j) = \frac{p(w_i,w_j)[p(w_i)+p(w_j)]}{p(w_i).p(w_j)} \quad (2)$$

If the value returned by crv is greater than the threshold (0.20), then crv is added to the co-occurrence vector for the word w_i , otherwise, 0 will be added. After calculating the co-occurrence relation value (crv) between word w_i and all other words, the co-occurrence vector for the word w_i is added to the co-occurrence matrix. Figure 1 shows co-occurrence vector using the co-occurrence relation value (crv) between word w_i and all other words:

Representation						
words	w_1	w_2	w_3	w_4	…	w_n
w_1	$crv_{1\times1}$	$crv_{1\times2}$	$crv_{1\times3}$	$crv_{1\times4}$	…	$crv_{1\times n}$
w_2	$crv_{2\times1}$	$crv_{2\times2}$	$crv_{2\times3}$	$crv_{2\times4}$	…	$crv_{2\times n}$
:	:	:	...	:	…	:
w_m	$crv_{m\times1}$	$crv_{m\times2}$	$crv_{m\times3}$	$crv_{m\times4}$	…	$crv_{m\times n}$

Fig. 1. Co-occurrence Vector Construction

3. *Step 3*: Co-occurrence Graph Construction: in this step, **k**-nearest neighbours method is used, and a K-NN graph representation for each word in the dataset is constructed as follows:
   a) Node assignment: for each word in the dataset, a vertex is assigned.
   b) K_{cu}NN vertex calculation: to construct the graphs, the k nearest neighbors method is used. $k_{cu}NN(w_i)$ is a set of k nearest neighbours of the word w_i from class cu. A word w_j from category words of class C_u is assigned as one of the k_{cu} nearest neighbours set of word w_i if cosine similarity between their co-occurrence vectors is greater than ε. Cosine similarity was used by the following equation:

$$\mathrm{co\_sim}_{ij} = \cos(WV_i, WV_j) \frac{\sum_{k=1}^{n} wv_i^k . wv_j^k}{\sqrt{\sum_{k=1}^{n}(wv_i^k)^2} \cdot \sqrt{\sum_{k=1}^{n}(wv_j^k)^2}} \quad (3)$$

Where WV_i and WV_j are the co-occurrence vectors of a normal word w_i and class word w_j , respectively.

   c) Representation Construction: a representation vector rv for each word w_i ($rv(w_i)$) of length $|z \times C|$ is constructed for each word from both training and testing data. $|z|$ is the length of each category words set and C is the number of classes. Figure 2 shows representation vector using co-occurrence graph-based word representation:

Representation										
Words	**Category Words Of Class 1**				**Category Words Of Class 2**				…	**Category Words Of Class C**
	w_1	w_2	…	w_z	w_1	w_2	…	w_z	…	w_{zc}
w_1	$rs_{1\times1}$	$rs_{1\times2}$	…	$rs_{1\times z}$	$rs_{1\times1}$	$rs_{1\times2}$	…	$rs_{1\times z}$	…	$rs_{1\times zc}$
w_2	$rs_{2\times1}$	$rs_{2\times2}$	…	$rs_{2\times z}$	$rs_{2\times1}$	$rs_{2\times2}$	…	$rs_{2\times z}$	…	$rs_{2\times zc}$
:	:	:	...	:	:	:	...	:	…	:
w_m	$rs_{m\times1}$	$rs_{m\times2}$	…	$rs_{m\times z}$	$rs_{m\times1}$	$rs_{m\times2}$	…	$rs_{m\times z}$	…	$rs_{m\times zc}$

Fig. 2. Co-occurrence Graph-Based Word Representation by cosine similarity

D. Feature Level Graph-Based Representation Method

The following describe the main steps of this algorithm:

1. *Step 1*: Category Words extraction: as in step 1 of co-occurrence graph-based representation method.
2. *Step 2:* Feature Extraction: this work represents each word using a set of morphological features.
3. *Step 3:* Feature Graph Construction: in this step **k**-nearest neighbours method is used, a K-NN graph representation for each word in the dataset is constructed as follows:
   a) Node assignment: for each word in the dataset, a vertex is assigned.
   b) K_{cu}NN vertex calculation: to construct the graphs, the k nearest neighbors' method is used. $k_{cu}NN(w_i)$ is a set of k nearest neighbours of the word w_i from class cu. A word w_j from category words of class C_u is assigned as one of the k_{cu} nearest neighbours set of word w_i if the Jaccard index similarity between their feature vectors is greater than ε. Jaccard index similarity was used by the following equation:

$$F\_sim_{ij} = \text{Jacard}\left(fv_i, fv_j\right) = \frac{|fv_i \cap fv_j|}{|fv_i \cup fv_j|} \quad (4)$$

   Where $\boldsymbol{fv_i}$ and $\boldsymbol{fv_j}$ are the feature vectors of a normal word w_i and category word w_j, respectively.
   c) Representation Construction: a representation vector **rv** for each word $\mathbf{w_i}$ ($\mathbf{rv(w_i)}$) of length $|\mathbf{z} \times \mathbf{C}|$ is constructed for each word from both training and testing data. $|\mathbf{z}|$ is the length of each category words set and C is the number of classes.

Figure 3 shows representation vector using Feature Level graph-based word representation:

Representation										
Words	**Category Words of Class 1**				**Category Words of Class 2**				**…**	**Category Words of Class C**
	w_1	w_2	…	w_z	w_1	w_2	…	w_z	…	w_{zc}
w_1	$rs_{1\times1}$	$rs_{1\times2}$	…	$rs_{1\times z}$	$rs_{1\times1}$	$rs_{1\times2}$	…	$rs_{1\times z}$	…	$rs_{1\times zc}$
w_2	$rs_{2\times1}$	$rs_{2\times2}$	…	$rs_{2\times z}$	$rs_{2\times1}$	$rs_{2\times2}$	…	$rs_{2\times z}$	…	$rs_{2\times zc}$
:	:	:	…	:	:	:	…	:	…	:
w_m	$rs_{m\times1}$	$rs_{m\times2}$	…	$rs_{m\times z}$	$rs_{m\times1}$	$rs_{m\times2}$	…	$rs_{m\times z}$	…	$rs_{m\times zc}$

Fig. 3. Feature Level Graph-Based Representation by Jaccard index similarity

E. Graph-Based Word Representation Integration

Several proposed strategies have been considered to integrate two graph-based data representations. These strategies are:

1. *Single Representation:* each of the co-occurrence graph-based word representation and feature-based graph-based representation are used as a standalone representation. This allows us to better understand the limits of considering a single representation at a time.
2. *Concatenation*: The concatenated representation is defined as the vector concatenation of both representations in one representation. This representation shows the advantages of multi-information. Figure 4 shows the strategy of graph concatenation representation.

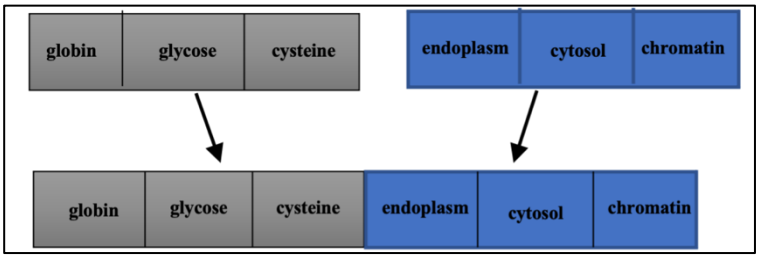

Fig. 4. The strategy of graph concatenation representation.

3. *Combination*: The representation is defined as a principled aggregation of both representations. In this scenario, equation (3) and equation (4) are integrated and combined as in the following equation:

$$\text{CF\_sim}_{ij} = \lambda_1 \cos\left(\text{WV}_i, \text{WV}_j\right) + \lambda_2 \text{ Jacard } \left(\text{WV}_i, \text{WV}_j\right) \quad (5)$$

F. Machine Learning Models

This section briefly overviews the supervised machine-learning techniques used: Conditional Random Fields (CRF) and Support Vector Machines (SVM), both known for their reliability and high performance in biomedical named entity recognition. The following describes these classifiers:

1. *Support vectors Machine (SVM):* Support Vector Machine (SVM) is a supervised machine learning model that was initially conceived for binary classification tasks. However, their utility has been extended to accommodate multi-class classification as well as regression challenges. SVMs have

garnered a solid reputation as an efficient classifier, standing out as one of the top choices across diverse data mining and machine learning applications. SVM achieves this by constructing a decision hyperplane that effectively partitions the training data into two primary classes. Given training data consists of n k-dimensional real vectors X, and labels Y, where y_i is either -1 or 1. The label y_i is +1 or -1 for the vector x_i. The training phase of the SVM aims to plot data vectors in a k-dimensional hyperspace and to draw a hyperplane, which as possible separates points from both classes.

$$\vec{\alpha} = \text{argmin}\left\{-\sum_{i=1}^{n}\alpha_i + \sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_i\alpha_j y_i y_j \langle \vec{x_i}, \vec{x_j}\rangle\right\} \quad (6)$$

$$\text{Subjectto: } \sum_{i=1}^{n}\alpha_i y_i = 0;\ 0 \le \alpha_i \le C \quad (7)$$

2. *Conditional Random Fields (CRFs):* Conditional Random Fields (CRF) is a statistical sequence-labeling framework initially introduced by Lafferty, McCallum, and Pereira in 2001. CRF is a statistical model structured as an undirected graphical model, commonly employed for tasks such as pattern recognition and sequence labeling, including applications in Biomedical Named Entity Recognition. Formally, given a sentence $X = (x_1, x_2, \dots, x_n)$ to represent an input sentence, where x_i is the input vector of the i-th word, and $Y = (y_1, y_2, \dots, y_n)$ represents a sequence of predicted biomedical labels for input sentenceX. All classes or labels $y_i$of Y are restricted sets of labels over a set L(X). The global feature of CRF, F(y, x), is the summation of CRF's local feature vector f(y, x, i) for input sequence x and label sequence y, where i ranges over input positions. The probabilistic model for the CRF calculates the conditional probability of all possible sequences of labels y, given x using the following equation:

$$p(y|x) = \frac{1}{z(X)}\prod_{t=1}^{T}\exp\left\{\sum_{k=1}^{k}\omega_k f_k(y_t, y_{t-1}, x_t)\right\} \quad (8)$$

$$z(x) = \sum_y \exp\left(\sum_k \omega_k f_k(y, x)\right) \quad (9)$$

Where $Z(x)$is a normalization factor. where $\omega_k$is a parameter to be learned and estimated during training and shows the informativeness of the particular feature.

G. Experimental Setting

The primary objective of this study is to assess the effectiveness of the improved models proposed for biomedical named entity recognition. To achieve this, we employed the widely accepted and frequently used GENIA corpus as our dataset, which is a standard benchmark dataset for biomedical named entity recognition. The GENIA corpus is a comprehensive compilation of biomedical literature created as part of the GENIA project. While the original GENIA corpus contains a diverse array of 36 entity classes, a more commonly adopted version for tasks like BioNLP/NLPBA groups these entities into five major categories: protein, DNA, RNA, cell line, and cell type. To gain a more in-depth understanding of the models' performance, this work uses the confusion matrix to calculate recall and precision metrics. The confusion matrix as in Table 2 helps evaluate the classifier's effectiveness for each of these specific classes.

Table 2. Confusion Matrix

	actual (yes)	**actual (no)**
predicated (yes)	True Positive (TP)	False Positive (FP)
predicated (no)	False Negative (FN)	True Negative (TN)

In this work, three evaluation metrics are used as performance metrics namely, precision, recall, and F-measure.

1. *Precision*: Precision is the proportion of true positive predictions out of all positive predictions made by the model. It measures the model's ability to correctly identify named entities without making many false positive errors.

$$P_i = \frac{TP_i}{TP_i + FP_i} = \frac{Relevant\ Entites\ Recognized}{Total\ Entites\ Recognized} \quad (10)$$

2. *Recall*: Recall is the proportion of true positive predictions out of all actual positive instances in the dataset. It assesses the model's ability to identify all relevant named entities without missing many.

$$R_i = \frac{TP_i}{TP_i + FN_i} = \frac{\text{Relevant Entites Recognized}}{\text{Relevant Entities In Corpus}} \quad (11)$$

3. *F1-Score:* The F1-Score is the harmonic mean of precision and recall, providing a balanced measure of a model's overall performance

$$F1_i = \frac{2(P_i * R_i)}{P_i + R_i} \quad (12)$$

A series of experiments were conducted to assess the performance of both baseline feature representation techniques and enhanced graph-based word representation methods for biomedical named entity recognition. Initially, the focus was on evaluating the baseline recognition models, which were constructed using traditional feature extraction and representation techniques. As well as two supervised models, Conditional Random Fields (CRF) and Support Vector Machines (SVM) were used.

In these baseline experiments, words were represented as vectors, with values assigned to various morphological, orthographical, and contextual features, as detailed in Table 3. The primary objective was to investigate how supervised machine learning models could leverage these features and understand their impact on the model's performance.

The results presented in Table 3 display the outcomes achieved when using Conditional Random Fields (CRF) and Support Vector Machines (SVM) in conjunction with the morphological, orthographical, and contextual features. It is worth noting that the results clearly demonstrate that Conditional Random Fields (CRF) outperform Support Vector Machines (SVM) in the domain of biomedical named entity recognition. This is because CRF excels in handling sequential data, which is essential in the biomedical field,

where term order and context are critical for accurate recognition.

Table 3. Performance of Conditional random fields (CRF) and support vector machines (SVM) models on GENIA Dataset with Traditional Feature Representation

Training size	Precision	Recall	F-Measure
SVM	84.2	40.4	54.6
CRF	83.5	80.3	81.87

In the second part of our study, we conducted multiple experiments to assess the effectiveness of ennhanced graph-based representation methods in combination with conditional random fields (CRF) and support vector machines (SVM) for biomedical named entity recognition. We developed several enhanced learning models for this purpose. We evaluated four graph-based methods, which can be categorized into two types: standalone and integrated representations. The standalone methods included co-occurrence graph-based representation (CGBR) and feature graph-based representation (FGBR), while the integrated methods were represented by concatenated graph-based representation (ICCGBR) and combined graph-based representation (ICMGBR).

Figure 5 illustrates the results achieved using these proposed graph-based representations in conjunction with the two supervised models. The findings demonstrate that these novel representations significantly enhance the performance of the conditional random fields (CRF) and support vector machines (SVM) models compared to traditional feature representations.

When considering the word representations, all four proposed graph-based methods substantially improve the performance of the two supervised machine-learning methods compared to the baseline feature representation methods.

From the perspective of standalone graph-based representations, Figure 5 reveals that the results obtained with the co-occurrence graph-based representation surpass those achieved with the feature graph-based representation.

Regarding integrated graph-based representations, Figure 5 demonstrates that the results of the two supervised models with the concatenated graph-based representation significantly outperform their counterparts with the combined graph-based representation.

When we consider both standalone and integrated graph-based representations, Figure 5 emphasizes that the results obtained with the concatenated graph-based representation stand out as the most effective among all representation methods.

In terms of supervised machine learning methods, Table 3 and Figure 5 consistently show that conditional random fields (CRF) consistently outperform support vector machines (SVM), regardless of the word representation method used.

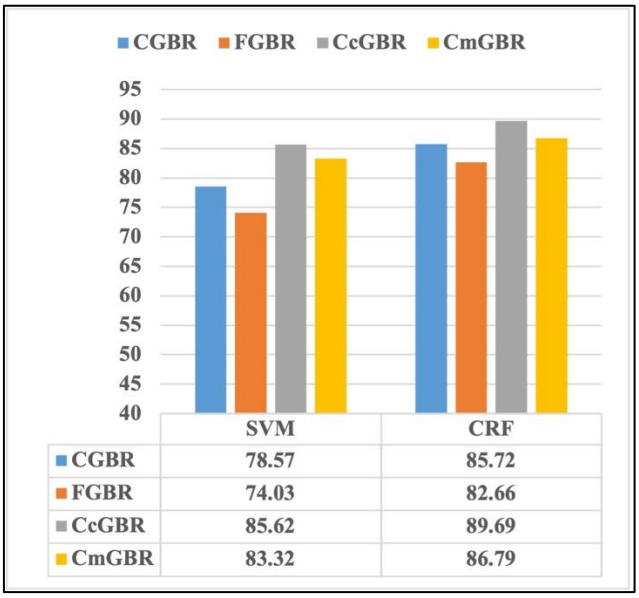

Fig. 5. Performance of the proposed (four) graph-based representation with conditional random fields (CRF) and support vector machines (SVM) on GENIA Dataset

H. Baseline Feature Extraction and Representation Methods for Biomedical Named Entity Recognition

The underperformance of traditional machine learning models namly (CRF, SVM) in biomedical text analysis is primarily attributed to the inadequate traditional feature representation techniques of biomedical literature through manually created features based on existing literature and encompass morphological, orthographic, and contextual characteristics. Subsequently, these techniques aren't capable of capturing valuable information for recognition and classification while remaining dependent of specific domains and datasets.

I. Enhanced Graph-Based Word Representation Methods for Biomedical Named Entity Recognition

Enhanced graph based word representation methods improving the performance of machine learning methods namely (CRF, SVM) in biomedical named entity recognition through:

- The correlation (using PIM) between the word and its class as feature set of class c (eg. Category Words of Class c).
- The co-occurrence relation value (crv) to measure the association between the wi and word wj as word embedding (eg. co-occurrence vectors all of words).
- K-NN graph representation is used for similarity between co-occurrence vectors all of words with co-occurrence vectors of category words of class c (using cosine similarity and Jaccard index similarity) as more feature set of class c (eg. More Category Words of class c).

Subsequently, these methods are capable of capturing valuable information for recognition and classification while remaining independent of specific domains and datasets.

IV. CONCLUSIONS

The quality of traditional machine learning methods highly depends on data and words representation. However, a critical issue of such techniques is the choice of the data and word representation. many machine learning for NER that are trained using data represented using based feature-engineering that have been selected using domain experts. These approaches are the need of manually engineering features for each specific dataset [4, 17, 18]. This means they are dataset and domain dependent.

This research study introduces new enhanced graph-based word representation methods for biomedical named entity recognition, specifically co-occurrence graph-based representation and feature graph-based representation methods that are not datasets dependent. The results show that the proposed graph-based representation methods significantly enhance the performance of both conditional random fields (CRF), and support vector machines (SVM) compared to the baseline representation.

Furthermore, the findings show that incorporating concatenated graph-based representations significantly improves the overall quality of biomedical named entity recognition across all machine learning models. This highlights graph-based representations as a more effective approach than traditional methods for this task.

V. FUTURE WORKS

Future research study is required for better development and contribution in this research area. The following are some suggestions for future work:

- The proposed graph-based word representation method should be tested on other datasets. To verify the effectiveness of the proposed model, experiments should be conducted on several datasets that belong to the biomedical domain.
- Future work should build other ensemble graph-based word representation methods.
- Future work should evaluate with proposed graph-based word representation method with advanced deep-learning models.
- Future works are encouraged to engage other integration algorithms to combine graph-based and advanced representation methods and evaluate them with recognition methods.

REFERENCES

[1] Á. A. Casero, *Named entity recognition and normalization in biomedical literature: a practical case in SARS-CoV-2 literature*, ETSI Informatica, 2021.

[2] Z. Chai *et al.*, "Hierarchical shared transfer learning for biomedical named entity recognition," *BMC Bioinformatics*, vol. 23, no. 1, pp. 1–14, 2022.

[3] J. Lee *et al.*, "BioBERT: a pre-trained biomedical language representation model for biomedical text mining," *Bioinformatics*, vol. 36, no. 4, pp. 1234–1240, 2019.

[4] R. Ramachandran and K. Arutchelvan, "ArRaNER: A novel named entity recognition model for biomedical literature documents," *J. Supercomput.*, pp. 1–14, 2022.

[5] R. M. Rivera-Zavala and P. Martínez, "Analyzing transfer learning impact in biomedical cross-lingual named entity recognition and normalization," *BMC Bioinformatics*, vol. 22, no. 1, pp. 1–23, 2021.

[6] B. Song *et al.*, "Deep learning methods for biomedical named entity recognition: a survey and qualitative comparison," *Brief. Bioinform.*, vol. 22, no. 6, Article ID bbab282, 2021.

[7] P. Malik *et al.*, "NLP techniques, tools, and algorithms for data science," in *Artificial Intelligence for Signal Processing and Wireless Communication*, vol. 11, pp. 123, 2022.

[8] I. Lauriola *et al.*, "Learning adaptive representations for entity recognition in the biomedical domain," *J. Biomed. Semant.*, vol. 12, no. 1, pp. 1–13, 2021.

[9] U. Kanimozhi and D. Manjula, "A systematic review on biomedical named entity recognition," in *Proc. Int. Conf. Data Sci. Analytics and Applications (DaSAA)*, Chennai, India, Jan. 2017, pp. 1–12. Revised Selected Papers. Springer, 2018.

[10] A. Alves-Pinto *et al.*, "Iterative named entity recognition with conditional random fields," *Appl. Sci.*, vol. 12, no. 1, Art. no. 330, 2021.

[11] L. A. Mady, Y. M. Afify, and N. L. Badr, "Biomedical named entity recognition using structured support vector machine," *Int. J. Comput. Appl.*, vol. 28, no. 4, 2021.

[12] R. Ramachandran and K. Arutchelvan, "Optimized version of tree-based support vector machine for named entity recognition in medical literature," in *Proc. 3rd Int. Conf. Intelligent Sustainable Systems (ICISS)*, 2020, pp. 1124–1129.

[13] Y. Li, L. Song, and C. Zhang, "Sparse Conditional Hidden Markov Model for Weakly Supervised Named Entity Recognition," *arXiv preprint*, arXiv:2205.14228, 2022.

[14] M. T. Abd and M. Mohd, "A comparative study of word representation methods with conditional random fields and maximum entropy Markov for bio-named entity recognition," *Malays. J. Comput. Sci.*, pp. 15–30, 2018.

[15] H. Chen, S. Yuan, and X. Zhang, "ROSE-NER: Robust Semi-supervised Named Entity Recognition on Insufficient Labeled Data," in *Proc. 10th Int. Joint Conf. Knowledge Graphs*, 2021.

[16] L. Liu *et al.*, "A semi-supervised approach for extracting TCM clinical terms based on feature words," *BMC Med. Inform. Decis. Mak.*, vol. 20, no. 3, pp. 1–7, 2020.

[17] M. Song, H. Yu, and W.-S. Han, "Developing a hybrid dictionary-based bio-entity recognition technique," *BMC Med. Inform. Decis. Mak.*, vol. 15, no. S1, p. S9, 2015.

[18] H.-C. Kuo and K.-I. Lin, "Extracting protein names from biological literature," *Adv. Comput. Sci.: Int. J.*, vol. 3, no. 2, pp. 58–68, 2014.

[19] M. T. Pilehvar and J. Camacho-Collados, "WiC: the word-in-context dataset for evaluating context-sensitive meaning representations," *arXiv preprint*, arXiv:1808.09121, 2018.

IMPROVEMENT AND CONTROL OF THE SPEED RESPONSE OF THE PERMANENT MAGNET SYNCHRONOUS MOTOR DRIVE USING A FUZZY – PI CONTROLLER

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Improvement And Control of The Speed Response of The Permanent Magnet Synchronous Motor Drive Using a Fuzzy – PI Controller

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***Abstract*—**High-speed and high-performance electric motors are designed to reach a high level of demand control. The permanent magnet synchronous motors (PMSMs) drive has a non-linear model that is not easy to deal with using traditional control methods when controlling the three phase motors because of their nature, (intricate highly non-linear model). Therefore, neural networks controllers compared with fuzzy logic controllers (FLCs) are getting more attention among researchers, as they can be used for such systems. The neural networks controller relies on training of this mathematical model, and the fuzzy controller also relies on experience. The performance of these two controllers were compared to each other in terms of output response. As all the real systems exhibit non-linear behavior, conventional PI (Proportional-Integral) controllers are unable to provide good and acceptable results. For this reason, when designing intelligent control systems, the corresponding model for simulation should reflect all characteristics of the real system to be controlled. The basic idea of this paper is to apply the fuzzy-PI controller on PMSMs drive and compare the obtained results with the traditional PI. Also, one intelligent controller, which is the NN (Neural Network) controller, is applied and its performance is simulated and studied. MATLAB/SIMULINK environment is used for design, implementation and testing. Therefore, the speed and torque of the PMSMs drive can be controlled satisfactorily. Finally, simulation results have shown decent results in the improvement of the system behavior.

Keywords— Fuzzy logic control, Neural Network controller, Permanent Magnet Synchronous Motors (PMSMs) drive, PI controller, Speed control, Torque.

I. INTRODUCTION

The escalating cost of fuel has intensified the focus on Permanent Magnet Synchronous Motor (PMSM) systems, driven by the imperative for enhanced energy efficiency. PMSMs are recognized for their high efficiency, reduced maintenance costs, and superior performance, rendering them critical components in energy conservation strategies. In the context of PMSM speed regulation, scalar control offers a simplified solution for applications where precise speed control is not paramount. Conversely, Field Oriented Control (FOC) and Direct Torque Control (DTC) are prevalent in industrial applications, valued for their high efficiency, operational simplicity, structural robustness, and reliability. These advanced control methodologies facilitate improved performance and efficiency. PMSM motors, characterized by their permanent magnet flux, exhibit exceptional efficiency by minimizing heat dissipation; however, operational limitations constrain their maximum achievable speed [1]. Surface-mounted PMSMs, favored for their compact design and high efficiency, find extensive application in wind power generation and industrial transmission systems. Achieving high-performance control typically necessitates the integration of costly speed and position sensors. To address this, sensorless control techniques have been developed. Current sensorless methods can be broadly categorized into high-frequency signal injection and motor parameter-based estimation. However, challenges such as chattering in commonly employed algorithms necessitate the investigation of alternative control strategies, with a critical consideration of the trade-offs between noise reduction and system phase delays, as detailed in [2].

In precision-centric applications such as robotics and mechanical processes, Permanent Magnet Synchronous Motors (PMSMs) play an indispensable role [3]. However, their performance is often compromised by uncertainties including noise, external loads, and friction forces. To mitigate these challenges, advanced control techniques, such as fuzzy logic and neural networks, have been employed to achieve fine regulation of motor speed and position. Field-Programmable Gate Arrays (FPGAs) facilitate the implementation of these algorithms by offering programmable hard-wired features, rapid computational speeds, and low power consumption. This integration of PMSMs, intelligent controls, and FPGA technology aims to enhance multi-axis robotic precision in machining and assembly.

The widespread adoption of PMSMs in machine tools is attributed to their streamlined design, broad speed range, and operational efficiency [4]. Despite the availability of real-time speed and position signal detection through encoders, complex machining environments present challenges, particularly in the form of encoder failures. Recent advancements in sensorless control, while promising, lack high-performance algorithms necessary for robust operation.

Consequently, research efforts are focused on developing advanced sensorless control strategies for high-speed PMSM systems, addressing limitations associated with existing methods such as back electromotive force and sliding mode observers, with an emphasis on improved stability and robustness.

The ubiquity of AC motors in both household and industrial settings underscores their importance [5]. While asynchronous motors (AMs) remain prevalent due to their simplicity and durability, PMSMs are gaining popularity due to their superior power density and efficiency. However, the nonlinear nature of PMSM systems poses challenges for precise regulation. This necessitates the development of high-performance controllers capable of enhancing stability and overcoming the limitations of traditional Proportional-Integral-Derivative (PID) controllers. The expanding utilization of PMSMs in industrial manufacturing highlights the need for advanced control methodologies, including PI control, adaptive control, model-referenced adaptation, Sliding Mode Control (SMC), H_∞ control, and Internal Model Control (IMC) [6]. Despite the widespread use of PI control, its parameter dependence in dynamic work environments hinders optimal performance. Similarly, issues with adaptive control laws and high-frequency jitter in conventional Sliding Mode Observers (SMOs) limit their broader industrial applicability.

The increasing prominence of Permanent Magnet Synchronous Machines (PMSMs) in industry is driven by their low inertia, high mass torque, and minimal maintenance requirements. In variable speed drives, the integration of AC machines and static converters offers new possibilities. Ensuring dynamic drive performance, including steady-state accuracy, overload capability, and disturbance resilience, is crucial. To achieve this, a decoupled control approach using vector control methods is adopted. Traditional controllers often struggle with stability due to parameter variations. To overcome this, innovative strategies employing adaptive fuzzy logic control (AFLC), a nonlinear system integrating algorithmic control laws, have been investigated. This approach, exemplified by an adaptive gain fuzzy controller, effectively mitigates external disturbances, thereby improving control precision in PMSMs with direct flux orientation driven by voltage inverters with hysteresis current control.

PMSMs are essential in various AC speed drive applications, encompassing power electronics, sensors, and high-speed microprocessors [7]. Control system-based PMSM drives, recognized for their dynamic response, low noise, and high efficiency, are pivotal in both domestic and industrial settings [8]. However, traditional speed sensing methods pose challenges related to robustness, cost, and volume. Research is therefore focused on developing motor speed-based sensorless control techniques to enhance the overall performance and reliability of PMSM drive systems. PMSMs are also characterized by their low moment of inertia, high start-up torque, and significant power in numerous industrial applications. To maximize torque in both induction motors and PMSM drives, control techniques such as Field-Oriented Control (FOC) and Direct Torque Control (DTC) with Space Vector Pulse Width Modulation (SVPWM) are essential. Intelligent control methods, particularly fuzzy logic, have demonstrated effectiveness in refining system modeling, speed control, and estimation for PMSM drives, indicating their potential for enhanced performance [9].

In response to these challenges and to further advance control strategies for PMSM drives, this research introduces a novel intelligent controller based on a fuzzy-PI architecture. The performance of this proposed controller is rigorously compared with that of a neural network controller and a conventional PI controller, providing a comprehensive evaluation of its efficacy.

II. PMSM MOTOR DRIVE SYSTEM

The PMSM drive system, presented in figure (1), is characterized by five primary functional blocks: a controller, the d-q/abc coordinate transformation, pulse width modulation (PWM), the abc/d-q coordinate transformation, and the PMSM. The controller and PMSM model, which are the focus of this analysis, will be addressed individually in the ensuing subsections.

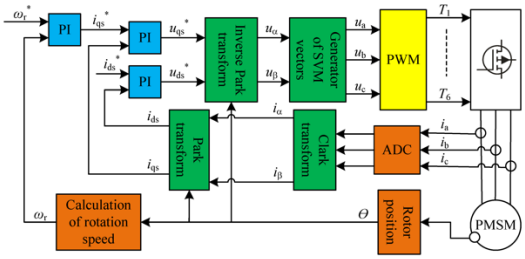


Fig. 1. PMSM drive system

A. *Control system of fuzzy logic (CSOFL)*

The proposed control methodology utilizes a fuzzy logic-based automatic controller to achieve desired system behavior through a self-regulating mechanism. The inherent advantages of fuzzy logic, namely its ability to operate using linguistic rules, render it a powerful tool for intelligent control applications. As noted by prior research [12], fuzzy control is often developed based on the experiential knowledge of process operators or design technologists. This approach contrasts with the conventional proportional-integral (PI) controller, which, while widely adopted in industrial settings due to its simplicity and ease of implementation in both digital and analog forms, lacks the adaptability of fuzzy logic.

Fuzzy controllers, however, necessitate a comprehensive understanding of fuzzy logic principles and the application of membership functions. The non-linear nature and complexity of mathematically characterizing fuzzy logic controllers (FLCs) necessitate the use of approximations, posing challenges for stability analysis. Moreover, while fuzzy controllers offer the potential for finer tuning compared to

traditional PI controllers, this increased precision also complicates error modification. Consequently, fuzzy controllers can be conceptualized as artificial decision-making systems capable of real-time implementation within closed-loop configurations. These systems process output data, y(t), compare it to a reference input, r(t), and determine the appropriate process input, u(t), to meet performance objectives. The development of a fuzzy controller relies on the acquisition of data representing the actions of the artificial decision-maker within the closed-loop system.

Data acquisition can involve leveraging the expertise of human decision-makers performing control tasks or independently developing a rule set based on a dynamic model of the system. These rules are typically formulated as "IF-THEN" statements, defining the relationship between the process output, reference input, and desired process input. Once these rules are incorporated into the rule base and an appropriate inference mechanism is selected, the system undergoes testing to validate its compliance with closed-loop control requirements. The design of a fuzzy logic control system generally encompasses three primary stages: (I) selection of the fuzzy controller's inputs and outputs; (II) determination of necessary preprocessing for controller inputs and potential post-processing for outputs; and (III) construction of the fuzzy controller's four constituent components, as illustrated in figure (2) [12].

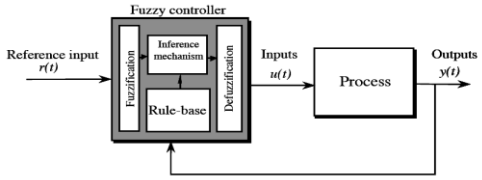


Fig. 2. Fuzzy Controller (FC) with process

B. *Fuzzy-PI Controller*

In the context of motor control applications, the implementation of a fuzzy logic controller is frequently integrated with either a proportional-integral (PI) or proportional-derivative (PD) controller. The selection of a PI controller in this study is predicated upon its demonstrated superior overall system performance compared to its PD counterpart. Moreover, the inherent limitations of PD fuzzy logic controllers, specifically their propensity to generate steady-state errors due to the absence of integral action, further justify the choice of a PI-based approach [10]. The architectural configuration of the implemented control system is presented in figure (3).

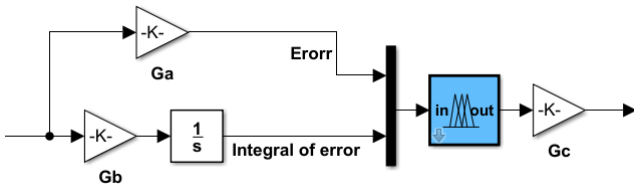


Fig. 3. Fuzzy logic PI controller

The control system incorporates several adjustable gains to optimize the output response. Specifically, G_c represents the gain applied to the output of the fuzzy logic controller, while G_a and G_b denote the proportional and integral tuning gains, respectively, associated with the error and the integral of the error. These gains serve as critical parameters for fine-tuning the system's dynamic behavior and enhancing its performance characteristics [10]. The judicious adjustment of these gains is essential for achieving the desired control objectives and mitigating potential performance degradations.

C. *Fuzzification*

Fuzzification is the process of transforming crisp numerical variables into linguistic variables, known as fuzzy numbers. The implemented fuzzy logic controller, depicted in figure (4), utilizes two inputs, the error (E) and the integral of the error (IE), to generate a single output. In the simulation, membership functions are designed with a 50% overlap, representing a logical and objective selection. Seven membership functions [Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (ZE), Positive Small (PS), Positive Medium (PM), and Positive Big (PB)] are employed for the E, IE, and output variables, as illustrated in figure (5) (a), (b), and (c).

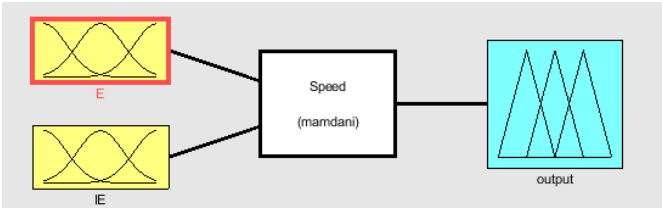
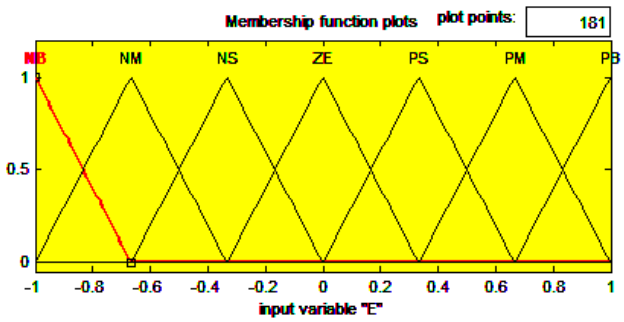
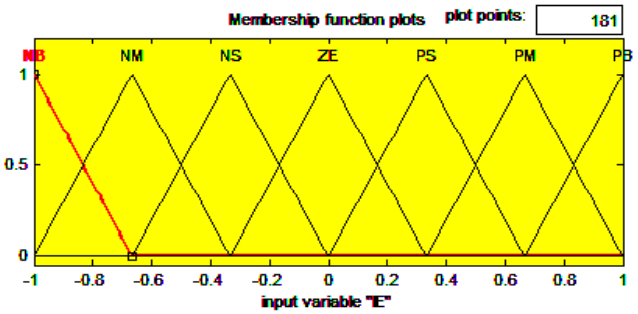


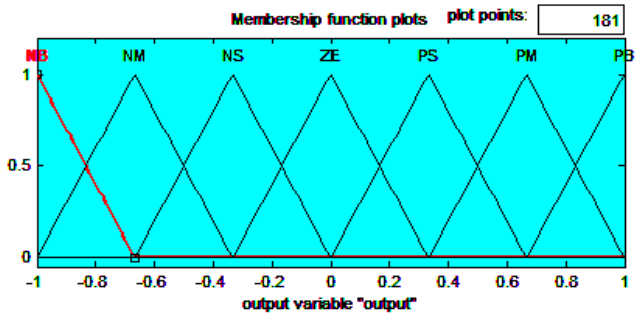
Fig. 4. FIS editor



(a)



(b)



(c)

Fig. 5. Membership functions

The scaling range for all variables is [-1, 1]. Table 1 presents the fuzzy sets defined for E, IE, and the output. For simplicity, symmetrical triangular membership functions are adopted. The linguistic terms correspond to: ZE (Zero), PS (Positive Small), PM (Positive Medium), PB (Positive Big), NB (Negative Big), NM (Negative Medium), and NS (Negative Small).

TABLE 1: Crisp to fuzzy set mapping for E, IE and output

Crisp set	Fuzzy set
-0.6666 — -1	Negative Big Error (*NB*)
-0.3334 — -1	Negative Medium Error (*NM*)
0— -0.6666	Negative Small Error (*NS*)
0.3334 — - 0.3334	Zero error (*ZE*)
0.6666 — 0	Positive Small error (*PS*)
1— 0.3334	Positive Medium error (*PM*)
1— 0.6666	Positive Big error (*PB*)

D. The rule base

When a system having seven membership functions, 49 rules will be obtained. The rule base for seven membership functions is shown in Table (2).

TABLE 2: Rule base for seven membership functions

IE	E						
	NB	***NM***	***NS***	***ZE***	***PS***	***PM***	***PB***
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

E. PI controller Modeling and simulation

The scope of this paper is limited to the application of a proportional-integral (PI) controller. The inclusion of integral control is motivated by its ability to minimize or eliminate steady-state errors; however, this is often associated with a trade-off in transient response performance. The mathematical description of the PI controller in the time domain is presented below, while figure (6) illustrates its implementation in the MATLAB/Simulink platform.

$$u(t) = k_p[R(t) - Y(t)] + k_i \int_0^t [R(t) - Y(t)]dt \quad (1)$$

$$u(t) = k_p e(t) + k_i \int_0^t e(t)dt \quad (2)$$

Where:
$\boldsymbol{u(t)}$ - controllers output signal
$\boldsymbol{e(t)}$ - controllers input error signal
$\boldsymbol{k_p}$ - proportional control gain
$\boldsymbol{k_i}$ - integral control gain

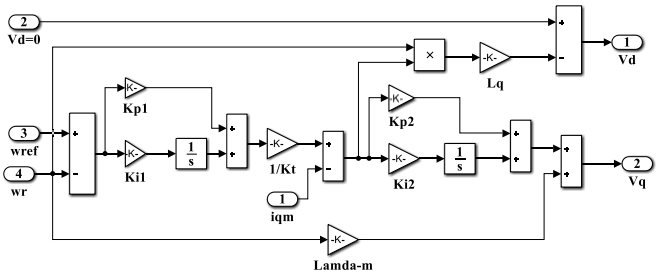


Fig.6. PI- controller MATLAB / Simulink

F. The d-q Modelling and Simulation of the PMSM drive

Vector control, also known as field-oriented control, facilitates independent control of torque and flux in permanent magnet synchronous motors (PMSMs) by transforming the three-phase stator currents into a two-axis d-q rotating reference frame [11]. This decoupling allows the PMSM to emulate the behavior of a separately excited DC machine, effectively linearizing the inherently nonlinear motor model. The application of vector control ensures a direct relationship between the control inputs and the motor's dynamic response.

To generate a rotating magnetic field and drive the rotor, balanced currents are injected into the ABC stator windings. The vector control strategy employs Park and inverse Park transformations to maintain equivalent current relationships between the synchronously rotating d-q frame and the stationary α-β and ABC stator frames. Figure (7) illustrates the PMSM vector diagram, highlighting the phase relationship between the d-axis current and the rotor flux. Specifically, the d-axis stator flux must be aligned with the

rotor motion, while the q-axis flux lags by 90 degrees. Consequently, an increase in the d-axis stator flux, when aligned with the rotor motion, enhances the rotor speed, leading to a corresponding increase in the net air gap flux [11].

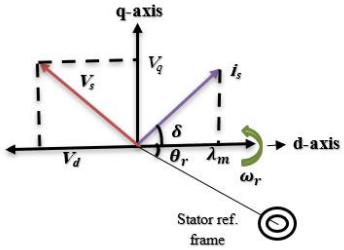


Fig. 7. PMSM's phasor representation

$$i_a = i_s \sin(\omega_r t + \delta) \quad (3)$$

$$i_b = i_s \sin\left(\omega_r t + \delta - \frac{2\pi}{3}\right) \quad (4)$$

$$i_c = i_s \sin\left(\omega_r t + \delta - \frac{2\pi}{3}\right) \quad (5)$$

Where $\theta_r = \omega_r t$, Using the phasor representation, we obtain:

$$i_q = i_s \begin{bmatrix} \sin\delta \\ \cos\delta \end{bmatrix} \quad (6)$$

If $i_d = 0$ by $\delta = 90^\circ$ Hence, the equation for electric torque:

$$T_e = \left(\frac{3}{2}\left(\frac{p}{2}\lambda_m i_q\right)\right) \quad (7)$$

One can get a constant torque, if i_q is constant. Hence, only the quadrature axis current can alter the electric torque

voltage of the d-axis stator:

$$V_d = R_i + L_d \frac{d_{i_d}}{dt} - L_q \omega_s i_q \quad (8)$$

voltage of the q-axis stator:

$$V_q = R_{i_q} + L_q \frac{d_{i_q}}{dt} - L_d \omega_s i_d + \omega_s \lambda_{af} \quad (9)$$

Magnetic flux linkage on the d axis:

$$\lambda_d = L_d \lambda_d + \lambda_{af} \quad (10)$$

Magnetic flux linkage on the q-axis:

$$\lambda_q = L_q i_q \quad (11)$$

Electromagnetic torque

$$T_e = J\frac{d}{dt}\omega_r + B\omega_r + T_l \quad (12)$$

Using the torque equation

$$T_e = K_t i_q + \frac{3}{2}\frac{P}{2}\left(L_d - L_q\right) i_d i_q \quad (13)$$

$$K_t = \frac{3}{2}\frac{P}{2}\lambda_m \quad (14)$$

Where: λ_m Permanent magnet flux, and $\omega_r = \frac{2}{p}\omega_s$

Speed of the rotor in angular frequency

$$\omega_e = \int \frac{1}{\omega_r}\left[\frac{1}{J}\frac{P}{2}\left(T_s - T_m - B\frac{2}{P}\omega_s\right)\right] \quad (15)$$

Depending on the above-mentioned equations, the motor can be simulated using the MATLAB / Simulink environment as demonstrated in figure (8).

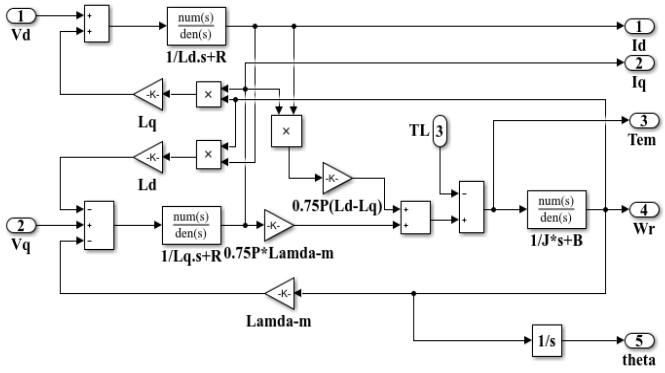


Fig.8. MATLAB / Simulink of the d-q Model of PMSM

G. Pulse Width Modulation (PWM)

Pulse width modulation (PWM), also referred to as pulse duration modulation (PDM) or pulse time modulation (PTM), represents an analog modulation technique where the pulse carrier's width, time, or length is varied proportionally to the instantaneous amplitude of the modulating message signal. This methodology maintains a constant signal amplitude while modulating the pulse width. To ensure amplitude stability, amplitude limiters are incorporated, which effectively mitigate noise by clipping the amplitude to a predetermined level.

Various forms of PWM are employed, and examples are illustrated in figures (9)(a), (b), and (c), which depict pulse width modulated waveforms within discrete time windows [13]. These figures demonstrate the principle of PWM, showcasing the relationship between the message signal's amplitude and the resulting pulse width variation.

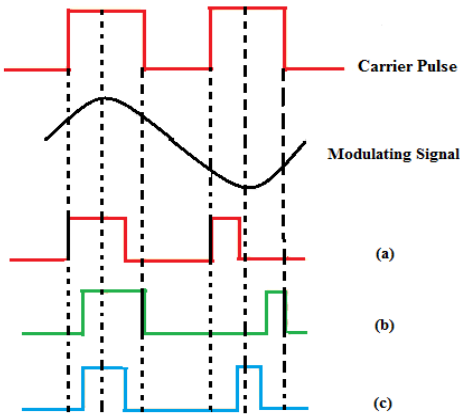


Fig.9. Waves with modulated pulse width and distinct time slots

H. Simulation of Pulse Width Modulation (PWM)

The generation of a three-phase sinusoidal pulse width modulation (PWM) waveform within the Simulink environment is facilitated by the utilization of source, repeating sequence, SUM, and SWITCH blocks. Specifically, the repeating sequence block provides the necessary triangular carrier waveform, while the source block generates the three-phase sinusoidal modulation signals. As depicted in figure (10), the Simulink implementation of the three-phase sinusoidal PWM inverter accepts the carrier frequency, modulation index, and fundamental frequency as input parameters, and produces three-phase voltage signals as its output.

For the purposes of this investigation, and to maintain model simplicity, only the PWM inverter section of the power circuit was modeled. Consequently, a constant DC link voltage, denoted as V_{dc}, is assumed. This simplification allows for a focused analysis of the PWM modulation process without the added complexity of DC link voltage variations.

$$V_{an} = \frac{(2V_{ao} - V_{bo} - V_{co})}{3} \quad (16)$$

$$V_{bn} = \frac{(2V_{bo} - V_{co} - V_{ao})}{3} \quad (17)$$

$$V_{cn} = \frac{(2V_{co} - V_{bo} - V_{ao})}{3} \quad (18)$$

Where:

A	phase- A
B	phase -B
C	phase -C
PMSM	Permanent Magnet Synchronous Motor
PWM	Pulse Width Modulation
rpm	Revolution Per minute
PI	Proportional Integral
$\boldsymbol{T_{em}}$	Electromagnetic Torque
$\boldsymbol{T_L}$	Load Torque
d	Direct Polar Axis
q	Quadrature or Interpolar Axis
$\boldsymbol{V_q}$	q-axis voltage
$\boldsymbol{V_d}$	d-axis voltage
$\boldsymbol{R_s}$	stator resistance
$\boldsymbol{i_q}$	q-axis current
$\boldsymbol{i_d}$	d-axis current
$\boldsymbol{\omega_r}$	electrical speed
$\boldsymbol{L_d}$	Direct-axis inductance
$\boldsymbol{L_q}$	Quadrature-axis inductance
$\boldsymbol{\lambda_q}$	flux linkage due q axis
$\boldsymbol{\lambda_d}$	flux linkage due d axis
$\boldsymbol{\lambda_m}$	Permanent magnet flux
λ	flux linkage

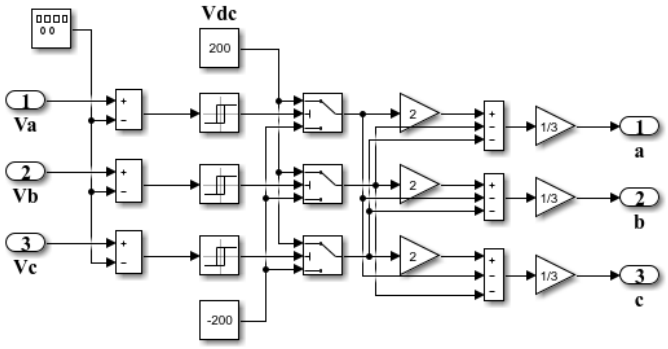


Fig.10. MATLAB / Simulink of Pulse Width Modulation

1. Simulation of the whole System:

The simulation of the complete PMSM drive system was conducted within the MATLAB/Simulink environment. To achieve a modular and hierarchical system representation, the model was constructed using two distinct block types: a single mask-able block and a lower-level block, as illustrated in figure (11). This dual-block structure facilitates organized system modeling and allows for parameter encapsulation within the mask-able blocks. The specific control strategies employed for the PMSM drive simulation encompassed both speed and current control loops are:

- PI speed controller with PWM current controller.
- Fuzzy-PI Controller with PWM current controller.
- Table (3) illustrate the PMSM drive simulation setting [14].

TABLE 3: The PMSM drive parameters

Parameters	Symbol	Value
Rated stator voltage	V_S	380 V
Load Torque	T_L	6.45 N.m
Moment of inertia	J	0.015 kg.m^2
Armature resistance	R_a	3.59 Ω
Per phase inductance	L Ph	0.0435 H
Rated Frequency	F	60 Hz
Pole pairs	*p*	6
Nominal rotor speed	nn	125.6 rad/sec (1200 rpm)
Permanent magnet flux	λ_m	0.545 Vs

Direct-axis inductance	L_d	0.036 H
Quadrature-axis inductance	L_q	0.051 H
constant	K_E	0.148 V.rad/s

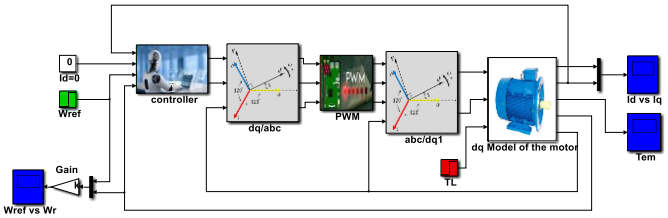


Fig.11. MATLAB / Simulink of the whole system

III. Simulation results

The efficacy of the proposed control strategy was evaluated through comparative simulations employing a standard proportional-integral (PI) controller, a fuzzy-PI based controller, and a neural network (NN) controller. To assess system reliability, a step input signal of unit amplitude was individually applied to each controller. Two distinct simulation conditions were considered: a nominal case and a case with an applied load. The resulting performance metrics were categorized and analyzed to determine the impact of each controller under varying operational scenarios.

The simulation results, depicted in the subsequent figures, provide a comprehensive overview of the system's response to the applied step input. Quantitative analysis of the system's time-domain specifications, under both nominal and loaded conditions, is presented in Tables (4) and (5). These tables facilitate a direct comparison of the controllers' performance, highlighting the advantages and disadvantages associated with each approach under different operating loads.

I. The results that are obtained by applying the proposed Fuzzy-PI controller:

- Nominal case

Under no-load conditions, the closed-loop system's transient response with unity feedback is depicted in figure (12) (a), (b), and (c), The output speed profile exhibits a smooth trajectory with an overshoot of 0.0243, indicating that the fuzzy-PI controller satisfies the performance criteria. Furthermore, the system demonstrates a settling time of 0.0572 seconds and a rise time of 0.0392 seconds. However, the steady-state error of 3.78987%.
When the setpoint was varied by 764 rpm, 955 rpm, and 1200 rpm, the overshoot, rise time, settling time, and steady-state error were as shown in Table (6).

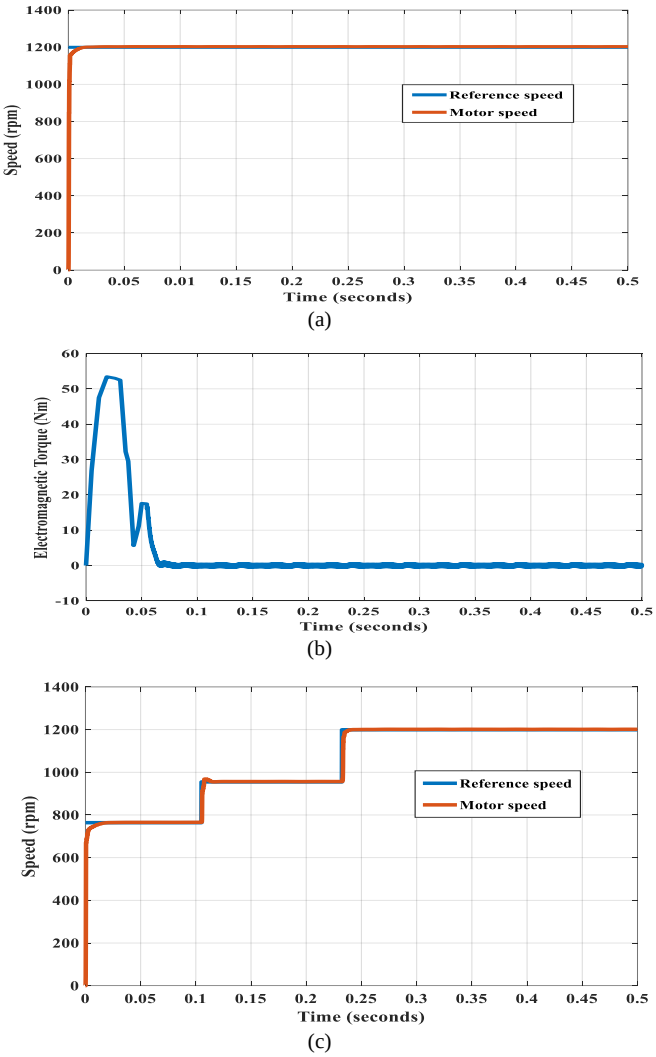


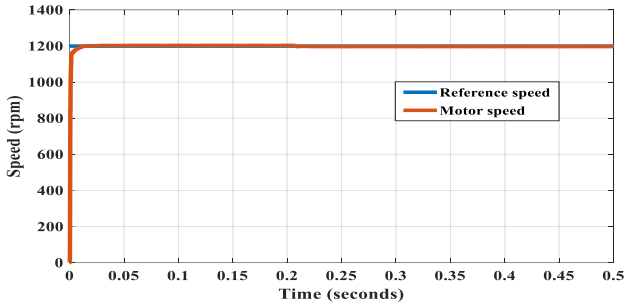
Fig.12. Response of the system with Fuzzy-PI controller without load

- With load

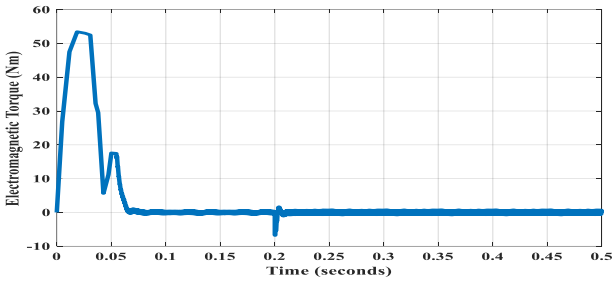
Upon the application of a 6.45 N.m load torque at 0.2 seconds, the system's speed-time response, as depicted in figure (13) (a), (b), and (c), demonstrates the robustness of the fuzzy-PI controller. The controller effectively restores the system to the desired trajectory, exhibiting a settling time of 0.0824 seconds, a rising time of 0.0540 seconds, and a steady-state error of 2.0186%. It is observed that an initial, instantaneous steady-state error arises at zero torque, impacting the system's performance. Furthermore, the fuzzy-PI controller demonstrates its capability to mitigate electromagnetic torque fluctuations and manage nonlinear behavior.

Specifically, the application of the 6.45 N.m load torque results in a reduction of the electromagnetic torque from 55N.m to zero N.m under no-load conditions and from 49N.m to zero N.m under loaded conditions, as illustrated in figures (12) and (13), respectively. This reduction highlights the controller's ability to effectively counteract the load disturbance and maintain system stability.

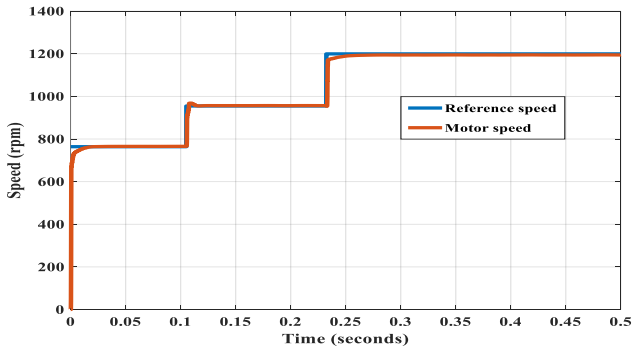
When the setpoint was varied by 764 rpm, 955 rpm, and 1200 rpm, the overshoot, rise time, settling time, and steady-state error were as shown in Table (7).



(a)



(b)



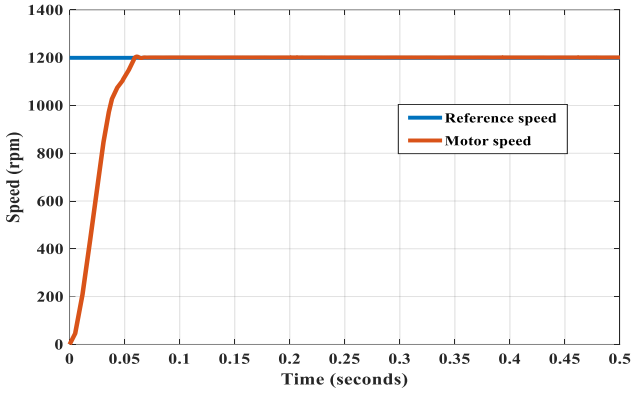
(c)

Fig.13. Response of the system with Fuzzy-PI controller with load

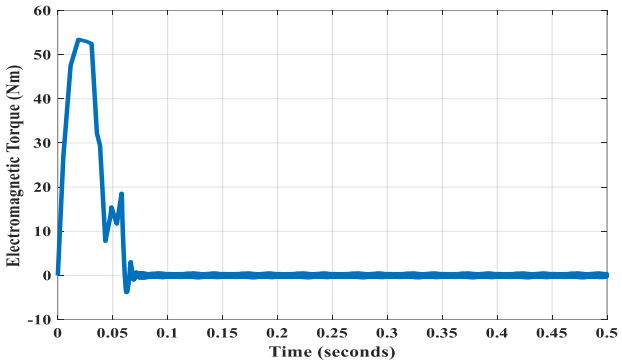
II. *The results that are obtained by applying the PI-controller*

- Nominal case

Figure (14) (a), and (b), illustrates the closed-loop system's response under no-load conditions, employing unity feedback. The output speed profile demonstrates a transient response characterized by a 0.3288 overshoot, a 0.0363-second rise time, and a 0.0567-second settling time. Furthermore, a 1.7525% steady-state error is observed. However, the response exhibits non-linear behavior, indicating limitations in the system's ability to fully compensate for inherent non-linearities, as further evidenced in figure (14).



(a)



(b)

Fig.14. Response of the system with PI-controller without load

- with load

Upon the application of a 6.45 N.m load, the system's speed-time response, as presented in figure (15) (a), and (b), reveals the limitations of the proportional-integral (PI) controller. While the controller demonstrates an attempt to restore the speed to the reference trajectory, its performance is characterized by significant deviations, indicating suboptimal regulation. Furthermore, the introduction of the load induces nonlinear behavior, which demonstrably affects the system's dynamic response, as illustrated in figure (15). Specifically, the observed settling and rising times are 0.0707 seconds and 0.0513 seconds, respectively, with a steady-state error of 0.5%. These performance metrics highlight the PI controller's inability to effectively mitigate the impact of the load and suppress the resulting nonlinearities.

The application of the 6.45 N.m torque also induces a substantial decrease in the electromagnetic torque. Under no-load conditions, the electromagnetic torque diminishes from 53 N.m to zero, while under load, it decreases from 49 N.m to zero, as evidenced in figures (14) and (15). This torque reduction underscores the controller's struggle to maintain stable operation in the presence of significant load disturbances and nonlinearities.

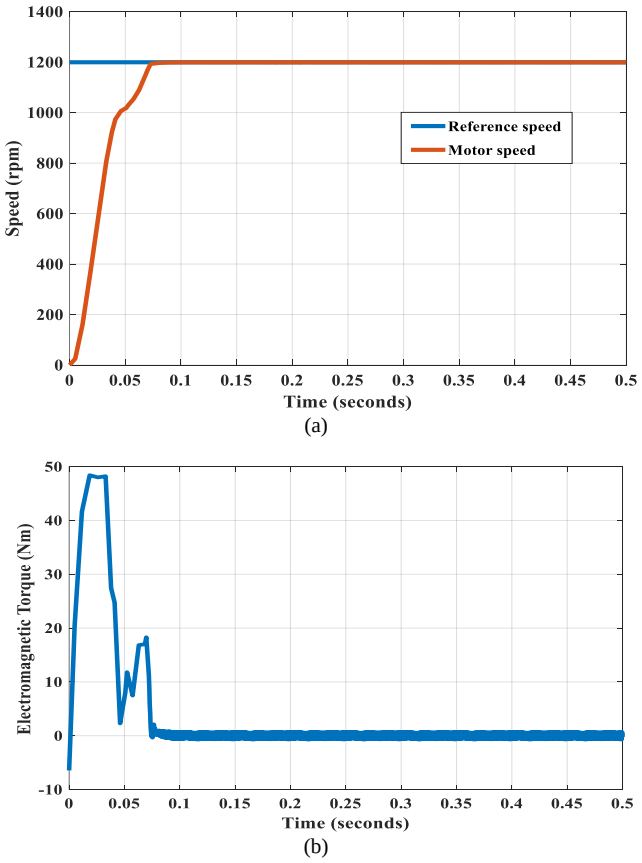


Fig.15. Response of the system with PI-controller with load

III. The results that are obtained by applying the suggested Neural Network (NN) controller

- Nominal case

Under no-load conditions, the closed-loop speed response with unity feedback, as depicted in figure (16) (a), (b), and (c), demonstrates a characteristic performance. The system achieves the reference speed with zero overshoot, a rise time of 0.0457 seconds, and a settling time of 0.0787 seconds. However, a steady-state error of 9.7098% is observed. In contrast, the application of a neural network controller effectively mitigates electromagnetic torque, reducing it from 53 N.m to zero without introducing non-linear behavior. This highlights the potential of neural network control in enhancing system performance and reducing steady-state errors, even in the absence of external loads.

When the setpoint was varied by 764 rpm, 955 rpm, and 1200 rpm, the overshoot, rise time, settling time, and steady-state error were as shown in Table (8).

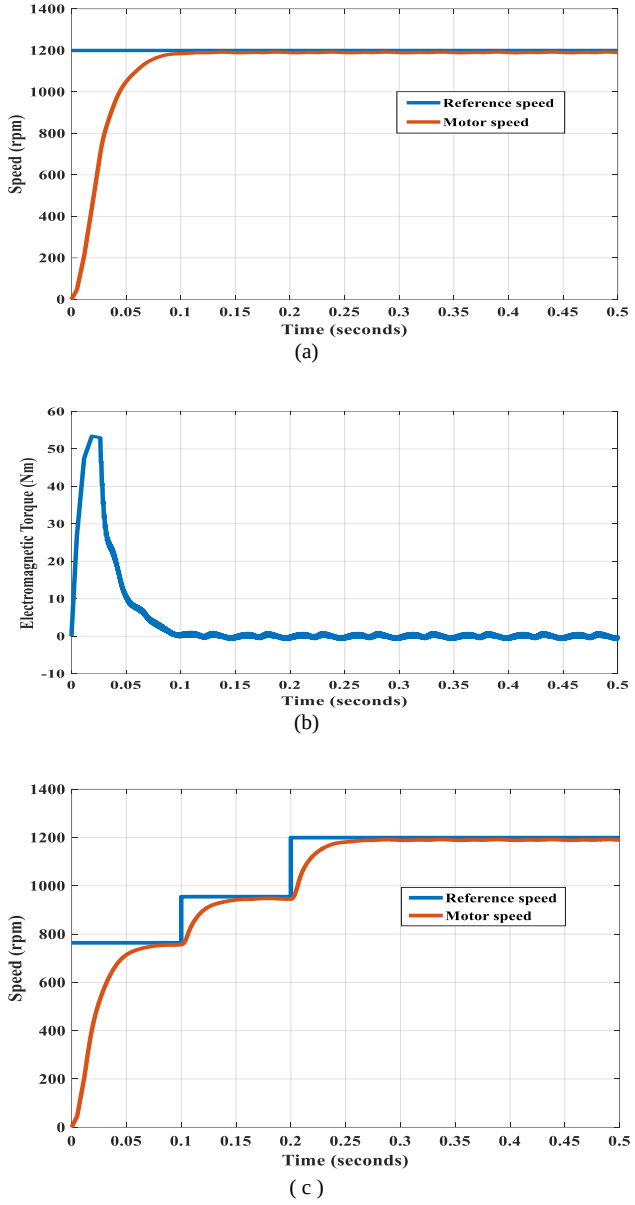
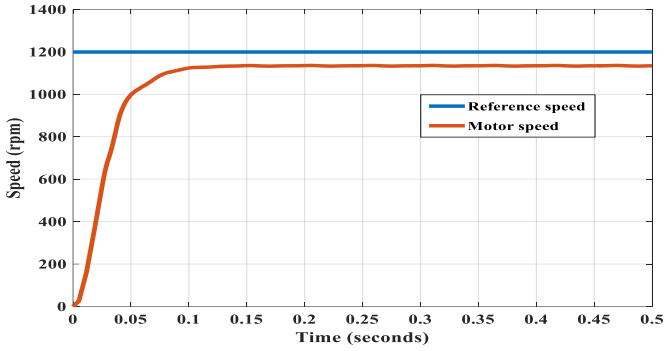


Fig.16. Response of the system with Neural Network controller without load

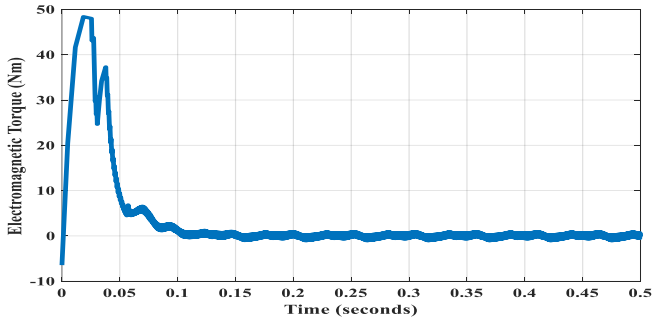
- With load case

When a 6.45 N.m load is applied, see figure (17) (a), (b), and (c), NN controller attempts to regulate the speed to the intended setpoint, it is clear that the controller performs poorly. Also, when the load is applied, the non-linear behavior affects the system behavior, as shown in figure (17). The settling and rising times are around (0.0894) and (0.0462) seconds respectively, whilst the steady-state error is (65.1070%). Furthermore, the NN controller couldn't reduce the electromagnetic torque and overcome nonlinear behavior. When the load is applied, it causes the electromagnetic torque to drop from 48 to Zero N.m with load, as illustrated in figure (16) and figure (17).

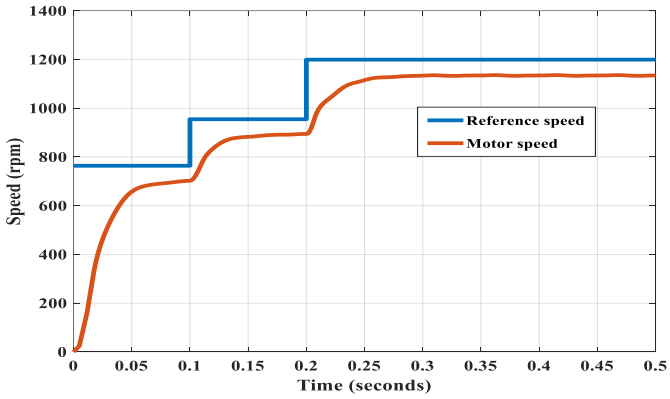
When the setpoint was varied by 764 rpm, 955 rpm, and 1200 rpm, the overshoot, rise time, settling time, and steady-state error were as shown in Table (9).



(a)



(b)



(c)

Fig.17. Response of the system with Neural Network controller with load

TABLE 4: The time domain specification of the system with load

Time domain specification	Controller With load		
	FLC	*NN*	*PI*
Rise Time	0.0540	0.0462	0.0513
Settling Time	0.0824	0.0894	0.0707
Overshoot	0.0156	0.1512	0.0107
Peak Time	0.4630	0.4696	0.4602
Error Steady-State (%)	2.0186	65.1070	0.5

TABLE 5: The time domain specification of the system without load

Time domain specification	Controller Without load		
	FLC	*NN*	*PI*
Rise Time	0.0392	0.0457	0.0363
Settling Time	0.0572	0.0787	0.0567
Overshoot	0.0243	0	0.3288
Peak Time	0.1268	0.4398	0.0611
Error Steady-State (%)	3.7987	9.7098	1.7525

TABLE 6: The time domain specification that are obtained by applying the proposed Fuzzy-PI controller without load

Time domain specification	Reference speed (rpm)		
	764	*955*	*1200*
Rise Time (sec)	0.078	0.1075	0.0392
Settling Time (sec)	0.082	0.151	0.0572
Overshoot (%)	0	1	0.0243
Error Steady-State (%)	1.9	1.8	3.7987

TABLE 7: The time domain specification that are obtained by applying the proposed Fuzzy-PI controller with load

Time domain specification	Reference speed (rpm)		
	764	*955*	*1200*
Rise Time (sec)	0.0308	0.0933	0.0540
Settling Time (sec)	0.0417	0.155	0.0824
Overshoot (%)	0	0	0.0156
Error Steady-State (%)	5.3	4.9	2.0186

TABLE 8: The time domain specification that are obtained by applying the suggested Neural Network (NN) controller without load

Time domain specification	Reference speed (rpm)		
	764	*955*	*1200*
Rise Time (sec)	0.092	0.045	0.0457
Settling Time (sec)	0.125	0.075	0.0787
Overshoot (%)	0	0	0
Error Steady-State (%)	4.5	8.7	9.7098

TABLE 9: The time domain specification that are obtained by applying the suggested Neural Network (NN) controller with load

Time domain specification	Reference speed (rpm)		
	764	*955*	*1200*
Rise Time (sec)	0.1032	0.0667	0.0462
Settling Time (sec)	0.1343	0.0978	0.0894
Overshoot (%)	0	0	0.1512
Error Steady-State (%)	61.2	63.9	65.1070

IV. **Conclusion**

A fuzzy-PI controller was designed for PMSMs drive and the obtained results compared with the traditional PI. The considered intelligent controller, which is the NN (Neural Network) controller, is studied and simulated in terms of

performance. In which MATLAB/SIMULINK environment is used for design, implementation, and testing. The speed and torque of the PMSMs drive were controlled satisfactorily. Simulation results have shown decent results for the two scenarios; with and without load. The fuzzy-PI controller demonstrated better performance in case of loading scenario than the PI and Neural Network controllers. This can be seen from the non-linear behavior of the other two (NN and PI) controllers; they were not able to overcome nonlinearity electromagnetic torque successfully.

REFERENCES

[1] Khanh, Pham Quoc, and Ho Pham Huy Anh. "Advanced PMSM speed control using fuzzy PI method for hybrid power control technique." *Ain Shams Engineering Journal* 14.12 (2023): 102222. DOI: https://doi.org/10.1016/j.asej.2023.102222.

[2] Zhang, Lei, Jing Bai, and Jing Wu. "Speed Sensor-Less Control System of Surface-Mounted Permanent Magnet Synchronous Motor Based on Adaptive Feedback Gain Supertwisting Sliding Mode Observer." *Journal of Sensors* 2021.1 (2021): 8301359. DOI: https://doi.org/10.1155/2021/8301359.

[3] Vu Quynh, Nguyen. "The fuzzy PI controller for PMSM's speed to track the standard model." *Mathematical Problems in Engineering* 2020.1 (2020): 1698213. DOI: https://doi.org/10.1155/2020/1698213.

[4] Liu, Xin, et al. "Active Disturbance Rejection Sensorless Control of Permanent Magnet Synchronous Motor Based on the Fuzzy Neural Network Left Inverse System." *Progress in Electromagnetics Research C* 130 (2023).

[5] Zeng, Xiaoli, Weiqing Wang, and Haiyun Wang. "Adaptive PI and RBFNN PID current decoupling controller for permanent magnet synchronous motor drives: Hardware-validated results." *Energies*15.17 (2022): 6353. DOI: https://doi.org/10.3390/ en15176353.

[6] Zhang, Qi, and Caiyue Zhang. "Speed Control of PMSM Based on Fuzzy Active Disturbance Rejection Control under Small Disturbances." *Applied Sciences* 13.19 (2023): 10775. DOI: https://doi.org/ 10.3390/app131910775.

[7] Hamdi Pacha, Fatima Zohra, et al. "Intelligent monitoring of PMSM based on adaptive fuzzy logic for diagnosis." *Przeglad Elektrotechniczny* 99.4 (2023). DOI:10.15199/48.2023.04.42.

[8] Sahridayan, Parvathy Thampi Mooloor, and Raghavendra Gopal. "Modeling and analysis of field-oriented control based permanent magnet synchronous motor drive system using fuzzy logic controller with speed response improvement." *International Journal of Electrical and Computer Engineering (IJECE)* 12.6 (2022): 6010-6021. DOI: 10.11591/ijece. v12i6.pp6010-6021.

[9] VO, Hau Huu, and Pavel BRANDSTETTER. "Modified Fuzzy Logic PI Speed Controller with Scheduling Boundaries of Integral Time Constant for PMSM Drive." *Przeglad Elektrotechniczny* 2023.11 (2023). DOI:10.15199/48.2023.11.30.

[10] Fayek, Haytham M., and I. Elamvazuthi. "Type-2 fuzzy logic PI (T2FLPI) based dc servomotor control." *Journal of Applied Sciences Research* 8.5 (2012): 2564-2574.

[11] Tummala, Suresh Kumar, and G. Dhasharatha. "Artificial neural networks based SPWM technique for speed control of permanent magnet synchronous motor." *E3S web of conferences*. Vol. 87. EDP Sciences, 2019. DOI: https://doi.org/10.1051/e3sconf/2019870103.

[12] Jantzen, Jan. "Tutorial on fuzzy logic." *Technical University of Denmark, Dept. of Automation, Technical Report* (1998).

[13] Kart, Diagram Source Brain. "Pulse width modulation." (2001).

[14] عبدالكريم حدود, et al. "The Application of An Intelligent Adaptive Controller for Permanent Magnet Synchronous Motor Drive Using Neural Network."586-574 :(2021) 6.5 مجلة الجامعة الأسمرية.

ON EXTENSIONS OF EXTENDED BETA AND GAUSS HYPERGEOMETRIC FUNCTIONS WITH THEIR APPLICATIONS

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On Extensions of Extended Beta and Gauss Hypergeometric Functions with Their Applications

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Abstract— The Beta function and its extensions play a crucial role in the study of some special functions; several researchers have introduced and investigated various extensions of this important function. In this paper we present further extensions of the Beta and the Gauss hypergeometric functions. We also explore some of their properties, derive integral representation, and establish summation formulas. Furthermore, we investigate the relationship between these generalized Beta functions and other special functions, such as the Fox Wright function, Fox's H-function, and generalized hypergeometric function.

Keywords— Beta function, Extended Beta function, Hypergeometric function, Extended Hypergeometric function, Mittag-Leffler function.

I. INTRODUCTION

We start with the classical Beta and Gamma functions defined respectively as follows (see [22], [27]):

$$B(x,y)=\int_0^1 u^{x-1}(1-u)^{y-1}\,du, \qquad (Re(x)>0, Re(y)>0), \tag{1.1}$$

and

$$\Gamma(x)=\int_0^\infty u^{x-1}e^{-u}\,du, \qquad (Re(x)>0). \tag{1.2}$$

$$B(x,y)=\frac{\Gamma(x)\Gamma(y)}{\Gamma(x+y)}, \qquad (Re(x)>0, Re(y)>0). \tag{1.3}$$

The Gauss hypergeometric function and its integral representation defined respectively as follows (see [22, p. 85]):

$${}_2F_1(\alpha,\beta;\gamma;z)=\sum_{n=0}^{\infty}\frac{(\alpha)_n(\beta)_n}{(\gamma)_n}\frac{z^n}{n!}, \qquad (|z|<1, \alpha,\beta,\gamma\in\mathbb{C}\ and\ \gamma\neq 0,-1,-2,-3,\dots), \tag{1.4}$$

$${}_2F_1(\alpha,\beta;\gamma;z)=\frac{\Gamma(\gamma)}{\Gamma(\beta)\Gamma(\gamma-\beta)}\times\int_0^1 u^{\beta-1}(1-u)^{\gamma-\beta-1}(1-zu)^{-\alpha}du, \qquad (Re(\gamma)>Re(\beta)>0, |arg(1-z)|<\pi). \tag{1.5}$$

The Mittag-Leffler function and its diverse generalizations are important, in particular, in connection with the theories of fractional calculus and special functions.

Various researchers have presented and explored several extensions and generalization of Gamma and Beta functions related to the Mittag-Leffler function have been investigated (see [1-12], [14-8], [13-17], [18-21], [23-27]).

Shadab et al. [26] introduced a new extension of Beta function as:

$$B_p^{\alpha}(x,y)=\int_0^1 u^{x-1}(1-u)^{y-1}E_{\alpha}\left(-\frac{p}{u(1-u)}\right)du, \tag{1.6}$$

Where $Re(x)>0, Re(y)>0$ and $E_\alpha(.)$ is the Mittag-Leffler function is defined as follows: (see [17])

$$E_\alpha(z)=\sum_{n=0}^{\infty}\frac{z^n}{\Gamma(\alpha n+1)}, \qquad Re(\alpha)>0, \qquad z\in\mathbb{C}. \tag{1.7}$$

Obviously, for $\alpha=1, p=0$,(1.6) reduces to (1.1).

In the same paper, they defined the following integral representations of extended hypergeometric function as:

$$F_p^{\alpha}(\alpha,\beta;\gamma;z)=\frac{1}{B(\beta,\gamma-\beta)}\times\int_0^1 u^{\beta-1}(1-u)^{\gamma-\beta-1}(1-zu)^{-\alpha}E_{\alpha}\left(\frac{-p}{u(1-u)}\right)du, \tag{1.8}$$

$(Re(p)>0, Re(\gamma)>Re(\beta)>0, |arg(1-z)|<\pi)$.

Obviously, for $\alpha=1, p=0$, (1.8) reduces to (1.5).

Goyal et al. [10] provide the following extension of Beta function by treating the Waiman function (two parameter's Mittag- Leffler function) as kernel:

$$B_{k_1,k_2}^{p}(x,y)=\int_0^1 u^{x-1}(1-u)^{y-1}E_{k_1,k_2}\left(-\frac{p}{u(1-u)}\right)du, \tag{1.9}$$

Where $Re(x)>0, Re(y)>0$, $k_1,k_2\in R_o^+$, and $E_{k_1,k_2}(.)$ is defined as (see [26])

$$E_{k_1,k_2}(z)=\sum_{n=0}^{\infty}\frac{z^n}{\Gamma(k_1n+k_2)}. \tag{1.10}$$

Al Gonah and Mohammed [2] used the generalized Mittag-Leffler function introduced by Prabhaker to present the following extended of Beta functions as:

$$B_p^{(\alpha,\beta,\gamma)}(x,y)=\int_0^1 t^{x-1}(1-t)^{y-1}\,E_{\alpha,\beta}^{\gamma}\left(-\frac{p}{u(1-u)}\right)du, \tag{1.11}$$

Where $Re(x)>0, Re(y)>0$, $Re(\alpha)>0, Re(p)\geq 0$, and $E_{\alpha,\beta}^{\gamma}(.)$ *is* Mittag-Leffler function which defined in Prabhakar [21] as:

$$E_{\alpha,\beta}^{\gamma}(z)=\sum_{n=0}^{\infty}\frac{(\gamma)_n}{\Gamma(\alpha n+\beta)}\frac{z^n}{n!}, \quad (1.12)$$

Where $Re(\alpha)>0,\alpha,\beta,\gamma\in\mathbb{C}$.

Abubakar and Kabara [1] study and studied the following extended Beta function by using the four- parameter Mittag-Leffler function (Salim function):

$$B_{k_1,k_2,k_3}^{k_4,p}(x,y)=\int_0^1 u^{x-1}(1-u)^{y-1}E_{k_1,k_2,k_3}^{k_4}\left(-\frac{p}{u(1-u)}\right)du, \quad (1.13)$$

Where $Re(x)>0, Re(y)>0, k_1,k_2,k_3,k_4\in R_0^+, Re(p)>0$.

and $E_{k_1,k_2,k_3}^{k_4}(.)$ is defined as follows:(see [24])

$$E_{k_1,k_2,k_3}^{k_4}(z)=\sum_{n=0}^{\infty}\frac{(k_3)_n}{(k_4)_n\Gamma(k_1n+k_2)}z^n, \quad (1.14)$$

Where,

$$k_1,k_2,k_3,k_4\in\mathbb{C}, Re(k_1)>0, Re(k_2)>0, Re(k_3)>0, Re(k_4)>0.$$

Dudi and Abubakar [7] study another extension of Beta functions related to the generalized Mittag-Leffler function

$$B_{k_1,k_2,p,\omega}^{k_3,k_4,q}(x,y)=\int_0^1 u^{x-1}(1-u)^{y-1}E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega}{u(1-u)}\right)du, \quad (1.15)$$

Where, $Re(x)>0, Re(y)>0, k_1,k_2,k_3,k_4\in R_0^+, \omega\geq 0$,

$E_{k_1,k_2,p}^{k_3,k_4,q}(.)$ the generalized Mittag-Leffler function is introduced by Salim and Faraj, as follows: (see [25])

$$E_{k_1,k_2,p}^{k_3,k_4,q}(z)=\sum_{n=0}^{\infty}\frac{(k_3)_{qn}}{(k_4)_{pn}\Gamma(k_1n+k_2)}z^n, \quad (1.16)$$

Where,

$$k_1,k_2,k_3,k_4\in\mathbb{C}, min\{Re(k_1),Re(k_2),Re(k_3),Re(k_4)\}>0, p,q>0, q<Re(k_1)+p.$$

Throughout this paper, we need the following well-known facts and rules.

Wright generalized hypergeometric function (Fox- Wright function ${}_p\psi_q$)(see [27])

$${}_p\psi_q\left[\begin{matrix}(\alpha_1,A_1),\dots,(\alpha_p,A_q);\\(\beta_1,B_1),\dots,(\beta_q,B_q);\end{matrix}z\right]=\sum_{n=0}^{\infty}\frac{\prod_{j=1}^{p}\Gamma(\alpha_j+A_jn)z^n}{\prod_{j=1}^{q}\Gamma(\beta_j+B_jn)n!}, \quad (1.17)$$

where the coefficients $A_j\in\mathbb{R}^+(j=1,\dots,p)$ and $B_j\in\mathbb{R}^+(j=1,\dots,q)$such that

$$1+\sum_{n=0}^{q}B_j-\sum_{n=0}^{p}A_j\geq 0.$$

A special case of (1.17) reduce to the generalized hypergeometric function ${}_pF_q$

$${}_p\psi_q\left[\begin{matrix}(\alpha_1,A_1),\dots,(\alpha_p,A_q);\\(\beta_1,B_1),\dots,(\beta_q,B_q);\end{matrix}z\right]=\frac{\prod_{j=1}^{p}\Gamma(\alpha_j)}{\prod_{j=1}^{q}\Gamma(\beta_j)}\,{}_pF_q\left[\begin{matrix}\alpha_1,\dots,\alpha_p;\\\beta_1,\dots,\beta_q;\end{matrix}z\right]. \quad (1.18)$$

Fox- H- function $H_{p,q}^{m,n}$ (see [13])

$$H_{p,q}^{m,n}\left[z\left|\begin{matrix}(a_1,\alpha_1),\dots,(a_p,\alpha_q)\\(b_1,\beta_1),\dots,(b_q,\beta_q)\end{matrix}\right.\right]=\frac{1}{2\pi i}\int_L\frac{\prod_{j=1}^{m}\Gamma(b_j+\beta_js)\prod_{j=1}^{n}\Gamma(1-a_j+\alpha_js)}{\prod_{j=m+1}^{q}\Gamma(1-b_j-\beta_js)\prod_{j=n+1}^{q}\Gamma(a_j-\alpha_js)}z^{-s}ds \quad (1.19)$$

2. Further Extension of Beta function and its properties

In this section, we define a new generalization of Beta function as follows:

Definition 2.1. The Further extension of extended Beta function is defined as:

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y)=\int_0^1 u^{x-1}(1-u)^{y-1}E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)du, \quad (2.1)$$

Where$Re(x)>0, Re(y)>0, Re(\omega_1)>0, Re(\omega_2)>0$, $k_1,k_2,k_3,k_4\in\mathbb{C}$, $min\{Re(k_1),Re(k_2),Re(k_3),Re(k_4)\}>0, p,q>0, q<Re(k_1)+p$ and $E_{k_1,k_2,p}^{k_3,k_4,q}(.)$ is the generalized Mittag- Leffler function defined in (1.16).

Remark 2.1. Note that:

(i) If $\omega_1=\omega_2$ then (2.1) reduces to the well-known extended Beta function (1.15) given by Dudi and Abubakar [7].

3. Properties of extended Beta function

In this section, we investigate various properties of the extended Beta function $B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y)$ as follows:

Theorem 3.1. The extension of Beta function satisfies the following functional relation

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x+1,y)+B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y+1)=B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y) \quad (3.1)$$

Proof. Consider the left-hand side of (3.1), we have

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x+1,y)+B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y+1)$$
$$=\int_0^1\{u^x(1-u)^{y-1}+u^{x-1}(1-u)^y\}\times E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)du,$$
$$=\int_0^1 u^{x-1}(1-u)^{y-1}\{u+(1-u)\}\times E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)du,$$
$$=\int_0^1 u^{x-1}(1-u)^{y-1}E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)du$$

which proves the desired result.

Theorem 3.2. The extension of Beta function satisfies the following summation formulas:

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,1-y)=\sum_{n=0}^{\infty}\frac{(y)_n}{n!}B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x+n,1) \quad (3.2)$$

Proof. Consider the generalized binomial theorem

$$(1-u)^{-y}=\sum_{n=0}^{\infty}\frac{(y)_n}{n!}u^n, \quad (|u|<1). \quad (3.3)$$

Applying (3.3) to the definition (2.1) of extended Beta function

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,1-y)$$
$$=\int_0^1\sum_{n=0}^{\infty}\frac{(y)_n}{n!}u^{x+n-1}E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)du\cdot$$

Now, interchanging the order of summation and integration in above equation and using (2.1) proves the desired result.

Theorem 3.3. The extension of Beta function satisfies the following infinite summation

Formulas:

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y)=\sum_{n=0}^{\infty}B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x+n,y+1)\cdot \quad (3.4)$$

Proof. Using the relation

$$(1-u)^{y-1}=(1-u)^y\sum_{n=0}^{\infty}u^n,$$

In (2.1), we obtain

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y)$$
$$=\int_0^1(1-u)^y\sum_{n=0}^{\infty}u^{x+n-1}E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)du\cdot$$

By interchanging the order of integration and summation in above equation and using (2.1), we get the desired result.

Theorem 3.4. The following relation holds true

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y)$$
$$=\sum_{m=0}^{n}\binom{n}{m}B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x+m,y+n-m), \quad (3.5)$$
$$(n\in\mathbb{N}_0).$$

Proof. Using (3.1),

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y)$$
$$=B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x+1,y)+B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y+1),$$

Taking $x=\alpha$ and $y=-\alpha-n$ in above relation, we have

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,-\alpha-n)=B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,-\alpha-n+1)$$
$$+B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha+1,-\alpha-n),$$

Starting with $n=1,2,3,\ldots$, we have

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,-\alpha-1)=B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,-\alpha)$$
$$+B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha+1,-\alpha-1),$$
$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,-\alpha-2)=B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,-\alpha)$$
$$+2B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha+1,-\alpha-1)$$
$$+B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha+2,-\alpha-2),$$
$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,-\alpha-3)$$
$$=B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,-\alpha)+3B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha+1,-\alpha-1)+$$
$$3B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha+2,-\alpha-2)+B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha+3,-\alpha-3)$$

and so on. The above series behaves like as finite binomials series does. Thus, we can finally obtain the desired relation (3.5). Note that, we can also prove the desired inequality by applying induction on n.

4. Extension of Hypergeometric Functions

In this section, we introduce further extension of hypergeometric function by using the extension of Beta function (2.1) as follows:

Definition 6.1. The extension of extended hypergeometric function is defined as:

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)$$
$$=\sum_{n=0}^{\infty}(\alpha)_n\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n,\gamma-\beta)}{B(\beta,\gamma-\beta)}\frac{(z)^n}{n!}, \quad (4.1)$$
$$(k_1,k_2,k_3,k_4\in R_0^+,Re(\gamma)>Re(\beta)>0,\omega_1,\omega_2\geq 0,|z|<1,p,q>0,q<Re(k_1)+p).$$

Theorem 4.2. The extended hypergeometric has the following integral representation:

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)$$
$$=\frac{1}{B(\beta,\gamma-\beta)}\int_0^1u^{\beta-1}(1-u)^{\gamma-\beta-1}(1-zu)^{-\alpha}$$
$$\times E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)du, \quad (4.2)$$

$$(k_1,k_2,k_3,k_4\in R_0^+,Re(\gamma)>Re(\beta)>0,\omega_1,\omega_2\geq 0,|z|<1,p,q>0,q<Re(k_1)+p).$$

Proof. By using (2.1) in (4.1), we have

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)$$
$$=\frac{1}{B(\beta,\gamma-\beta)}\int_0^1u^{\beta-1}(1-u)^{\gamma-\beta-1}$$
$$\times E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)\sum_{n=0}^{\infty}(\alpha)_n\frac{(zu)^n}{n!}d\varphi,$$

Thus, by using, the relation

$$\sum_{n=0}^{\infty}(\alpha)_n\frac{(zu)^n}{n!}=(1-zu)^{-\alpha},$$

We get the desired relation.

Theorem 4.3. Consider $F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(.)$ function. Then, the following functional relation hold:

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=\frac{\beta}{\gamma}F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta+1;\gamma+1;z)$$
$$+\frac{\gamma-\beta}{\gamma}F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma+1;z), \quad (4.3)$$
$$(k_1,k_2,k_3,k_4\in R_0^+,Re(\gamma)>Re(\beta)>0,\omega_1,\omega_2\geq 0,|z|<1,p,q>0,q<Re(k_1)+p).$$

Proof. Using the following relation (3.1) in (4.1), we get

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n+1,\gamma-\beta)$$
$$+B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n,\gamma-\beta+1)$$
$$=B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n,\gamma-\beta),$$
$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=$$
$$\sum_{n=0}^{\infty}(\alpha)_n\frac{\left(B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n+1,\gamma-\beta)+B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n,\gamma-\beta+1)\right)}{B(\beta,\gamma-\beta)}\frac{z^n}{n!},$$
$$=\sum_{n=0}^{\infty}(\alpha)_n\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n+1,\gamma-\beta)}{B(\beta,\gamma-\beta)}\frac{z^n}{n!}+$$
$$\sum_{n=0}^{\infty}(\alpha)_n\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n,\gamma-\beta+1)}{B(\beta,\gamma-\beta)}\frac{z^n}{n!},$$
$$=\frac{B(\beta+1,\gamma-\beta)}{B(\beta,\gamma-\beta)}\sum_{n=0}^{\infty}(\alpha)_n\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n+1,\gamma-\beta)}{B(\beta+1,\gamma-\beta)}\frac{z^n}{n!}+$$
$$\frac{B(\beta,\gamma-\beta+1)}{B(\beta,\gamma-\beta)}\sum_{n=0}^{\infty}(\alpha)_n\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n,\gamma-\beta+1)}{B(\beta,\gamma-\beta+1)}\frac{z^n}{n!}.$$

Then, using the value of Beta function in terms of gamma function together with (3.1), allow us to get the desired result.

Theorem 4.2. Consider $F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(.)$ function. Then, the following sum relation hold:

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=\sum_{m=0}^{\infty}\frac{(1+\beta-\gamma)_m}{m!}\frac{B(\beta+m,1)}{B(\beta,\gamma-\beta)}\times F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta+m;\beta+m+1;z),\quad(4.4)$$
$$(k_1,k_2,k_3,k_4\in R_0^+,Re(\gamma)>Re(\beta)>0,\omega_1,\omega_2\geq 0,|\varphi|<1,p,q>0,q<Re(k_1)+p).$$

Proof. Using the following relation (3.2) in (4.1), we get

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n,c-\beta)=\sum_{m=0}^{\infty}\frac{(1-\gamma+\beta)_m}{m!}B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n+m,1)\cdot$$

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=\sum_{n=0}^{\infty}(\alpha)_n\frac{1}{B(\beta,\gamma-\beta)}\times\sum_{m=0}^{\infty}\frac{(1-\gamma+\beta)_m}{m!}B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n+m,1)\frac{(z)^n}{n!},$$

$$=\sum_{m=0}^{\infty}\frac{(1+\beta-\gamma)_m}{m!}\frac{B(\beta+m,1)}{B(\beta,\gamma-\beta)}\sum_{n=0}^{\infty}(\alpha)_n\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+n+m,1)}{B(\beta+m,1)}\frac{(z)^n}{n!},$$

Then, using the definition of Gauss hypergeometric function (4.1), allow us to get the desired result.

Theorem 4.3. Consider $F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(.)$ function. Then, the following sum relation hold:

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=(\gamma-\beta)\times\sum_{m=0}^{\infty}\frac{(\beta)_m}{(\gamma)_m}F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta+m;\gamma+m+1;z),\quad(4.5)$$
$$(k_1,k_2,k_3,k_4\in R_0^+,Re(\gamma)>Re(\beta)>0,\omega_1,\omega_2\geq 0,|z|<1,p,q>0,q<Re(k_1)+p).$$

Proof. Using the following relation (3.4) in (6.1), we get

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y)=\sum_{m=0}^{\infty}B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x+m,y+1)\cdot$$

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=\sum_{n=0}^{\infty}(\alpha)_n\sum_{m=0}^{\infty}\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+m+n,\gamma-\beta+1)}{B(\beta,\gamma-\beta)}\frac{(z)^n}{n!},$$

$$=\sum_{m=0}^{\infty}\frac{B(\beta+m,\gamma-\beta+1)}{B(\beta,\gamma-\beta)}\sum_{n=0}^{\infty}(\alpha)_n\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+m+n,\gamma-\beta+1)}{B(\beta+m,\gamma-\beta+1)}\frac{(z)^n}{n!}.$$

Then, using the value of Beta function in terms of gamma function together with (3.1), allow us to get the desired result.

Theorem 4.4. Consider $F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(.)$ function. Then, the following result hold:

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=\sum_{m=0}^{n}\binom{n}{m}\frac{B(\beta+m,\gamma-\beta+n-m)}{B(\beta,\gamma-\beta)}\times F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta+m;\gamma+n;z),\quad(4.6)$$
$$(k_1,k_2,k_3,k_4\in R_0^+,Re(\gamma)>Re(\beta)>0,\omega_1,\omega_2\geq 0,|z|<1,p,q>0,q<Re(k_1)+p).$$

Proof. Using the following relation (3.5) in (4.1), we get

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y)=\sum_{m=0}^{n}\binom{n}{m}B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x+m,y+n-m),$$

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=\sum_{r=0}^{\infty}(\alpha)_r\sum_{m=0}^{n}\binom{n}{m}\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+r+m,\gamma-\beta+n-m)}{B(\beta,\gamma-\beta)}\frac{(z)^r}{r!},$$

$$=\sum_{m=0}^{n}\binom{n}{m}\frac{B(\beta+m,\gamma-\beta+n-m)}{B(\beta,\gamma-\beta)}\sum_{r=0}^{\infty}(a)_r\times\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta+r+m,\gamma-\beta+n-m)}{B(\beta+m,\gamma-\beta+n-m)}\frac{(z)^r}{r!},$$

Then, using the definition of Gauss hypergeometric function (4.1), allow us to get the desired result**.**

5. Transformation and Summation Formulas

In this section, we obtain transformation and summation formulas for the extended hypergeometric function as follows:

Theorem 5.1. The following transformation for extended hypergeometric function holds true for $\omega_1,\omega_2\geq 0$;

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=(1-z)^{-\alpha}F_{k_1,k_2,p,\omega_2}^{k_3,k_4,q,\omega_1}\left(\alpha,\gamma-\beta;\gamma;\frac{-z}{1-z}\right),\quad(5.1)$$
$$(k_1,k_2,k_3,k_4\in R_0^+,Re(\gamma)>Re(\beta)>0,\omega_1,\omega_2\geq 0,|z|<1,p,q>0,q<Re(k_1)+p).$$

Proof. Replacing $u\longrightarrow 1-u$ in (4.2) and using the following result:

$$\left(1-z(1-u)\right)^{-\alpha}=(1-z)^{-\alpha}\left(1-\frac{z}{1-z}u\right)^{-\alpha},\quad(5.2)$$

We obtain

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;z)=\frac{(1-\varphi)^{-\alpha}}{B(\beta,\gamma-\beta)}\int_0^1 u^{\gamma-\beta-1}(1-u)^{\beta-1}\left(1-\frac{z}{1-z}u\right)^{-a}\times E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)du\cdot$$

Which, by applying (4.1) yields the desired result.

Theorem 5.2. The following summation formula holds true:

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;1)=\frac{B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\beta,\gamma-\alpha-\beta)}{B(\beta,\gamma-\beta)},\quad(5.3)$$
$$\left(\begin{array}{c}k_1,k_2,k_3,k_4\in R_0^+,Re(\gamma)>Re(\beta)>0,Re(\gamma-\alpha-\beta)>0,\omega_1,\omega_2\geq 0,p,q>0,\\|z|<1,q<Re(k_1)+p\end{array}\right)$$

Proof. Taking $\varphi=1$ in (4.2), we have

$$F_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(\alpha,\beta;\gamma;1)=\frac{1}{B(\beta,\gamma-\beta)}\times\int_0^1 u^{\beta-1}(1-u)^{\gamma-\alpha-\beta-1}E_{k_1,k_2,p}^{k_3,k_4,q}\left(-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right)du\cdot$$

By applying definition (2.1) to the above equation, we get the desired result.

6. Connection with the other Special Functions

In this section we obtain certain connections of the generalized Beta function (2.1) in terms of other functions and polynomials. The results obtained here are interesting and can further be applied to other extensions of beta and other functions.

Theorem 6.1. The following relationship further generalized extended Beta function between the Wright function holds true:

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y)=\frac{\Gamma(k_4)}{\Gamma(k_3)}\int_0^1 u^{x-1}(1-u)^{y-1}\times{}_2\psi_2\left[\begin{matrix}(k_3,q),(1,1);\\(k_4,q),(k_1,k_2);\end{matrix}-\frac{\omega_1}{u}-\frac{\omega_2}{(1-u)}\right]du.\quad(6.1)$$

Proof: Applying the result from Salim et al., (see [25], (29))

$$E_{k_1,k_2,p}^{k_3,k_4,q}(z) = \frac{\Gamma(k_4)}{\Gamma(k_3)}\,{}_2\psi_2\left[\begin{matrix}(k_3,q),(1,1);\\(k_4,q),(k_1,k_2);\end{matrix} z\right]. \quad (6.2)$$

On setting $z \longrightarrow -\frac{\omega_1}{u} - \frac{\omega_2}{(1-u)}$, multiplying both sides by $u^{x-1}(1-u)^{y-1}$ and integrating with respect to u limit from 0 to 1, gives the desired result.

Theorem 6.2. The following relationship further generalized extended Beta function between the Fox's H-function holds true:

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y) = \frac{\Gamma(k_4)}{\Gamma(k_3)}\int_0^1 u^{x-1}(1-u)^{y-1} \times H_{2,3}^{1,2}\left[\frac{\omega_1}{u} + \frac{\omega_2}{(1-u)}\middle|\begin{matrix}(0,1), & (1-k_3,q)\\(0,1),(1-k_2,k_1), & (1-k_4,p)\end{matrix}\right] du. \quad (6.3)$$

Proof: Applying the result from Salim et al., (see [25], (32))

$$E_{k_1,k_2,p}^{k_3,k_4,q}(z) = \frac{\Gamma(k_4)}{\Gamma(k_3)} H_{2,3}^{1,2}\left[-z\middle|\begin{matrix}(0,1), & (1-k_3,q)\\(0,1),(1-k_2,k_1), & (1-k_4,p)\end{matrix}\right]. \quad (6.4)$$

On setting $z \longrightarrow -\frac{\omega_1}{u} - \frac{\omega_2}{(1-u)}$, multiplying both sides by $u^{x-1}(1-u)^{y-1}$ and integrating with respect to t limit from 0 to 1, gives the desired result.

Theorem 6.3. The following relationship further generalized extended Beta function between the Generalized hypergeometric function holds true:

$$B_{k_1,k_2,p,\omega_1}^{k_3,k_4,q,\omega_2}(x,y) = \frac{1}{\Gamma(k_2)}\int_0^1 u^{x-1}(1-u)^{y-1} \times {}_{q+1}F_{p+n}\left[\begin{matrix}1, & \Delta(q,k_3)\\ \Delta(n,k_2), & (p,k_4)\end{matrix}; \left(-\frac{\omega_1}{u} - \frac{\omega_2}{(1-u)}\right)\frac{q^q}{p^p n^n}\right] \times du, \quad (6.5)$$

Where $k_1 = n \in \mathbb{N}$, $\Delta(n,k)$is k −tuple $\frac{n}{k}, \frac{n+1}{k}, \ldots, \frac{n+k-1}{k}$.

Proof: Applying the result from Salim et al., (see [25], (30))

$$E_{k_1,k_2,p}^{k_3,k_4,q}(z) = \frac{1}{\Gamma(k_2)}\,{}_{q+1}F_{p+n}\left[\begin{matrix}1, & \Delta(q,k_3)\\ \Delta(n,k_2), & \Delta(p,k_4)\end{matrix}; \frac{zq^q}{p^p n^n}\right]. \quad (6.6)$$

On setting $z \longrightarrow -\frac{\omega_1}{u} - \frac{\omega_2}{(1-u)}$, multiplying both sides by $u^{x-1}(1-u)^{y-1}$ and integrating with respect to u limit from 0 to 1, gives the desired result.

7. Conclusions

This study introduced a new extension of the extended Beta and Gauss hypergeometric functions, exploring their properties, integral representations, and connections with other special functions. These findings provide a foundation for further research into broader generalizations and applications in mathematical and applied sciences.

References

[1] U. M. Abubakar and S. R. Kabara, "New generalized extended Gamma and Beta functions with their applications," *International Scientific Research and Innovation Congress*, pp. 446–465, 2021.

[2] A. A. Al-Gonah and W. K. Mohammed, "A new extension of extended Gamma and Beta functions and their properties," *Journal of Scientific and Engineering Research*, vol. 5, no. 9, pp. 257–270, 2018.

[3] A. A. Al-Gonah and W. K. Mohammed, "A new form of extended hypergeometric function and their properties," *Engineering and Applied Science Letters*, vol. 4, no. 1, pp. 30–41, 2021. Available: https://1030538/psp-eas/2021.0059.

[4] M. Ali, "A further extension of Beta and Related functions," *Palestine Journal of Mathematics*, vol. 12, no. 3, pp. 65–73, 2023.

[5] A. A. Atash, S. S. Barahmah, and M. A. Kulib, "On a new extension of extended Gamma and Beta functions," *International Journal of Statistics and Applied Mathematics*, vol. 3, no. 6, pp. 14–18, 2018.

[6] A. A. Atash, S. S. Barahmah, and M. A. Kulib, "On extensions of extended Gauss hypergeometric function," *Communications in Advanced Mathematical Sciences*, vol. 2, no. 3, pp. 199–205, 2019.

[7] N. Dudi and U. M. Abubakar, "A further extension of Gamma and Beta functions involving generalized Mittag-Leffler function and its applications," *Journal of Physical Sciences*, vol. 26, pp. 61–71, 2021.

[8] A. Enes and İ. O. K., "Generalized gamma, beta and hypergeometric functions defined by Wright function and applications to fractional differential equations," *Cumhuriyet Science Journal*, vol. 43, no. 4, pp. 684–695, 2022.

[9] K. S. Gehlot and K. S. Nisar, "Extension of two-parameter Gamma, Beta functions and its properties," *Applications and Applied Mathematics: An International Journal (AAM)*, vol. 15, no. 3, pp. 39–55, 2020.

[10] R. Goyal, S. Momani, P. Agarwal, and M. T. Rasiaas, "An extension of Beta function by using Wiman's function," *Axiom*, vol. 10, no. 187, pp. 1–11, 2021. Available: http://dx.doi.org/10.3390/axiom1003087.

[11] S. R. Kabara, A. H. Abdullahi, M. A. Lawan, F. A. Idris, M. S. Musa, and S. I. Musa, "Generalized extended Beta function," *International Journal of Applied Science and Research*, vol. 6, pp. 2581–7876, 2023.

[12] N. Khan and S. Husain, "A note on extended Beta function involving generalized Mittag-Leffler function and its applications," *TWMS Journal of Applied and Engineering Mathematics*, vol. 12, no. 1, pp. 71–81, 2022.

[13] A. A. Kilbas and M. Saigo, *H-Transforms: Theory and Applications*. London, New York: Chapman and Hall/CRC, 2004.

[14] M. A. Kulib and A. A. Al-Gonah, "New extended Beta function defined by product of two Wright functions," *International Journal of Mathematics Modelling & Computations*, vol. 15, no. 1, pp. 21–27, 2025.

[15] M. A. Kulib, F. B. F. Mohsen, and S. S. Barahmah, "Further extended Gamma and Beta functions in terms of generalized Wright function," *Electronic Journal of University of Aden for Basic and Applied Sciences*, vol. 1, no. 2, pp. 77–83, 2020.

[16]. M. A. Kulib, A. A. Al-Gonah, and S. S. Barahmah, "Certain investigations in the field of special functions," *Journal of Mathematical Analysis and Modeling*, vol. 1, no. 1, pp. 87–98, 2020.
[17] M. J. Luo, G. V. Milovanovic, and P. Agarwal, "Some results on the extended beta and extended hypergeometric functions," *Applied Mathematics and Computation*, vol. 248, pp. 631–651, 2014.
[18] G. M. Mittag-Leffler, "Sur la nouvelle fonction Eα(x)E_{\alpha}(x)Eα(x)," *C. R. Acad. Sci. Paris*, vol. 137, pp. 554–558, 1903.
[19] K. Oraby, A. Rizq, M. Ahmed, M. Khaled, E. Ahmed, and M. Magdy, "Generalization of Beta functions in terms of Mittag-Leffler function," *Frontiers in Scientific Research and Technology*, vol. 1, pp. 81–88, 2020.
[20] M. A. Ozarslan and B. Yılmaz, "The extended Mittag-Leffler function and its properties," *Journal of Inequalities and Applications*, vol. 2014, no. 1, p. 85, 2014.
[21] T. R. Prabhakar, "A singular integral equation with a generalized Mittag-Leffler function in the kernel," *Yokohama Mathematical Journal*, vol. 19, pp. 7–15, 1971.
[22] E. D. Rainville, *Special Functions*, New York, NY, USA: Chelsea Publishing Company, 1960.
[23] M. K. Rasheed and A. H. Majeed, "Generalization of gamma and beta functions with certain properties and statistical applications," *Iraqi Journal of Science*, vol. 64, no. 7, pp. 4487–4495, 2023.
[24] T. O. Salim, "Some properties relating to the generalized Mittag-Leffler function," *Advances in Mathematics Analysis*, vol. 4, pp. 21–23, 2009.
[25] T. O. Salim and A. W. Faraj, "A generalization of Mittag-Leffler function and integral operator associated with fractional calculus," *Journal of Fractional Calculus and Applications*, vol. 3, no. 5, pp. 1–13, 2012.
[26] M. Shadab, S. Jabee, and J. Choi, "An extension of beta function and its application," *Far East Journal of Mathematical Sciences*, vol. 103, no. 1, pp. 235–251, 2018.
[27] H. M. Srivastava and H. L. Manocha, *A Treatise on Generating Functions*, Chichester, UK: Halsted Press (Ellis Horwood Limited), John Wiley & Sons, 1984.

GENERATIVE AI AND ENGINEERING EDUCATION: MEASURING ACADEMIC PERFORMANCE AMIDST SOCIOECONOMIC CHALLENGES IN YEMEN

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Generative AI and Engineering Education: Measuring Academic Performance Amidst Socioeconomic Challenges in Yemen

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Abstract— This study assessed the impact of generative artificial intelligence (GenAI) usage on the academic outcomes of engineering students within the context of Yemen's unique socioeconomic challenges. This study employed a quantitative approach through a structured 5-point Likert-scale questionnaire, which was distributed to 277 engineering students from Taiz University, Yemen. In a resource-constrained environment, the results exhibited a strong correlation between GenAI usage and engineering students' overall grades and skills development. Additionally, findings showed that socioeconomic challenges that students face in Yemen have moderately hindered students from the effective usage of GenAI for educational purposes, which is a key finding for higher education institutions (HEIs). Also, statistical results showed that almost all respondents are familiar with GenAI tool usage, while 89.17% use ChatGPT as a fundamental component of learning. Of course, the integration of GenAI into education has become inevitable, compelling HEI policymakers to regulate its use and formally adopt it as a primary source of learning systems. Students and educators should obtain continuous training to effectively benefit from GenAI while conforming to ethics and boosting their intellectual capabilities and skills. Raised concerns that the students overreliance on AI tools could undermine their problem-solving abilities and practical skills development while complicating students' evaluation process for educators. The outcomes of this study could serve as a foundational reference for policymakers, educators, and students in Yemen and similar settings. It also recommends in-depth studies that cover other educational contexts and respondents from other states, rather than undergraduate engineering students in the present study.

Keywords— Academic Achievement; Generative Artificial Intelligence; Engineering Education; ChatGPT; Academic Achievement; Engineering; Students; Socioeconomic; Challenges, Higher Education Institutions (HEIs).

I. INTRODUCTION

The rapid pace of technological advancement has compelled both public and private organizations to adapt swiftly to these changes. Beyond mere adaptation, organizations must now focus on training and upskilling their workforce while modernizing their infrastructure to effectively integrate these advancements. Among the most transformative developments is the remarkable evolution of AI software and big data visualization tools [1]. These technologies are designed to empower intelligent machines and computer programs to replicate human cognitive processes, revolutionizing how tasks are performed and decisions are made. By integrating these tools with advanced intelligent programs, such systems can not only mimic but also surpass human intelligence in many tasks.

AI has become a transformative force across a wide range of sectors, including military, industrial, commercial, and technological fields. Its applications have steadily expanded into critical areas such as healthcare, agriculture, education, and beyond, revolutionizing processes, enhancing efficiency, saving time and money, and enabling innovative solutions to complex systems [1-3]. It alters all people's daily life perspectives, including their communication, education, health, well-being, family, social, and economic affairs [4-8]. HEIs today face significant challenges in improving the quality of education and enhancing students' academic achievement, particularly considering rapid technological advancements in information resources and data mining. It was proposed that integrating technology into the HEIs improves education sustainability and quality and boosts institutions' competitiveness [9, 10]. Among these technological advancements, AI algorithms have begun to play a pivotal role in the educational process. It is now considered a primary source of learning in school and university education systems. However, there is widespread speculation about the potential risks of AI tools replacing human thought and reasoning, especially at the university level, a critical stage for shaping students' minds and equipping them with the knowledge and skills needed to enter the workforce and overcome life challenges.

University students in Yemen, particularly engineering students, face unique challenges shaped by the country's distinct sociopolitical and economic context and HEIs' poor infrastructure [11, 12, 13, 14]. Key factors such as political conflict and division, economic collapse, and social restrictions significantly influence their educational experiences and outcomes [11-15]. Recent research highlights the profound impact of socioeconomic factors on the academic achievement of engineering students [11]. Political instability has further compounded these challenges, creating obstacles not only during their undergraduate studies but also in securing employment after graduation [15, 15]. Additionally, the conservative nature of Yemeni society imposes extra barriers, particularly for female engineering students and graduates [11, 15].

In response to the lack of official educational platforms, engineering students in Yemen have turned to social media as a tool for learning and collaboration [12]. However, a survey study conducted across engineering colleges in Yemen revealed that universities lack the necessary technological infrastructure to support diversifying modern educational resources, such as online education platforms and AI-based models [15]. Given these circumstances, it is crucial to

consider these variables when examining the potential impact of integrating AI models into the educational system. Understanding these challenges is essential for developing effective strategies to enhance the quality of education and support the academic and professional success of engineering students in Yemen. Additionally, there is a dearth of research studies examining these variables among university students in Yemen, especially given the exceptional circumstances Yemen is experiencing at all levels. This study aims to investigate the impact of GenAI usage on the educational achievement of engineering students in Yemen amidst socioeconomic challenges specific to the Yemeni situation.

II. LITERATURE REVIEW

GenAI belongs to AI algorithms that are extensively pre-trained, with the ability to generate new content, such as texts, images, videos, etc. They behave like intelligent humans and even surpass them. They can generate interactive conversations, visuals, audio, meetings, presentations, research, programming, and data analysis [17]. In terms of coding, GenAI models are built based on the principles of machine learning algorithms in which an output could be released without prior programming to perform a predefined outcome [18]. Put simply, various learning algorithms are used to achieve these complicated tasks. Furthermore, GenAI consists of effective and fast-response models that perform various language processing tasks and smart problem-solving capabilities with ultimately high accuracy [19]. Notably, it can perform text generation, data analysis, translation over dozens of languages, original essay writing, summarization, interactive question answering, etc.

The early stages of AI tools were rooted in the prediction of rule-based decision-making theories during the 1940s. After World War II, the science of operations research was developed, which is considered the base of AI-based generative decision-making models. During the 1950s, Alan Turing and John von Neumann announced the first attempt at AI models. Their exceptional prediction was to examine a machine's ability to exhibit intelligent behavior [20]. Throughout the last five decades, numerous algorithms have been developed to help provide human-like interactive decisions with slow progress. The rapid development of robots, automation, programming, control systems, and advanced electronic circuits paved the way for effective AI tools [20, 21].

ChatGPT received the most attention from researchers globally due to its wide popularity and miraculous features [18, 19]. A large experimental survey investigation showed that ChatGPT improves students' problem-solving and self-efficacy skills [22]. Following the emergence of ChatGPT with its exceptional features, international companies rapidly competed to launch similar programs with even better features. Initially, competition was limited to US companies, but the emergence of the Chinese-made DeepSeek program was considered a breakthrough in this field, breaking the US monopoly [23, 24].

Integration of GenAI models with higher education is today's pressing topic that has shown a dramatic change in HEI policies [17, 25, 26, 27]. However, the integration process faces various barriers, including funds, community acceptance, digital literacy, data availability and reliability, and HEIs' infrastructures, among many other challenges [26]. One significant benefit of GenAI models for students is their ability to support asynchronous communication, enhancing student engagement and collaboration. They enable students' discussion' engagement and asking questions without the need to be online simultaneously [17]. Additionally, certain GenAI models, such as chat APIs, can facilitate collaboration by enabling the creation of student groups, allowing students to work together on projects and assignments in real-time or asynchronously [28]. Additionally, GenAI tools are valuable for supporting remote learning, offering critical assistance to students who face physical or mental health challenges [29].

GenAI models can effectively promote learning approaches by directing seekers to the preferred resources, including books, articles, consultants, and websites, to satisfy their needs and preferences. This easy access to technology and services assists students to engage more deeply with the resources and emphasize self-directed learning [17]. Additionally, AI-powered chatbot applications allow instant access to educational resources, such as study guides, lecture notes, and practice exercises, further supporting students in mastering complex concepts. By delivering targeted assistance and resources, AI not only improves comprehension but also empowers learners to take ownership of their educational process.

Focused studies have investigated the relationships between GenAI tools and educational achievement from student views [17] and educator views [30, 31, 32]. It was reported that students interact with new technologies better than their educators [13, 33]. Overall, the impact of GenAI on the education system has become an unavoidable reality, raising voices to HEI policymakers to establish controls and regulations to organize its use, maximize its benefits, and mitigate its potential negative effects. The impact is volumetric; integrating GenAI into education has raised voices to redesign the HEI curriculum, enabling sustainable education and expanding learning resources [34, 35].

Conversely, there are rising global concerns about the potential negative excessive use of GenAI models on students' critical thinking and their ability to develop problem-solving skills for complex challenges [29]. Although these concerns are fundamental and require in-depth survey analysis, this topic is beyond the scope of this study.

Integration of GenAI into education has emerged as a pivotal and dynamic topic in recent years, attracting focused evaluation from sociologists, educationalists, programmers, and policymakers across diverse educational settings worldwide. This study aims to investigate the impact of GenAI use on educational attainment within an economically and politically unstable environment and amidst educational institutions with poor infrastructure to engage with such technologies. The study's outcomes could provide unique insights far beyond those observed in more stable contexts.

III. Methods & Research Design

A. Research Design

This study was mainly structured to explore the importance of adopting GenAI tools as a supporting learning resource and the impact of their frequent usage on engineering students' educational achievement. The research study extends to study many students' surrounding variables, such as social, economic, and educational influences, as illustrated in Figure 1. Specifically, this study investigated the effects of students' gender, marital status, financial conditions, living stability, engineering specialization, study level, and internet access facilities such as personal computers and smartphones.

The study's independent variable is students' use of GenAI models, while the dependent variable is academic achievement. Students' usage of AI tools was measured by introducing three questions in the questionnaire; these questions are (1) their usage density of AI tools (always, often, sometimes, seldom, and never), (2) the period between each entry to the AI sites (daily, weekly, monthly, etc.), and (3) students were asked to select from a predefined list of many AI tools frequently used by university students. Accordingly, this study identified the students' usage of AI tools among these questions. These measures were standardized by many studies from the literature review [36].

Academic achievement was measured using students' overall grades in the university and high secondary schools.

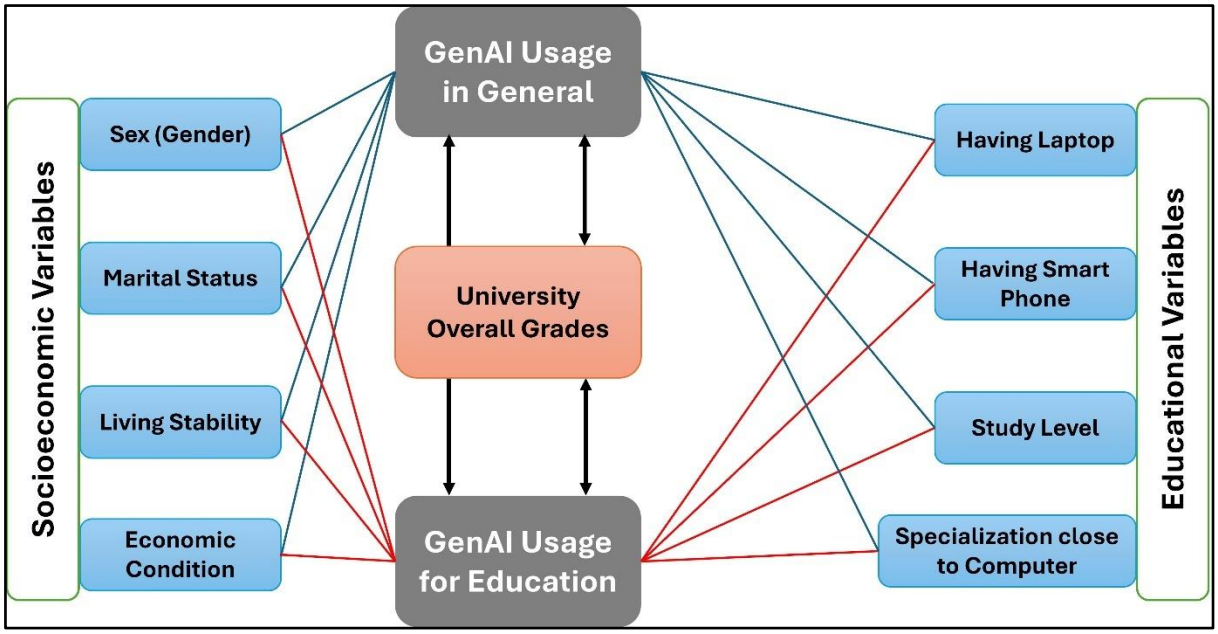

Fig. 1. Turbine Test Schematic Diagram

Students were directly asked many demographic questions, such as their sex, marital status, study level, specialization, and whether they have personal computers and smartphones. Demographic data were examined as variables in this study to investigate their effects on students' usage of GenAI models for educational purposes. "Living stability" is a socioeconomic variable that has been proven to negatively impacts on university students' overall grades in Yemen [11]. To measure the "living stability" variable, engineering students were asked if they constantly lived with their families, in university hostels, with relatives' homes, or with friends and classmates.

The harsh economic conditions in Yemen undoubtedly affect students' performance, attendance rate, academic achievement, and access to technology and GenAI tools at university. For that, it was considered a variable in this study, and it was measured by asking students about their average daily expenses within many ranges. These measures align well with other studies from the literature [11].

Finally, students were asked many questions to explore their views regarding four aspects: (1) the extent to which students use AI programs and their impact on their educational attainment, (2) students' awareness of the importance of AI as a primary learning resource for undergraduate students, (3) the dimension of developing practical skills, and (4) expected drawbacks and challenges associated with using AI tools. These research dimensions are in line with other studies performed on similar works worldwide [17].

B. Research Hypotheses

H1: The use of GenAI tools for education positively impacts students' academic achievement.

H2: Students in computer-related majors benefit more from AI tools compared to other majors.

H3: Senior students derive greater benefits from AI tools than fresh ones.
H4: Students' gender has a neutral effect on the use of AI tools for educational purposes.
H5: Socioeconomic variables of Yemeni students have a negligible effect on their usage of AI tools.
H6: Students who have personal computers show higher interaction with AI tools than other students.
H7: Frequent use of AI technologies enhances students' overall academic performance at the university.
H8: Frequent use of AI tools contributes to the improvement of students' practical and technical skills.

C. Data collection

This study employs a quantitative approach for answering research questions. A structured questionnaire was developed to address research questions and hypotheses. It targeted engineering students from the Faculty of Engineering and Information Technology at Taiz University, Yemen.
Engineering students were selected as a sample of undergraduate students in Yemen due to their proximity to technology and computing advancements. Questions were structured based on a 5-point Likert scale and first asked for demographic information of respondents, followed by questions related to research variables, both dependent and independent variables.
The questionnaire was reviewed by two statistical specialists to ensure that its questions effectively validated the research questions and hypotheses. After that, the questionnaire was randomly distributed to engineering students in lecture rooms during classes in February 2025. The research population was limited to undergraduate engineering students at Taiz University during the academic year 2024–2025, totaling approximately 1,830 students. A total of 300 responses were collected from students across various study levels and specializations. Of these, 277 responses were complete and accurately recorded in an Excel file for further analysis.
Demographic questions were included in the survey to gather information about the respondents' characteristics. The respondents were classified by their sex, with 84 female students and 193 male students participating in the survey. Additionally, among all respondents, 20 students were married, while 257 were single. These demographic classifications were structured as key research variables to examine the potential influence of sex and marital status on the relationship between AI tool usage and educational attainment.

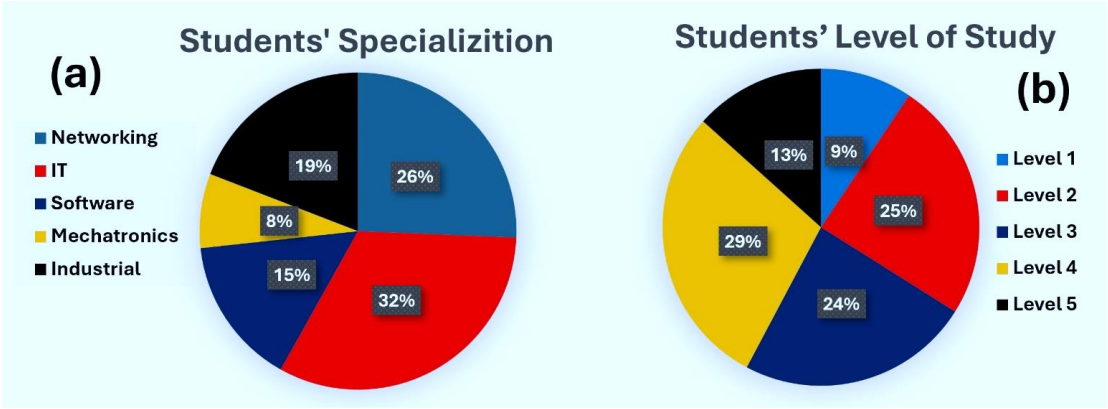

Figure 2. Questionnaire respondents' classifications based on their (a) discipline and (b) study level.

The engineering specializations of the students were categorized as illustrated in Figure 2(a). The distribution of respondents across specializations was as follows: 53 from the Industrial Engineering department, 21 from Mechatronics, 42 from Software Engineering, 90 from Information Technology, and 71 from Computer Networks and Cyber Security. Similarly, Figure 2(b) displays respondents' classification based on their study level. The division of students was as follows: 26 students from the 1ST level, 68 from the 2ND level, 66 from the 3RD level, 80 from the 4TH level, and 37 from the 5TH level. This diversity and uniformity of respondents across both specializations and academic levels make them effective variables influencing the correlation between GenAI usage and educational achievement. Furthermore, a good selection of respondents' frameworks enhances the quality of the research sample to effectively validate the research questions and the study's hypotheses.

Statistical analysis was conducted using SPSS software, which was used to calculate the mean, standard deviation, and variance of the variables. Additionally, the correlation coefficient between the variables was also assessed. The data were exhibited in the form of tables, diagrams, and graphs for better understanding of the relation between various variables.

IV. Results and Discussion

This section presents the analysis of questionnaire responses of 277 engineering students from different engineering disciplines in Yemen. Many variables were studied to predict the relationship between GenAI usage and educational attainment. These variables are, for example, sex, marital status, engineering specialization (with a focus on its proximity to computer-related fields), living stability, economic condition, study level, and having a personal computer and smartphone.

The interactions of these variables were systematically analyzed, and the results are presented in tables and charts. Figure 3 demonstrates the percentage of various AI tools frequently used by engineering students in Yemen for educational purposes and general knowledge acquisition.
The results indicated that 89.17% of engineering students rely on ChatGPT as their primary AI tool. This finding is in consistent with other studies highlighting ChatGPT's dominance as the most widely promoted GenAI model for higher education after its release in November 2022 [18, 19, 32]. For instance, a 2023 survey study performed in Germany indicated that two-thirds of university students use ChatGPT as a main AI model for their studies [37]. However, this survey was conducted just a few months after its initial release by OpenAI.

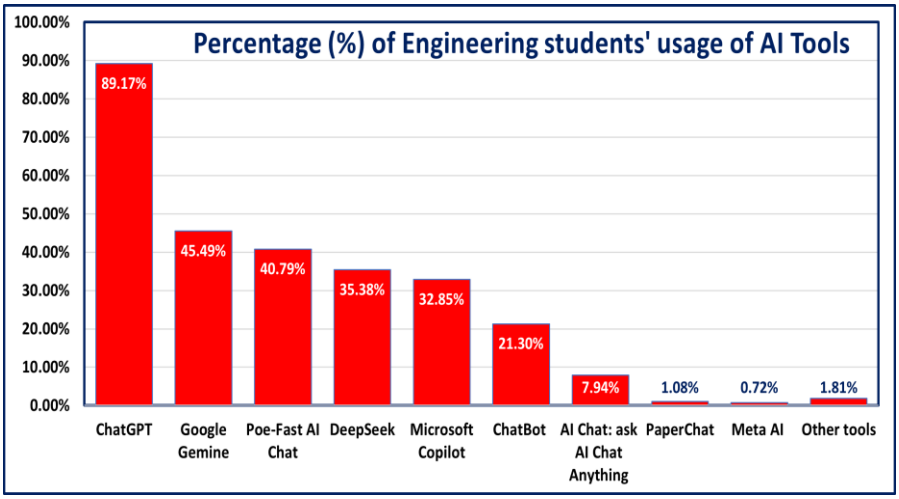

Figure 3. A diagram of percentage (%) of student users among list of GenAI tools. Sample size, n=277.

According to Figure 3, Google Gemini and Poe-Fast AI Chat came in second and third orders, with usage rates of 45.5% and 40.8%, respectively. Although DeepSeek was officially launched on January 27, 2025, it quickly gained popularity, likely because it is an open-source and cost-effective model. It demonstrated very good results comparable to what can be obtained by ChatGPT. Its Chinese origin, which filled a gap in an AI market previously dominated by U.S.-based tools, also raised its popularity. Accordingly, the survey results of this study indicated that over 35% of Yemeni engineering students began using DeepSeek frequently within a few weeks of its global release. Additionally, about 32.85% and 21.3% of students use Microsoft Copilot and ChatBot AI tools, respectively. Other tools, such as PaperChat and Meta AI, are rarely used by Yemeni engineering students, with only about 1% reporting using them.
Table 1 elucidates the statistical values of the main variables corresponding to this study. There are identical matching mean value results of secondary school grades and university grades at $\mu = 3.516$ and $\mu = 3.58$, respectively. Most students showed higher "living stability" at $\mu = 4.018$, while the "economic conditions" of engineering students in Yemen are ultimately bad at $\mu = 2.516$. Students who frequently use GenAI tools for general purposes are at $\mu = 3.92$, but students' usage for educational purposes is high at $\mu = 4.246$. These values provide an initial indication about the respondents' characteristics and variables' features in the context of the Yemeni environment.

Table 1. Statistical analysis (Range, Mean, and Standard Division) of main variables. Sample size, n = 277.

Code	Variable	n	Range	Mean (μ)	S. D.
A1	Sex (Male 1, Female 2)	277	1 -2	1.30	0.46
A2	Marital Status	277	1 -2	1.072	0.259
A3	Specialization close to computer	277	1 -5	3.841	1.614
A4	Study level	277	1 -5	3.11	1.187
A5	Having computer	277	1 -2	1.144	0.352
A6	Having smart phone	277	1 -2	1.011	0.104
A7	Secondary school score	277	1 -5	3.516	1.153
A8	University Score	277	1 -5	3.58	.947
A9	Living stability	277	1 -5	4.018	1.392
A10	AI Usage, in general	277	1 -5	3.92	.885
A11	AI Usage for Education	277	1 -5	4.246	.764
A12	Economic conditions	277	1 -5	2.516	1.082

Table 2. Statistical analysis based on variables' significance (P< 0.05) with dependent variables.

Code	Variable	Uni. Overall Grades (A8)		Students' AI Usage (A10)	
		F	P	F	P
A1	Sex (Male 1, Female 2)	.850	0.357	4.662	**0.032**
A2	Marital Status	0.155	0.694	0.624	0.430
A3	Specialization close to computer	1.049	0.383	2.638	**0.035**
A4	Study level	2.419	**0.049**	2.395	**0.050**
A5	Having computer	0.000	0.995	1.142	0.286
A6	Having smart phone	0.956	0.564	0.363	0.547
A7	Secondary school score	6.465	**0.000**	0.615	0.652
A8	University Overall Grade	XXX	XXX	1.581	0.180
A9	Living stability	0.387	0.818	1.336	0.257
A10	AI Usage, in general	1.425	0.226	XXX	XXX
A11	AI Usage for Education	4.741	**0.003**	20.822	**0.000**
A12	Economic condition	1.052	0.381	1.549	0.189

The results of the survey indicated that three factors—study level (F = 2.419, p < 0.049), secondary school score (F = 6.465, p < 0.0001), and AI usage for education (F = 4.741, p < 0.003)—had a significant effect on A8, as shown in T**able 2**. Similarly, the results of the survey indicated that four variables—sex (F = 4.662, p < 0.032), study level (F = 2.395, p < 0.050), specialization close to computer (F = 2.638, p < 0.035), and AI usage for education (F = 20.822, p < 0.000)—had a significant effect on A10. Notably, gender, a key social variable in Yemeni conservative society, represents a significant barrier to students' AI usage (F = 4.662, p < 0.032), which agrees with a recent study confirming the effect of gender on female students' effective communication with new technologies and computer-based models [13]. This significant analysis will be validated in the coming subsections.

Table 3. Correlation coefficient (f) values based on linear Pearson's model. n = 277 engineering students, data was collected in February 2025.

Code	Variable	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
A1	Sex (Male 1, Female 2)	1	-0.002	**0.26**	-0.12	-0.092	-0.07	0.127	0.076	**0.376**	0.086	-0.086	**-0.30**
A2	Marital Status		1	0.062	0.092	-.075	-0.029	-0.04	0.035	-0.164	0.072	-0.017	0.164
A3	Specialization close to computer			1	-0.019	-0.157	-0.011	0.091	0.084	0.146	0.118	0.002	0.041
A4	Study level				1	-0.159	0.049	0.147	-0.021	0.016	0.136	0.026	**0.233**
A5	Having computer					1	0.155	-0.077	0.008	-0.109	-0.114	0.029	-0.025
A6	Having smart phone						1	-0.047	-0.101	-0.052	-0.03	-0.079	**0.176**
A7	Secondary school score							1	**0.288**	0.184	0.115	0.057	-0.145
A8	University Overall Grade								1	0.000	**0.185**	**0.213**	0.014
A9	Living stability									1	0.060	-0.031	**-0.252**
A10	AI Usage, in general										1	**0.447**	0.153
A11	AI Usage for Education											1	0.043
A12	Economic condition												1

Table 3 demonstrates crucial findings of the correlation between research variables. The interaction coefficient results reveal a strong correlation between the frequent use of AI tools and students' overall university grades. Specifically, students who regularly use GenAI tools, both in general (f = 0.185) and for educational purposes (f = 0.213), achieved higher overall grades compared to their peers, which aligns well with the first hypothesis. Although the correlation factors have positive values (f = 0.185 and f = 0.213), their values are close to zero, indicating that the role of GenAI for enhancing education is still facing diverse barriers and requires continuous investigation in the future. Moreover, students who frequently utilize GenAI tools tend to leverage them positively to enhance their educational performance (f = 0.447). These findings are particularly encouraging for the educational landscape in Yemen, despite the country's limited technological infrastructure and internet accessibility.
The living stability of engineering students exhibited a neutral impact on both their frequency of GenAI usage (f = 0.06) and their overall academic performance (f = 0.000), as shown in Table 3. In contrast, the economic condition variable behaves in another way, it showed a minimal effect on the university overall grades (f = 0.014) but had a more pronounced influence on students' access ability to GenAI tools (f = 0.153), indicating that economic condition is crucial for students boosting their accessibility to GenAI models. These findings hold particular significance for policymakers and educators in Yemen and any similar settings, especially given Yemen's ongoing political and economic challenges.
Despite facing financial hardships, engineering students have demonstrated resilience, refusing to let their difficult economic circumstances hinder their academic pursuits [11]. In other words, these students have not succumbed to the pressures of their financial constraints or family situations, and they continue to strive for academic excellence [15]. Consequently, the challenging financial conditions faced by students in Yemen have moderately hindered students from engaging with technology and AI tools to enhance their education and expand their knowledge.
Students' social variables, such as gender and marital status, exhibit only slight influences on their usage of GenAI tools and their overall university grades. The results indicate that female students use GenAI tools more frequently than male students (f = 0.086), though they are less likely to use these tools specifically for educational purposes (f = -0.086). These findings slightly deviate from the fourth hypothesis of this study, plausibly due to the conservative nature of society in Yemen. Similarly, married students show slightly higher usage of GenAI tools compared to unmarried students, as well as marginally better overall university grades.
Engineering students from computer-related specializations interact with GenAI tools more frequently than those from other engineering disciplines (f = 0.118); this result matches the second hypothesis of this research. That is because students from computer-related disciplines deal with AI advancements as a vital part of their core specializations. Additionally, senior students demonstrated greater engagement with GenAI tools compared to freshmen (f = 0.136), which supports the third hypothesis of this study. Students from the first and second study levels are focusing on fundamental and applied sciences courses at this stage of the engineering curriculum.
Finally, the ownership of personal computers or smartphones among engineering students has only a minor impact on their engagement with GenAI tools, matching well with the sixth hypothesis. This is likely due to the widespread availability of fast internet connections through personal phones, which supports all students with almost equal opportunities to internet access.

Table 4. Students' opinions about their skills in dealing with GenAI tools and skills' development. Sample size n =277 engineering students.

Code	Statement	Range	Mean (μ)	S.D.	Variance
B1	I use several AI tools to help me for studying	1 - 5	4.25	0.764	0.584
B2	I can select suitable AI tools for my education purposes	1 - 5	4.11	0.824	0.679
B3	I can deal with technical and design AI tools during their use.	1 - 5	3.84	0.988	0.977
B4	I can predict the best AI tools for specific use.	1 - 5	3.74	0.919	0.845
B5	I often go for GenAI tools for more knowledge	1 - 5	4.22	0.940	0.885
B6	I can evaluate the quality of AI tools used for education purposes	1 - 5	3.73	1.091	1.191
C1	GenAI tools constantly help students with cooperative education	1 - 5	3.61	1.210	1.464
C2	GenAI tools improve students' self-education and continuous education	1 - 5	4.06	0.954	0.910
C3	The use of AI tools helps students perform their duties in time	1 - 5	4.29	0.819	0.671
C4	The use of AI tools increases students' motivation to learn.	1 - 5	3.77	1.109	1.229
C5	The use of AI tools allows students with diverse teaching approaches.	1 - 5	3.97	0.918	0.843
C6	The use of AI tools enhances students' thinking skills	1 - 5	3.51	1.218	1.483

Table 4 presents the statistical analysis of the questionnaire responses, including the mean, standard deviation, and variance for each statement. It reflects students' perspectives on their awareness and understanding of the benefits associated with the frequent use of GenAI tools for educational purposes. Overall, most students expressed positive attitudes toward AI tools, viewing them as a reliable and continuous source of information and knowledge. This

trend is evident from the high mean values (μ) for all statements listed in Table 4.

Students believe that GenAI tools significantly aid their studies (μ = 4.25), enhance their general knowledge (μ = 4.22), and provide quick and timely answers (μ = 4.29). However, their self-reported experience and interaction with GenAI tools received relatively lower scores compared to other general statements. Specifically, engineering students feel moderately confident in selecting the appropriate AI tool for specific tasks (μ = 3.74), effectively using technical and design-oriented AI tools (μ = 3.84), and evaluating the quality of data and information generated by AI tools (μ = 3.61). Notably, students are more familiar with GenAI tools that are directly related to their educational purposes (μ = 4.11).

Students displayed good agreement with several statements, shedding light on the role of GenAI tools in enhancing their practical and technical skills. These include fostering cooperative learning (μ = 3.61), promoting self-directed and continuous learning (μ = 3.74), increasing motivation to learn (μ = 3.77), and improving critical thinking abilities (μ = 3.51). Additionally, students acknowledged that AI tools have diversified teaching methods and expanded approaches to acquiring information (μ = 3.97), moving beyond the conventional face-to-face education model of direct information reception. Although students' perspectives towards these measures are not fully supported, this study proposes that students' beliefs in effective usage of GenAI for enhancing education will grow exponentially shortly.

Table 5. Students' opinions about the drawbacks and challenges associated with their AI use. Sample size n =277 engineering students.

Code	Statement	Range	Mean (μ)	S.D.	Variance
F1	GenAI tools weaken students' ability to think creatively	1 - 5	3.69	1.243	1.547
F2	Students don't have sufficient skills and experience to deal with GenAI tools.	1 - 5	3.49	1.058	1.120
F3	GenAI tools increase reliance on technology and dismiss practical skills.	1 - 5	4.00	1.005	1.011
F4	Technological and financial resources required for accessing AI tools are weak in Yemen.	1 - 5	4.03	1.088	1.184
F5	I don't believe information provided by GenAI tools	1 - 5	3.40	1.063	1.130
F6	GenAI tools boost motivation for scientific research	1 - 5	3.96	0.896	0.803
F7	GenAI tools help conduct scientific research at time.	1 - 5	4.08	0.901	0.813

There is growing concern among education policymakers that excessive reliance on AI tools by university students may undermine their self-reflection skills and make it increasingly challenging to differentiate between students' true intelligence levels. Table 5 highlights engineering students' perspectives on the drawbacks and challenges associated with the frequent use of GenAI tools for educational purposes. Students believe that over-reliance on AI tools as a primary source of information, without putting in sufficient effort, diminishes their creative thinking abilities and negatively impacts their reading skills (μ = 3.69). Additionally, students strongly agree that GenAI tools increase dependency on technology and reduce the development of practical skills (μ = 4.00). They also expressed skepticism about the accuracy and reliability of information provided by these tools (μ = 3.40). Finally, students highlighted the challenges of accessing AI tools in the Yemeni context, citing limited technological and financial resources (μ = 4.03) and a lack of training on how to effectively select and interact with the most suitable AI tool for specific tasks (μ = 3.49). These concerns, clearly expressed by engineering students, should be taken seriously by policymakers of HEIs, ensuring that access to GenAI tools is not unfettered. This sensitive topic requires in-depth studies that examine these growing concerns and propose recommendations to control them.

Students also provided valuable insights into the role of GenAI tools in scientific research. Students believe that these tools are not only essential for improving their projects and homework reports but also enhance their motivation to conduct high-quality scientific research (μ = 3.96) in a quick and timely manner (μ = 4.08). However, the use of AI tools in scientific research remains a controversial topic, with conflicting studies on how they can be effectively integrated without undermining the researcher's role [34]. In other words, GenAI tools should complement, not replace, human effort. Another concern is the potential for AI tools to generate virtual or fabricated data, which could compromise the quality and reliability of scientific research and undermine HEIs' reputation.

Table 6. Students' opinions about the influence of GenAI tools on University Education in general. The sample size was 277respondents from engineering students in Yemen.

Code	Statement	Range	mean (μ)	S.D.	Variance
G1	**GenAI tools enhance students' education attainment**	**1 - 5**	**3.80**	**0.849**	**0.721**
G2	**GenAI tools enhance students' education skills**	**1 - 5**	**3.34**	**0.982**	**0.964**
G3	**Students who use GenAI tools are intelligent and excel academically**	**1 - 5**	**3.63**	**1.050**	**1.103**
G4	**Using AI tools boosts students' ability to solve problems.**	**1 - 5**	**3.75**	**1.074**	**1.154**
G5	**There is a positive relationship between the use of AI tools and students' academic achievement**	**1 - 5**	**3.80**	**0.969**	**0.940**

Table 6 summarizes students' thoughts and fears about the relationship between the reliance on GenAI tools and their educational attainment. Students expressed support for adopting AI tools as a supporting learning resource, but with some reservations. This is evident from the low mean values in Table 6. Students' responses to issues such as (1) GenAI tools boost students' education skills (μ = 3.34), and (2) using AI tools effectively is an indication of intelligence and excellent academic performance (μ = 3.63). Finally, students agreed with the research statement: There is a positive relationship between the use of GenAI tools and students' academic achievement.

The outcomes of this study align well with almost all studies in the literature review discussing this unique topic [38-40]. Although the correlation between primary variables varies from one society to another, the correlation results are moderately accepted in Yemeni, considering the socioeconomic challenges. Indicators from this study infer that university education in Yemen relatively benefits from the most advanced AI tools to support technology-based cognitive learning and reinforce their knowledge.

Overall, the integration of GenAI tools into higher education in Yemen is a critical, dynamic, and timely topic that requires further in-depth studies across primary, secondary, university, graduate, and vocational education. Studies that entail other student respondents from different states in Yemen with varied sociocultural norms are needed for a comprehensive understanding of this sustainable integration. This study provides positive indicators useful to decision-makers, educators, and students in HEIs.

Conclusions and Recommendations

This study surveyed 277 engineering students from Taiz University in Yemen to explore how the frequent usage of GenAI models enhances their education. Many socioeconomic variables peculiar to Yemeni students were investigated to demonstrate their impact on the relationship between GenAI tools and educational performance. The study showed a strong and positive correlation between the frequent use of GenAI tools and students' university overall grades, encouraging their integration into the educational system in Yemen as a supporting source of learning and knowledge seeking. Despite the worse socioeconomic conditions of Yemeni Engineering students, the results of this study showed their moderate effect on the relationship between the usage of AI models and students' university overall grades. These findings hold particular significance for policymakers and educators in Yemen and any similar settings, especially given Yemen's ongoing political and economic challenges.

The results showed that almost all students use GenAI tools with varying usage levels. Interesting results showed that 89.17% of engineering students in Yemeni Universities rely on ChatGPT as a primary AI tool that satisfies their needs. Other AI models showed less interest, but the DeepSeek GenAI model has been observed as a strong AI competitor, despite its being a few weeks old since its launch on 27th January 2025.

This study recommends that HEIs establish guidelines to control students' effective usage of GenAI tools without breaking research ethics and dismissing their intellectual and problem-solving capabilities. In terms of the wide variety of

GenAI tools, students should be trained and upskilled to identify their features, merits, and drawbacks to get the most appropriate AI tools for their specific needs.

REFERENCES

[1] I. Taj, N. Zaman, ‘‘Towards industrial revolution 5.0 and explainable artificial intelligence: Challenges and opportunities,” Int. J. Computing and Digital Systems, Vol. 12, No. 1, PP. 295-320, 2022.

[2] M. I. Jordan, ‘‘Artificial intelligence—the revolution hasn’t happened yet,” Harvard Data Science Review, Vol. 1, PP. 1-9, 2019, doi:10.1162/99608f92.f06c6e61.

[3] S. Makridakis, ‘‘The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms, ” Futures, Vol. 90, PP. 46-60, 2017. https://doi.org/10.1016/j.futures.2017.03.006.

[4] A. Jose, S. Nandagopalan, C. M. V. S. Akana, ‘‘Artificial Intelligence techniques for agriculture revolution: a survey, ” Annals of the Romanian Society for Cell Biology, Vol. 25, No. 4, PP. 2580-2597, 2021. http://annalsofrscb.ro/index.php/journal/article/view/2796.

[5] Q. Sun, A. Akman, B. W. Schuller, ‘‘Explainable artificial intelligence for medical applications: A review, ” ACM Transactions on Computing for Healthcare, Vol. 6, No. 2, PP. 1-31, 2025. https://doi.org/10.48550/arXiv.2412.01829.

[6] H. H. Al-Baity, ‘‘The artificial intelligence revolution in digital finance in Saudi Arabia: A comprehensive review and proposed framework,” Sustainability, Vol. 15, No. 18, Art. No. 13725, 2023, doi: 10.3390/su151813725.

[7] Z. H. İpek, A. I. C. Gözüm, S. Papadakis, M. Kallogiannakis, ‘‘Educational Applications of the ChatGPT AI System: A Systematic Review Research,” Educational Process: International Journal, Vol. 12, No. 3, PP. 26-55, 2023. DOI: 10.22521/edupij.2023.123.2.

[8] S. Shafiee, ‘‘GenAI in manufacturing: a literature review of recent applications and future prospects,” Procedia CIRP, Vol. 132, PP. 1-6, 2025. https://doi.org/10.1016/j.procir.2025.01.001.

[9] A. K. Alhazmi, A. Zain, N. Alsakkaf, Y. Othman, “Identification of Sustainability Barriers in Higher Education Institutions (HEIs) and the Role of Technology in Improving Sustainability in HEIs,” Journal of Science and Technology, Vol. 28, No. 1, PP. 31-37, 2023. https://doi.org/10.20428/jst.v28i1.2126.

[10] A. S. AL- Aidrus, N. M. Munassar, “Effects of Information and Communication Technology Adoption on University Competitive Advantage via Education Quality: A field Study on Science & Technology and Hadhramout Universities,” Journal of Science and Technology, Vol. 29, No. 2, PP. 14-22, 2024, https://doi.org/10.20428/jst.v29i2.2417.

[11] A.M. Ghaleb, M. A. Amrani, R. A. M. Al Selwi, H. A. Hebah, M. A. Saeed, S. Mejjaouli, ‘‘Socioeconomic Status as a Predictor of the Academic Achievement of Engineering Students in Taiz State, Yemen,” Societies, Vol. 14, PP. 1-20, 2024, doi: 10.3390/soc14120246.

[12] A. H. Al-Zaghruri, M. A. Saeed, M. A. Amrani, ‘‘The Impact of Social Media on the Educational Attainment of Engineering Students under Conflict and Siege Conditions at Taiz City, Yemen,” Al-Saeed University Journal of Applied Sciences, Vol. 7, No. 1, PP. 45-70, 2024. https://journal.alsaeeduni.edu.ye/index.php/SJAS/article/view/225.

[13] M. A. Amrani, B. Al-Tayar, M. A. Saeed, A. M. Ghaleb, H. A. Hebah, H. Abd Al-nour, ‘‘Barriers to the effective use of technology in Higher Education institutions in Yemen: Case study of Engineering College,” Albaydha University Journal, Vol. 5, No. 4, PP. 889-901, 2023. DOI: https://doi.org/10.56807/buj.v5i4.494.

[14] N. Almekhlafi, A. Al-Hashedi, A. M. Mohsen, M. T. Ben Othman, “Cloud Computing Awareness among Practitioners in Yemeni Universities: An Exploratory Study,” Journal of Science and Technology, Vol. 23, NO . 1, PP. 1-15, 2018. https://doi.org/10.20428/JST.23.1.1.

[15] H. Abdalnour, L. Abdulkhaliq, A. M. Ghaleb, M. A. Amrani, F. Alduais, ‘‘Challenges to Female Engineers’ Employment in the Conservative and Unstable Society of Taiz State, Yemen: A Survey Study,” Sustainability, Vol. 15, Art. No. 14919, 2023, doi: 10.3390/su152014919.

[16] A.M. Ghaleb, L. Abdulkhaliq, H. Abd Al-nour, M. A. Amrani, H. A. Hebah, S. Mejjaouli, ‘‘Perceptions of Work–Family–Engineering Relationships Among Employed Female Engineers in Yemen: A Survey Study,” Societies, Vol. 15, No. 1, Art. No. 13, 2025, doi: 10.3390/soc15010013.

[17] C. K. Y. Chan, W. Hu, ‘‘Students’ voices on generative AI: Perceptions, benefits, and challenges in higher education,” Int. J. Educational Technology in Higher Education, Vol. 20, No. 1, Art. No. 43, 2023. https://doi.org/10.1186/s41239-023-00411-8.

[18] M. Keith, E. Keiller, C. Windows-Yule, I. Kings, P. Robbins, ‘‘Harnessing GenAI in chemical Engineering: Implementation and evaluation of the large language model ChatGPT v3.5,” Education for Chemical Engineers. Vol. 51, PP. 20-33, 2025, doi: 10.1016/j.ece.2025.01.002.

[19] T. Ma, ‘‘Systematically visualizing ChatGPT used in higher education: Publication trend, disciplinary domains, research themes, adoption and acceptance,” Computers and Education: Artificial Intelligence. Vol. 8, Art. No. 100336, 2025, doi: 10.1016/j.caeai.2024.100336.

[20] M. Haenlein, A. Kaplan, ‘‘A brief history of artificial intelligence: On the past, present, and future of artificial intelligence,” California management review, Vol. 61, No. 4, PP. 5-14, 2019.

[21] A. Toosi, A. G. Bottino, B, Saboury, E. Siegel, A. Rahmim, ‘‘A brief history of AI: how to prevent another winter (a critical review),” PET clinics, Vol. 16, No. 4, PP. 449-469, 2021.

[22] M. Urban, F. Děchtěrenko, J. Lukavský, V. Hrabalová, F. Svacha, C. Brom, K. Urban, ‘‘ChatGPT improves creative problem-solving performance in university students: An experimental study,” Computers and Education, Vol. 215, Art. No. 105031, 2024, doi: 0.1016/j.compedu.2024.105031.

[23] S. IS, A. DR, ‘‘Advancements in AI-Powered NLP Models: A Critical Analysis of ChatGPT and DeepSeek.” 2025, Available at SSRN 5125445. https://ssrn.com/abstract=5125445.

[24] F. Neha, D. Bhati, ‘‘A Survey of DeepSeek Models,” Authorea Preprints, 2025, doi: 10.36227/techrxiv.173896582.25938392.

[25] L. Chen, P. Chen, Z. Lin, ‘‘Artificial Intelligence in Education: A Review,” IEEE Access, Vol. 8, PP. 75264-75278, 2020. doi: 10.1109/ACCESS.2020.2988510.

[26] Y. Al-Hammadi A. K. Alhazmi, “Towards Effective AI Adoption in Higher Education: A Comprehensive Conceptual Model,” Vol. 30, No. 3, PP. 24-36, 2025, Journal of Science and Technology, https://doi.org/10.20428/jst.v30i3.2758.

[27] S. M. Alrashdi, A. Zeki, “Analyzing the Factors that Influence Enhancing Student Performance in Oman using Data Mining,” Journal of Science and Technology, Vol. 27, No. 1, PP. 1-14, 2022, https://doi.org/10.20428/jst.v27i1.1981.

[28] R. Baskara, (2024). ‘‘From AI to we: Harnessing generative AI tools to cultivate collaborative learning ecosystems in universities,” In Proc. Int. Conf. on Learning Community (ICLC), Vol. 1, No. 1, PP. 676-690, 2024. https://jurnal.untirta.ac.id/index.php/iclc/index

[29] D. R. E. Cotton, P. A. Cotton, J. R. Shipway, ‘‘Chatting and cheating: Ensuring academic integrity in the era of ChatGPT,” Innovations in Education and Teaching International, Vol. 61, No. 2, PP. 228–239, 2023, doi: 10.1080/14703297.2023.2190148

[30] Z. N. Khlaif, A. Ayyoub, B. Hamamra, E. Bensalem, M. A. Mitwally, A. Ayyoub, F. Shadid, ‘‘University teachers’ views on the adoption and integration of generative AI tools for student assessment in higher education,” Education Sciences, Vol. 14, No. 10, Art. No. 1090, 2024. https://doi.org/10.3390/educsci14101090.

[31] O. Zawacki-Richter, V. I. Marín, M. Bond, F. Gouverneur, ‘‘Systematic review of research on artificial intelligence applications in higher education – where are the educators? ,” Int. J. Educational Technology in Higher Education. Vol. 16, Art. No. 39, 2019, doi: 10.1186/s41239-019-01710.

[32] L. Guan, Y. Zhang, M. M. Gu, ‘‘Pre-service teachers’ preparedness for AI-integrated education: An investigation from perceptions, capabilities, and teachers’ identity changes,” Computers and Education: Artificial Intelligence, Vol. 8, Art. No. 100341, 2025, doi: 10.1016/j.caeai.2024.100341.

[33] D. Lee, M. Arnold, A. Srivastava, K. Plastow, P. Strelan, F. Ploeckl, D. Lekkas, E. Palmer, ‘‘The impact of GenAI on higher education learning and teaching: A study of educators’ perspectives,” Computers and Education: Artificial Intelligence. Vol. 6, Art. No. 100221, 2024, doi: 10.1016/j.caeai.2024.100221.

[34] E. J. Conrad, K. C. Hall, ‘‘Leveraging generative AI to elevate curriculum design and pedagogy in public health and health promotion,” Pedagogy in Health Promotion, Vol. 10, No. 3, PP. 178-186, 2024. https://doi.org/10.1177/23733799241232641.

[35] A. S. George, ‘‘The potential of generative AI to reform graduate education,” Partners Universal International Research Journal, Vol. 2, No. 4, PP. 36-50, 2023. https://doi.org/10.5281/zenodo.10421475.

[36] A. Fošner, ‘‘University Students’ Attitudes and Perceptions towards AI Tools: Implications for Sustainable Educational Practices,” Sustainability. Vol. 16, Art. No. 8668, 2024, doi: 10.3390/su16198668.

[37] J. V. Garrel, J. Mayer, ‘‘Artificial Intelligence in Studies—Use of ChatGPT and AI-Based Tools Among Students in Germany,” Humanit. Soc. Sci. Commun. Vol. 10, Art. No. 799, 2023. https://doi.org/10.1057/s41599-023-02304-7.

[38] U. J. Nzenwata, B. N. CL, E. O. Ojelabi, O. Oduware, Y. Yisau, A. T. Adeyela, O. A. Osisanya, “A systematic review of generative AI in education,” Journal of Computer Sciences and Applications, Vol. 12, No. 1, PP. 25-30, 2024. DOI:10.12691/jcsa-12-1-4.

[39] Z. Bahroun, C. Anane, V., Ahmed, A. Zacca, “Transforming education: A comprehensive review of generative artificial intelligence in educational settings through bibliometric and content analysis. Sustainability,” Vol. 15, No. 17, Art. No. 12983, 2023. https://doi.org/10.3390/su151712983.

[40] A. Yusuf, N. Pervin, M. Román-González, N. M. Noor, “Generative AI in education and research: A systematic mapping review,” Review of Education, Vol. 12, No. 2, Art. No. e3489, 2024. https://doi.org/10.1002/rev3.3489

SECURING FINTECH AND DIGITAL PAYMENTS: IDENTIFYING THREATS, MITIGATING VULNERABILITIES, AND STRENGTHENING DEFENSES

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Securing FinTech and Digital Payments: Identifying Threats, Mitigating Vulnerabilities, and Strengthening Defenses

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Abstract— Financial technology (FinTech) encompasses a broad range of digital solutions designed to enhance financial services through automation and accessibility. By integrating technology into banking, lending, insurance, and investments, FinTech companies streamline transactions and improve user experiences. In addition to traditional banking services, FinTech provides corporate solutions such as digital payment gateways, point-of-sale (POS) systems, and automated accounting tools. However, the rapid expansion of digital payments has also introduced significant security challenges, including identity theft, fraud, and regulatory compliance. Cybercriminals exploit vulnerabilities in online transactions, leading to financial losses and reputational damage. This study explores security risks in FinTech and the role of advanced technologies in mitigating these threats. Artificial Intelligence (AI) and Machine Learning (ML) enhance fraud detection by analyzing transaction patterns and automating real-time threat responses. Quantum cryptography and the Zero-Trust Security Model offer additional layers of security, ensuring data integrity and preventing unauthorized access. A four-layer security assessment model comprising data collection, preprocessing, presentation, and result analysis was developed to evaluate security measures. Survey findings indicate significant demographic insights into FinTech adoption. Strengthening security protocols and adhering to regulatory standards are essential for ensuring secure financial transactions and fostering trust in digital payments.

Keywords— Fintech, Security, Vulnerability, Artificial Intelligence, Technology, Digital Payment, Threat.

I. Introduction

The term financial technology, popularly known as FinTech, is a wide range of software, mobile apps, and other digital solutions intended to improve, simplify, and automate financial services for both individuals and enterprises [1]. By incorporating technology into services that banks, payment companies, and other financial organizations have historically provided, it includes a broad range of innovations that revolutionize the financial sector. FinTech solutions make banking, lending, insurance, and investing more accessible, facilitate more effective transactions, and improve customer experiences. FinTech companies offer corporate solutions in addition to traditional banking, such as digital payment gateways, point-of-sale (POS) systems, and business banking [2]. FinTech also offers automation and increased efficiency in fields like accounting, taxation, and inventory management that were previously unrelated to financial services. Also, tech firms that create payment processing, APIs, and interfaces. FinTech also offers automation and increased efficiency in fields like accounting, taxation, and inventory management that were previously unrelated to financial services. Also, the FinTech ecosystem includes tech firms that create payment processing solutions, APIs, and interfaces to improve the operations of the financial sector without having direct contact with end users. Financial institutions are always faced with security challenges, and to bridge this gap there is a need for strong security protocols to aid in shielding people and companies from online dangers, including identity theft, phishing, and hacking. Secure authentication techniques and encryption protect private financial information against breaches and unwanted access [3]. Users' confidence is increased by secure transactions, which motivates them to adopt digital payments and online banking. To protect customer data and stay out of trouble, financial institutions must abide by security regulations and standards (such as PCI DSS and GDPR). Security measures guarantee accuracy and dependability by preventing unauthorized changes to financial documents. By reducing the likelihood of fraud, chargebacks, and operational interruptions, a secure system safeguards both businesses and customers. Secure systems guarantee seamless and effective financial operations by preventing delays brought on by problems with fraud detection.

II. Background And Literature Review

A. Threat to FinTech and Digital Payment

Fintech and digital payments have revolutionized financial transactions, yet they face numerous threats. Because hackers target payment systems, there is a significant risk of cybersecurity breaches and financial theft. Another concern is regulatory obstacles, as governments impose strict compliance standards that could impede innovation [4]. Identity theft and fraud are on the rise, and criminals are taking advantage of lax authentication procedures.

Technological flaws, including software defects and infrastructure breakdowns that can halt transactions, pose a hazard as well. Smaller FinTech startups may be stifled by market competition and monopolization by larger companies, which would reduce industry variety. Furthermore, consumers who lack financial literacy are more vulnerable to phishing and scams.

Financial uncertainty is also a result of the sector's exposure to global economic instability and volatile digital currency valuations. The future of FinTech and digital

payments depends on strong security measures, flexible regulations, and ongoing technical development to reduce these dangers.

B. Key Components of FinTech and Digital Payments

The FinTech and digital payments ecosystem consists of three key players: **banks, FinTech companies, and regulators**. Banks continue to play a key role in financial services by offering payment processing, traditional banking infrastructure, and frameworks for regulatory compliance. By creating their own digital services or collaborating with FinTech companies, numerous banks are adjusting to the digital revolution [5]. They provide regulatory experience, security, and customer trust, but they frequently lack the agility of tech-driven startups. FinTech businesses propel advancements in blockchain technology, financing, investments, and payments. These businesses, which include PayPal, Stripe, and Square, use cutting-edge technologies like blockchain and artificial intelligence to provide smooth financial services. To make financial services more accessible, startups in this field frequently place a high priority on user experience, inexpensive transactions, and accessibility.

Consumer protection, stability, and compliance are guaranteed by regulators, such as central banks and financial authorities [6]. Regulations for digital transactions, data security, and anti-money laundering (AML) compliance are established by agencies such as the Financial Conduct Authority (FCA), the U.S. Securities and Exchange Commission (SEC), and the Central Bank of Nigeria. While regulations safeguard consumers, they can also create challenges for innovation due to complex compliance requirements.

Collaboration between these players is essential for a secure, efficient, and inclusive financial ecosystem. Banks, FinTech firms, and regulators must work together to balance innovation with security and regulatory oversight.

C. Threat Landscape in FinTech and Digital Payments

As technology evolves, the danger landscape in FinTech and digital payments keeps changing. With hackers using ransomware, phishing, and data breaches to target payment platforms, cybersecurity threats are still a big worry [7]. Users who have weak authentication mechanisms are more susceptible to identity theft and fraud. Risks related to regulations and compliance present additional difficulties. Governments and financial watchdogs enforce strict regulations, like data privacy and anti-money laundering (AML) rules, which can be expensive and difficult for

FinTech companies to comply with [8]. Heavy fines and harm to one's reputation may result from noncompliance. Another risk is technological vulnerabilities, including software bugs, infrastructure failures, and system downtimes that can disrupt transactions. Over-reliance on cloud computing and third-party providers increases the risk of service outages and data leaks.

Financial fraud, such as chargeback fraud and synthetic identity fraud, is on the rise. Criminals exploit digital payment systems to launder money and evade detection.

Market risks also affect FinTech, including economic downturns, fluctuations in cryptocurrency values, and competition from tech giants. Furthermore, a lack of user awareness makes individuals susceptible to scams.

To mitigate these threats, businesses must invest in strong security measures, AI-driven fraud detection, regulatory compliance, and consumer education to ensure a safer financial ecosystem. Below are some of the threats to online payments.

1. *Cyber Threats:* Cyber threats in FinTech and digital payments are a growing concern as cybercriminals develop more sophisticated attack methods. Phishing attacks remain one of the most common threats, where hackers trick users into revealing sensitive information such as login credentials or payment details through fake emails and websites. Ransomware attacks are another major risk, where cybercriminals encrypt financial data and demand payment for its release [9]. These attacks can cripple payment processors, banks, and FinTech platforms, leading to financial losses and reputational damage.Data breaches pose a serious threat, exposing customer information such as credit card details, personal identification, and transaction history. This stolen data is often sold on the dark web, leading to identity theft and financial fraud. Man-in-the-middle (MITM) attacks occur when hackers intercept and manipulate transactions between users and payment systems, allowing them to steal funds or alter transaction details. Furthermore, malware and trojans infect users' devices to capture keystrokes and access financial accounts. As digital payments become more prevalent, API vulnerabilities in payment gateways and banking apps can also be exploited. To combat these threats, FinTech companies must implement multi-factor authentication, encryption, AI-driven fraud detection, and continuous security monitoring to safeguard financial transactions.
2. *Fraud and Financial Crimes:* Fraud and financial crimes pose significant risks to FinTech and digital payment systems, leading to substantial financial losses and reputational damage. Criminals exploit vulnerabilities in online transactions, digital wallets, and banking apps through various fraudulent schemes [10]. One common type is identity theft, where fraudsters steal personal information to open accounts, apply for loans, or conduct unauthorized transactions. Account takeover fraud (ATO) occurs when cybercriminals gain access to a user's financial account and manipulate transactions. Synthetic identity fraud is another rising threat, where criminals combine real and fake personal details to create fraudulent identities and obtain credit [11]. Payment fraud, including chargeback fraud and card-not-present (CNP) fraud, is widespread in e-commerce and digital payments. Fraudsters use stolen credit card details for unauthorized purchases, leading to financial losses for businesses. Another major financial crime involves the funneling of illegal funds through digital transactions to conceal their origins, known as money laundering. To combat fraud, FinTech companies must implement AI-driven fraud detection, biometric

authentication, and transaction monitoring. Regulatory compliance with anti-money laundering (AML) laws and Know Your Customer (KYC) policies is also essential to protect users and ensure the integrity of digital payment ecosystems.

3. *Inside Threats:* Insider threats pose a significant risk to FinTech and digital payment systems, as employees, contractors, or business partners with access to sensitive financial data can intentionally or unintentionally compromise security. These threats are particularly dangerous because insiders often bypass traditional security measures. One type is malicious insiders, where employees or partners intentionally misuse their access to steal funds, leak confidential data, or manipulate transactions for personal gain. Unhappy employees may engage in sabotage, while others may sell user data to cybercriminals. Negligent insiders pose another risk, often due to human error. Employees may fall for phishing scams, misconfigure security settings, or mishandle sensitive data, unintentionally exposing financial systems to breaches. Furthermore, third-party risks arise when vendors or contractors with access to payment systems fail to follow security best practices, making them weak links in cybersecurity. To mitigate insider threats, companies should implement role-based access controls (RBAC), multi-factor authentication (MFA), behavioral monitoring, and strict data access policies [12]. Regular employee training and conducting background checks on staff with privileged access can also help prevent insider-related fraud and security breaches.

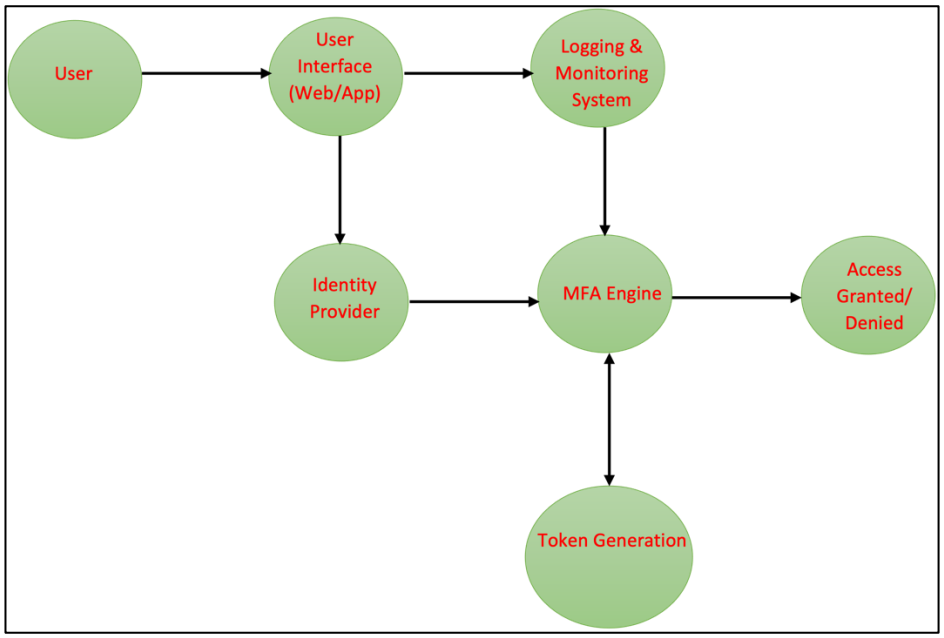

Fig. 1. Multi-factor Authentication

Encryption plays a vital role in securing digital transactions and protecting sensitive financial data from cyber threats. By implementing strong encryption protocols, FinTech companies and payment service providers ensure that user credentials, payment details, and transaction information remain confidential and protected from unauthorized access.

End-to-end encryption (E2EE) is a widely used security mechanism that ensures data remains encrypted from the sender to the receiver, preventing interception by third parties. This safeguard is particularly crucial in digital payments, where sensitive information such as credit card numbers and banking credentials must be protected from eavesdropping and data breaches. Secure communication channels, including TLS (Transport Layer Security), further enhance security by encrypting data in transit.

Tokenization is another critical security method that replaces sensitive data with randomly generated tokens. Unlike encryption, where data is transformed into ciphertext and can be decrypted, tokenization completely replaces the original information, making it useless to attackers. Cryptographic methods such as hashing, asymmetric encryption, and digital signatures further enhance security by ensuring data integrity and verifying transaction authenticity.

By integrating these encryption and cryptographic techniques, FinTech firms can prevent data breaches, mitigate fraud, and ensure secure communication across digital payment systems.

D. Social Engineering and Attacks

Social engineering is not about sophisticated technical hacking; it manipulates human behavior to breach security [13]. As technology advances, the complexity of technical cyberattacks increases, making them harder to execute. However, social engineering remains highly effective, using deception to exploit human vulnerabilities and bypassing even the most advanced security systems. Attackers leveraging this tactic can infiltrate networks, bypass firewalls, implant malware, or establish backdoor access. The key to social engineering lies in exploiting cognitive biases and human error, rather than technical flaws, to obtain sensitive information or access. Social engineering is defined as one of

the simplest ways to gather information about a target by exploiting human weaknesses present in every organization. Attackers use this technique to manipulate individuals into revealing confidential information, which is then used to compromise the organization's security [14]. This type of attack makes human vulnerability a critical weak point in cybersecurity.

While social engineering is often considered low-tech, it is highly successful because it preys on the psychological flaws of individuals. Security technologies may strengthen system defenses, but human factors remain the most exploitable link. In essence, attackers use social engineering to circumvent security measures by deceiving human insiders, making it a powerful tool in modern cyberattacks.

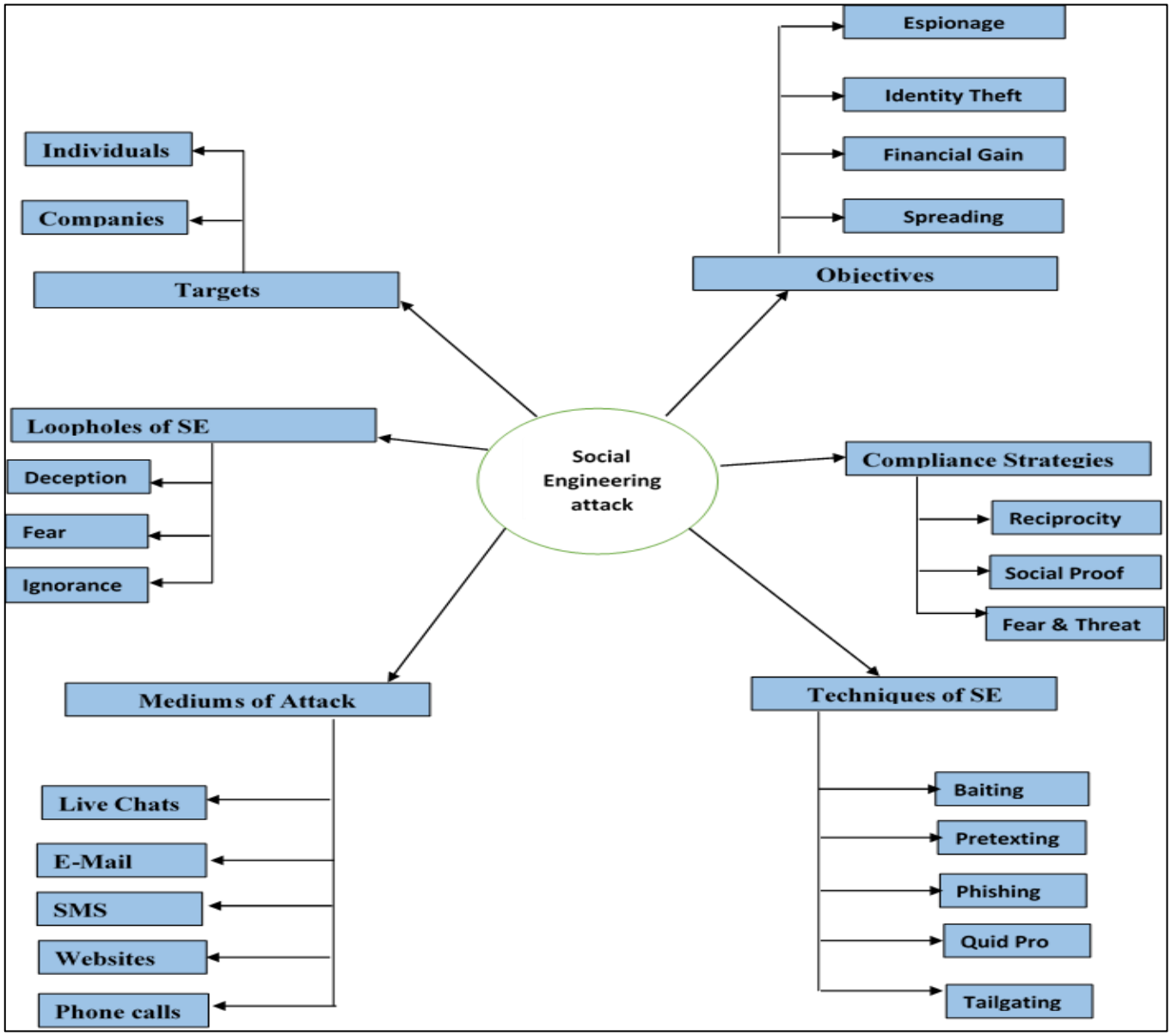

Fig. 2. Social Engineering [13]

E. Regulatory Compliance & Standards in FinTech and Digital Payments

Regulatory compliance is essential for ensuring security, transparency, and trust in FinTech and digital payment ecosystems. Governments and financial authorities impose strict regulations to prevent fraud, money laundering, and data breaches while ensuring consumer protection [15].

Globally, compliance frameworks such as AML (Anti-Money Laundering), KYC (Know Your Customer), GDPR (General Data Protection Regulation), and PCI-DSS (Payment Card Industry Data Security Standard) set guidelines for identity verification, data privacy, and secure transactions. The Financial Action Task Force (FATF) also provides international standards for combating financial crimes.

In Nigeria, regulatory bodies like the Central Bank of Nigeria (CBN), the Nigeria Financial Intelligence Unit (NFIU), and the Securities and Exchange Commission (SEC) oversee FinTech operations. CBN's Regulatory Framework for Open Banking promotes data security, while its AML/CFT (Anti-Money Laundering and Counter Financing of Terrorism) guidelines help combat financial fraud. The National Information Technology Development Agency (NITDA) enforces data protection laws similar to GDPR.

FinTech firms must comply with these regulations by implementing strong identity verification measures, secure transaction protocols, and regular compliance audits [16]. Adherence to these standards not only ensures legal operations but also enhances user trust and financial system stability in Nigeria and beyond.

F. Digital Currency

Digital Currency is a new concept popularized with the rapid rise of the Internet. CBDC (Central Bank Digital Currency) define Digital Currency as a form of a country's fiat currency. Instead of printing paper currency or minting coins, the central bank issues electronic tokens. Digital currency can also be referred to as virtual currency, a currency used in a virtual world that can indirectly hold value in real life [17]. Meanwhile, the introduction of digital currency produces various associated challenges in regulation, tracking of funding and taxing, purchasing by individuals, etc.

Typical example of digital currency is Crypto currency. By definition, Crypto currency is the name given to a system that uses cryptography to allow the secure transfer and exchange of digital tokens in a distributed and decentralized manner [18]. According to Ametrano, (2014), it is a currency that can be transferred instantly between any two parties, using the Internet infrastructure and cryptographic security with no need for a trusted third party. Its value is not backed by any single government or organization. Crypto currency uses distributed ledger, or blockchain, technology to enable a secure transaction [19].

It is a peer-to-peer system that can enable anyone anywhere to send and receive payments. Instead of carrying physical money around and exchanged in the real world, crypto currency payments exist purely as digital entries to an online database describing specific transactions. When you transfer crypto currency funds, the transactions are recorded in a public ledger [20]. From the definitions above, crypto currency can simply be described as a digital currency that uses cryptography for secure financial transactions, it operates a decentralized, secured system without a central authority, such as a government or bank.

The main idea behind crypto currencies is to provide a fast way to transfer funds globally, with minimal transaction costs and a certain amount of privacy in which the sender and receiver are always anonymous while being independent of a third party to handle the transactions. Transactions made with Bitcoin is irreversible; this way, the recipient of the funds is sure they own them for good. Therefore, less trust is needed to ensure the other party is reliable.

G. FinTech and Digital Payments

FinTech and digital payments in Nigeria have transformed nearly all aspects of financial transactions through mobile wallets, digital banks, and cryptocurrency platforms. Here is a brief overview of some of these technologies.

1. *Opay:* Founded in 2018, OPay is a leading fintech platform in Nigeria, offering mobile payments, money transfers, bill payments, and loans. Its app provides a seamless way for users to send money, pay for utilities, and shop online. OPay also supports businesses with merchant payment solutions, helping to streamline transactions. With a growing user base, it plays a significant role in promoting cashless payments and financial inclusion across Nigeria. Also, OPay has expanded its services to include savings by introducing Owallet.
2. *fintech:* The fintech, introduced by the Central Bank of Nigeria (CBN) in 2021, is a blockchain-based digital currency designed to complement the physical Naira. It is centrally controlled, backed by the Naira (1:1), and requires an fintech wallet for transactions. The currency enables instant, low-cost transactions across mobile devices, web browsers, and POS terminals. fintech aims to enhance financial inclusion, reduce cash management costs, boost tax revenue collection, and support economic growth through a secure, efficient digital payment system. Unlike cryptocurrencies, which are decentralized and volatile, fintech is stable and regulated by the CBN.Despite banning cryptocurrency transactions in 2021 due to concerns about financial fraud, the CBN acknowledges that crypto and fintech can coexist—fintech for everyday transactions and crypto for cross-border payments and remittances. The fintech wallet functions like a bank account but operates separately, providing Nigerians with a safe, digital alternative for financial transactions.

Fig. 3. Objectives of the fintech

3. *Flutterwave:* Flutterwave, founded in 2016 by a team of Nigerian entrepreneurs and technologists, is a financial technology company that provides digital payment infrastructure for businesses and individuals across Africa. The company was established to address the fragmented and often unreliable payment systems on the continent and to make financial transactions simpler, faster, and more secure. Since its inception, Flutterwave has become one of Africa's leading payment service providers. The platform enables merchants to accept payments

in over 150 currencies through various channels, such as debit and credit cards, bank transfers, mobile money, and USSD. This wide range of payment options helps businesses reach more customers, both locally and globally. Flutterwave supports seamless integration with international payment systems, which simplifies cross-border transactions and opens up African markets to global trade. According to [21], platforms like Flutterwave have played a significant role in improving financial accessibility and infrastructure in emerging markets. In addition to core payment processing, Flutterwave offers tailored products for different user needs. One such service is Barter, a digital wallet that allows individuals to send and receive money, create virtual dollar cards, and pay for services such as subscriptions and online shopping. Another product, Flutterwave Store, helps small and medium-sized businesses create online storefronts without the need for coding or extensive technical knowledge. This feature became particularly popular during the COVID-19 pandemic when many physical businesses shifted to online platforms. Flutterwave also provides a robust and developer-friendly API that enables software developers to embed secure and reliable payment solutions directly into web and mobile applications. This flexibility makes it easy for businesses of all sizes to integrate financial services without building them from scratch. By offering these services, Flutterwave contributes to increasing financial inclusion in Africa, where many people and businesses remain underserved by traditional banking systems. The platform reduces the barriers to entry for entrepreneurs and small businesses, enabling them to participate more actively in the digital economy. Furthermore, by facilitating easier access to global payment networks, Flutterwave helps African businesses scale beyond local markets.

4. *Apple Pay:* Apple Pay is a mobile payment and digital wallet service developed by Apple. Launched in 2014, it enables users to make secure, contactless payments using iPhones, iPads, Apple Watches, and Macs. It works with NFC technology, allowing payments at retail stores, apps, and websites. Apple Pay integrates with bank cards and supports tokenization, ensuring secure transactions without sharing card details. It is widely accepted globally and offers features like peer-to-peer payments via Apple Cash. With built-in encryption and Face ID or Touch ID authentication, Apple Pay provides a fast, secure, and convenient way to make digital payments worldwide.
5. *Stablecoins:*Stablecoins are a type of cryptocurrency designed to maintain a stable value by pegging their price to a reserve asset like fiat currency, commodities, or a basket of assets. Unlike traditional cryptocurrencies, which are highly volatile, stablecoins offer price stability, making them useful for payments, remittances, and store of value. There are three main types of stablecoins: Fiat-backed (e.g., USDT, USDC), Crypto-backed (e.g., DAI), and Algorithmic stablecoins, which use smart contracts to regulate supply. Stablecoins play a crucial role in decentralized finance (DeFi) by enabling seamless trading, lending, and cross-border transactions while reducing exposure to market fluctuations.
6. *Chipper Cash:* Chipper Cash is a fintech company that facilitates cross-border payments and remittances across Africa. Founded in 2018, it enables individuals and businesses to send and receive money instantly across multiple countries with low fees. The platform supports mobile wallets, bank transfers, and card payments, making digital transactions more accessible. Chipper Cash also offers virtual cards for online payments, cryptocurrency trading, and business payment solutions. It provides a fast, secure, and cost-effective alternative to traditional banking, promoting financial inclusion across the continent. With millions of users, the platform is transforming the way Africans handle money, making seamless cross-border transactions a reality for individuals and businesses alike.

H. Vulnerabilities in FinTech and Digital Payment Systems

FinTech and digital payment systems face multiple security challenges. Weak authentication mechanisms make accounts susceptible to unauthorized access. Poorly secured API integrations expose sensitive financial data to cyber threats. Data breaches and leakage risks remain significant concerns, potentially leading to financial losses and identity theft [22]. Regulatory compliance gaps create loopholes that cybercriminals can exploit, especially when financial institutions fail to meet evolving security standards. Insider threats pose another risk, as employees with access to sensitive information may misuse it for personal gain or inadvertently compromise security. To mitigate these risks, strong authentication protocols, robust API security measures, and stringent regulatory adherence are essential [23]. Financial institutions must also implement continuous monitoring and employee training to detect and prevent insider threats. Strengthening cybersecurity frameworks in FinTech and digital payment systems is crucial to ensuring data integrity, user trust, and the long-term stability of financial transactions.

I. Security Technologies and Best Practices

1. *Authentication & Authorization:* Implementing Multi-Factor Authentication (MFA) enhances security by requiring multiple verification factors. Biometric security, such as fingerprint or facial recognition, provides an additional layer of protection [3]. Passwordless authentication, using cryptographic keys or biometric data, reduces reliance on traditional passwords, minimizing phishing risks.
2. *Data Protection:* End-to-end encryption (E2EE) ensures data remains protected during transmission,

preventing unauthorized interception. Tokenization replaces sensitive data with unique tokens, reducing exposure to breaches. Secure cloud storage, combined with database encryption, safeguards information against unauthorized access. Enforcing strong access controls and real-time monitoring further enhances security. By integrating these technologies and best practices, organizations can strengthen cybersecurity defenses, mitigate risks, and protect user data from evolving threats.

3. *Fraud Prevention:* One key factor of cybersecurity is fraud prevention, especially in industries like banking, e-commerce, and finance where fraudulent activity can result in large financial losses as well as harm to an organization's reputation [24]. By spotting patterns and irregularities that point to questionable activity, artificial intelligence (AI) and machine learning (ML) have emerged as crucial instruments in the fight against fraud in recent years.

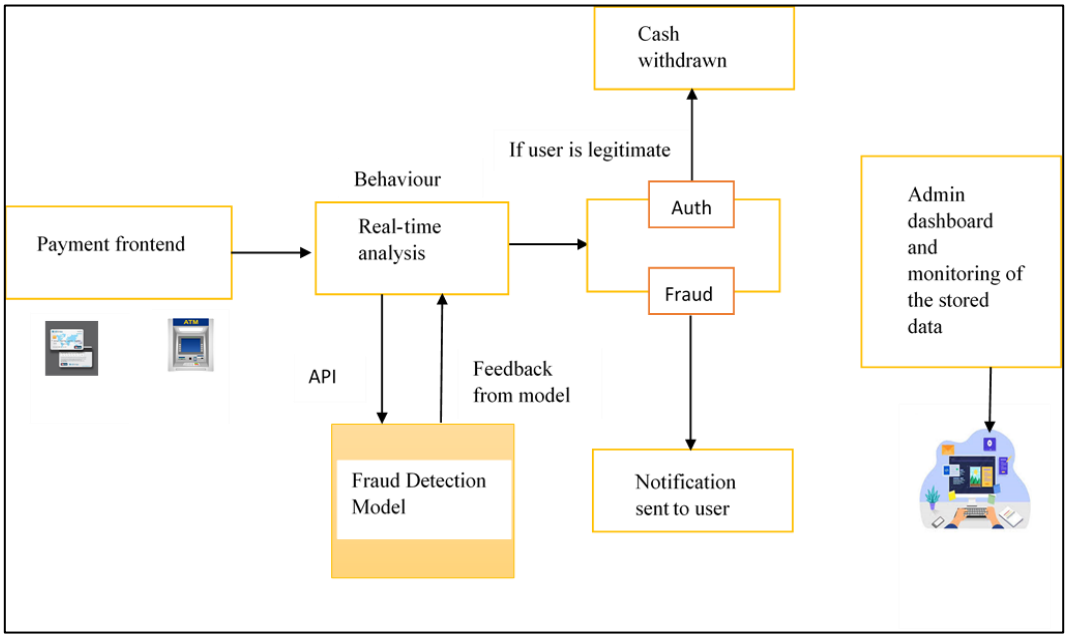

Fig. 4. Fraud Detection Model [24]

J. Future Trends and Innovations in FinTech Security

The financial technology sector is rapidly evolving, integrating advanced security measures to combat cyber threats. Artificial Intelligence (AI) and Machine Learning (ML) play a crucial role in detecting fraudulent activities, analyzing transaction patterns, and automating threat responses in real-time [25].

Quantum cryptography is emerging as a next-generation security solution, offering ultra-secure encryption for financial transactions, making it nearly impossible for cybercriminals to decrypt sensitive data. The Zero-Trust Security Model is transforming digital banking by enforcing strict identity verification at every access point, reducing the risk of unauthorized access and insider threats [26].

Decentralized identity verification leverages blockchain technology to give users control over their digital identities, minimizing data breaches and identity theft. As cyber threats evolve, these innovations will redefine FinTech security, ensuring safer financial transactions, stronger authentication, and enhanced data protection across digital payment platforms.

K. Some Security bridges in FinTech and Digital Payments

1. *Flutterwave Security Breaches:* Flutterwave, one of Nigeria's leading fintech companies, has suffered multiple security breaches, raising concerns about its cybersecurity framework. In February 2023, the company reported an unauthorized transfer of ₦2.9 billion from its accounts. Hackers exploited vulnerabilities in Flutterwave's system, moving funds into various bank accounts. The incident triggered an investigation, leading to the freezing of several accounts suspected to have received the stolen funds. In April 2024, Flutterwave experienced an even larger breach. This time, ₦11 billion was illicitly transferred across multiple accounts. The attackers strategically moved the money in small amounts, making it harder for fraud detection systems to flag the transactions immediately. Reports suggest that the breach may have involved insider collaboration or sophisticated hacking techniques that bypassed Flutterwave's security protocols. Following these breaches, concerns about weak internal controls, fraud monitoring gaps, and regulatory compliance have grown. Critics argue that the repeated attacks indicate systemic security flaws that could expose customer funds to future risks. Regulators and financial institutions have urged Flutterwave to enhance its cybersecurity measures, while customers remain wary of potential vulnerabilities in Nigeria's rapidly expanding fintech ecosystem.
2. *Hope Payment Service Bank Incident:* In October 2024, Hope Payment Service Bank, a digital-first financial institution in Nigeria, suffered a massive

security breach, resulting in the unauthorized transfer of ₦10 billion. Cybercriminals orchestrated a sophisticated attack, exploiting vulnerabilities in the bank's system to siphon funds into multiple accounts. The scale of the fraud quickly drew the attention of financial regulators and law enforcement agencies. Following an investigation, the Federal High Court ordered the freezing of 818 accounts suspected of receiving and distributing the stolen funds. The move aimed to prevent further withdrawals and trace the masterminds behind the cyber heist. While details of the attack remain unclear, cybersecurity analysts suspect that the breach involved a mix of social engineering, insider threats, and weaknesses in transaction monitoring systems. The incident has intensified discussions around Nigeria's fintech security landscape, emphasizing the need for stricter regulatory oversight, stronger fraud detection mechanisms, and enhanced cybersecurity frameworks to prevent future breaches.

III. METHODOLOGY

The architecture of the proposed security assessment model is in four layers. They are Data Collection layer, Data Preprocessing Layer, Data Presentation and Result layer. The layers are further explained below:

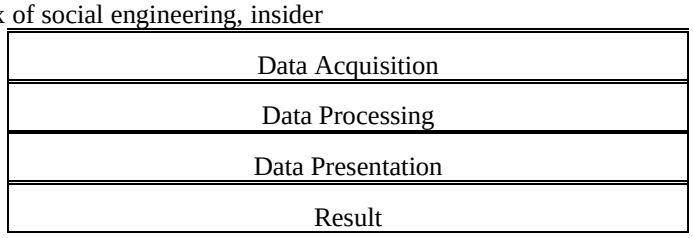

Fig. 5. Architectural Model

Data Collection: Data Collection is the data gathered from survey respondents and Google sources.
Data Preprocessing: This step involves preparing the collected data for analysis using the assessment model. Once the data is collected, it undergoes pre-processing through a data normalization module. This process handles data that may include large values, small values, and different data types.
Data Presentation: In this step, the analyzed data is presented in a tabular format to facilitate decision-making.
Result: At this stage, the presented results are utilized by the security model to make informed decisions. The detected outcomes also contribute to updating the knowledge of the fintech and digital payment software developers, enabling them to enhance security measures and be more security-conscious.

A. Demographic Information

Table 1 shows the Bio-data information of respondents, Sex of Respondent.

Table 1: Bio-data information based on Gender Respondent

Variable	Respondents	Percentage (%)
Male	65	81.25
Female	20	18.75
Total	85	100

The information shows that 65 of the respondents representing 81.25% were male, while 20 respondents representing 18.75%, were female. This implies that males are more in number than females. Table 2 depicts the marital status of respondents. The table indicated that 25 respondents representing 29.41% are married, 50 respondents representing 58.82% are Single, while 10 respondents representing 11.77% are divorced. This indicated that those that are Single are more in number.

Table 2: Marital Status of Respondent

Variable	Respondents	Percentage (%)
Married	25	29.41
Single	50	58.82
Divorced	10	11.77
Total	85	100

Table 3 show that 27 respondents representing 31.73% are between the ages of 15-24 years, 25 respondents representing 29.41% are between the ages of 25-34 years, 20 respondents representing 23.52% are between the ages of 35-44 years while 13 respondents representing 15.29% are ages of 45 and above years.

Table 3: Age Range of Respondents

Variable	Respondents	Percentage (%)
15-24years	27	31.73
25-34years	25	29.41
35-44	20	23.52
45 and Above	13	15.29
Total	85	100

Table 4 represent information on educational qualification of respondents.

Table 4: Educational Qualification of Respondents

Variable	Respondents	Percentage (%)
FLSC	13	15.29
WAEC/GCE	17	20
HND/BSc	25	29.42
Master Degree	20	23.53
Others	10	11.76
Total	85	100

The table shows that 13 respondents representing 15.29% are FLSC Holders , 17 respondents representing 20% are WACE/GCE Holders , 25 respondents representing 29.42%

are HND/BSc Holders,20 respondents representing 23.53% are Master's Degree Holders,10 respondents representing 11.76% are other Degree Holders . This shows that those with HND/BSc. Holders have the highest percentage of respondents in the labour market.

Table 5: Religion of Respondent

Variable	Respondents	Percentage (%)
Christian	46	54.1
Moslem	25	29.4
Pagan	14	16.5
Total	85	100

The above table 5 shows that 46 respondents representing 54.1% are Christian, 25 respondents representing 29.4% are Moslem, 14 respondents representing 16.5% are Pagan. This indicated that Christians are more in the target audience.

B. Analysis of Responses to the Research Questions

Table 6 (question 1): Is fraud prevention lectures given in the school and market places?

Variable	Respondents	Percentage (%)
Yes	68	80
No	15	17.65
I don't know	2	2.3
Total	85	100

The above table 6 show that 68 respondents representing 80% say Yes Fraud Prevention lectures is given in the school 15 respondents representing 17.65% says No, 2 respondents representing 2.3% says I don't know. This indicated that fraud prevention often lecture fraud prevention lectures in the school.

Table 7 (questions 2): Can you make payment with fintech Application?

Variable	Respondents	Percentage (%)
Yes	53	66.25
No	13	12.5
I don't know	19	21.25
Total	85	100

The above table 7 show that 53 respondents representing 66.25% say yes they can make payment with fintech app, 13 respondents representing 12.5% says No, while 19 respondents representing 21.25% say I don't know. This indicated that market women, professionals and student can make payment with fintech Application.

Table 8. (Question 3): Is the level of fraud prevention in the application up to 50%?

Variable	Respondents	Percentage (%)
Yes	70	82.45
No	9	10.58
I don't know	6	7.06
Total	85	100

The above table 8 show that 70 respondents representing 82.45% say yes that the level of safety compliance for fraud prevention are up to 50%, 9 respondents representing 10.58% say No while 6 respondents representing 7.06% say I don't Know that the level of fraud prevention 50%, .This indicated that the level of fraud prevention in the fintech application is up to 50%.

Table 9 (question 4): Are there any OTP mechanism to prevent fraud activities?

Variable	Respondents	Percentage (%)
Yes	62	72.94
No	15	17.65
I don't know	8	9.41
Total	85	100

The above table 9 show that 62 respondents representing 72.94% say yes there is OTP security mechanism while registration is ongoing in the fintech application, 15 respondents representing 17.65% say No there are OTP security mechanism while registration is ongoing in the fintech application, 8 respondents representing 9.41% say I don't know if there OTP security mechanism while registration is ongoing in the fintech application. This indicate that there are OTP security mechanism while registration is ongoing in the fintech application.

Table 10 (question 5): Are there trained ethical hackers working and updating the fintech and digital application?

Variable	Respondents	Percentage (%)
Yes	58	68.24
No	15	17.65
I don't know	12	14.11
Total	85	100

The above table 10 shows that 58 respondents representing 68.24% say yes there are trained ethical hackers, 15 respondents representing 17.65% say No there are no trained ethical hackers, 12 respondents representing 14.11% say I don't know if there are trained ethical hackers. This indicated that there are trained ethical hackers working for the federal government to prevent hackers intrude the fintech application.

Table 11 (Question 6): How would you rate the fraud preventive measures in the fintech application, is it high or low?

Variable	Respondents	Percentage (%)
Yes	66	77.7
No	15	17.5
I don't know	4	4.8
Total	85	100

The above table 11 shows that 66 respondents representing 77.7% say yes the fraud preventive measures in the fintech application is high 15 respondents representing 17.5% say No the fraud preventive measures in the fintech application is not high but low, 4 respondents representing 4.8% says I don't know How would you rate the fraud preventive measures in the fintech application is it high or low. This indicated that the fraud preventive measures in the fintech application is high.

Table 12 (Question 7): Are there frequent update on the app on playstore and app store?

Variable	Respondents	Percentage (%)
Yes	44	52
No	16	18.9
I don't know	25	29.4
Total	85	100

The above table 12 shows that 44 respondents representing 52% say yes. There are frequent upgrade and update on the fintech app on cross-platforms, 16 respondents representing 18.9% say No there are no update on the fintech application while 25 respondents representing 29.4% says I don't know if there are frequent upgrade and update on the application. This indicated there is frequent upgrade and update on the application.

Table 13 (Question 8): Have there ever being technical glitch in the fintech application?

Variable	Respondents	Percentage (%)
Yes	10	12
No	68	80
I don't know	7	8
Total	85	100

The above table 13 show that 10 respondents representing 12% say yes there are technical glitch in the fintech app, 68 respondents representing 80%, say No there have never being while 7 respondents representing 8% says I don't know if there are technical glitch. This indicated that the level technical problems influence the usage of the app.

Table 14 (Question 9): Are no signs visibly displayed in the app when a third party tried to login?

Variable	Respondents	Percentage (%)
Yes	16	18
No	50	59
I don't know	19	23
Total	85	100

The above table 14 show that 16 respondents representing 18% say yes no signs is visibly displayed in the app when a third party login, 50 respondents representing 59% says No, no visibly displayed sign when a third party login while 19 respondents representing 23% says I don't know if signs are visibly displayed when third party login. This indicated that signs are not visibly displayed in the app when third party login.

Table 15 (question 10): Do fintech app allow facial recognition in the authentication process?

Variable	Respondents	Percentage (%)
Yes	9	10.5
No	70	82.4
I don't know	6	7.1
Total	85	100

The table 15 above show that 70 respondents representing 82.4% say no there is facial recognition when login in process, 9 respondents representing 10.5%, say yes there are no facial recognition when registration in progress While 6 respondents represent 7.1% says I don't Know if there is facial recognition in the fintech application. This indicated that there is no facial recognition mechanism or technique when login or registration in progress.

Table 16: Result Model Table

Sample Variable	Level of Education	OPT Mechanism	Frequent Update	Technical Glitch	Level of Fraud Prevention
Yes		Yes	Yes		
No				No	
High	High				High
Low					

The Result Model table reveals the collated and analyzed data of correspondents, highlighting the Fraud Risk Assessment Model used in the fintech application. The analysis of the Result Model indicates a high level of education among the surveyed individuals. Additionally, the fintech application incorporates the OPT mechanism and receives regular updates on both Playstore and Appstore. It is noteworthy that technical glitches are infrequent, and the application implements robust fraud prevention measures.

In order to obtain the expected frequency we divided the total frequencies for each response by the number of rows.
Grand Total = 85
Number of Rows = 3

Expected Frequency (fe) $\frac{85}{3}$= 28.33

fe =28.33
Chi-square formula;
(fo — fe)2/ fe = chi-square
fo Observed Frequency
fe Expected Frequency

Table 17: The calculation of the chi-square is shown in the table below

Variable	Fo	Fe	Fo-fe	$(fo-fe)^2$	$(Fo-fe)^2/fe$
Yes	68	28.33	39.67	1,573.7	**55.55**
No	15	28.33	-13.33	177.69	**6.27**
I don't know	2	28.33	-26.33	693.27	**24.47**
Total	85				**86.29**

Critical value 5.991
Cal. value 86.29
The computed value of the X2 is (86.29). To find the critical value of X2, we used 5% (0.05) as our level of significance.
The degree of freedom is calculated by dfr – 1
Where;
df = Degree of Freedom
r = Number of Rows
c = Number of column
Where
df = (3- 1) (2-1) (2)(1)
(2)
Df = 2

Using the chi-square table to calculate the critical value, we look for two (2) under the df column and 0.05 along the level of significance. From the X2 table, our critical value is 5.991.

Decision
Since the calculated value (86.29) is greater than the critical value (5.991), we therefore reject the alternative hypothesis and accept the null hypothesis (H0) There may be fraud prevention lectures given in the school. IT professionals, students, and market women can make use of fintech application for payment and reception of cash. The above hypothesis was tested with data contains in table 4.7(question 7). In order to obtain the expected frequency we divided the total frequencies for each response by the number of rows.
Grand Total 85
Number of Rows = 3
Expected Frequency (fe) $\frac{85}{3}$= 28.33
fe = 28.33
Chi-square formula;
(fo fe)2
Fe
X2 = chi-square fo = Observed Frequency fe = Expected Frequency
The calculation of the chi-square is shown in the table below:
Critical Value 5.991
Cal Value = 32.84
The computed value of the X2 is (32.84). To find the critical value of X2, we used 5% (0.05) as our level of significance.
The degree of freedom is calculated by
Dfr- 1
Where;
= Degree of Freedom
= Number of Rows Number of column Where
df = (3 - 1) (2-1) (2)(l)
(2)
Df = 2
Using the chi-square table to calculate the critical value, we look for two (2) under the df column and 0.05 along the level of significance. From the X2 table, our critical value is 5.991.

Table 18: The calculation of the chi-square

Variable	Fo	Fe	Fo-fe	$(fo-fe)^2$	$(Fo-fe)^2/fe$
Yes	53	28.33	24.67	608.61	21.48
No	13	28.33	-15.33	235.01	8.3
I don't know	19	28.33	-9.33	87.05	3.07
Total	85				32.84

Decision
Since the calculated value (32.84) is greater than the critical value (5.991), we therefore reject the alternative hypothesis and accept the null hypothesis (H02) which states that professionals, market women and student can operate the fintech application.
Can fraud preventive training test the level of fraud risk assessment in the fintech app. In order to obtain the expected frequency we divided the total frequencies for each response by the number of rows.
Grand Total 85
Number of Rows = 3
Expected Frequency (fe) $\frac{85}{3}$= 28.33
fe = 28.33
Chi-square formula;
(fo - fe)2
fe
X2 chi-square
fo Observed Frequency fe = Expected Frequency
The calculation of the chi-square is shown in the table below:
The computed value of the X2 is (30.58). To find the critical value of X2, we used 5% (0.05) as our level of significance.
The degree of freedom is calculated by
df = r – 1 Where;
df = Degree of Freedom r Number of Rows c=Number of column Where df = (3-l)(2-1)
(2)(1)
(2)
Df = 2
Using the chi-square table to calculate the critical value, we look for two (2) under the df column and 0.05 along the level of significance. From the X2 table, our critical value is 5.991.

Table 19: The calculation of the chi-square

Variable	Fo	Fe	Fo-fe	$(fo-fe)^2$	$(Fo-fe)^2/fe$
Yes	10	28.33	-18.33	335.99	11.86
No	68	28.33	39.67	1,573.7	55.54
I don't know	7	28.33	-21.33	454.97	16.06
Total	85				83.46

Decision

Since the calculated value (83.46) is greater than the critical value (5.99 1), we therefore the reject the alternative hypothesis and accept the null hypothesis (H03) which stated that Can fraud preventive training test the level of fraud risk assessment in the fintech app.

fintech app allows BVN and other personal number verification before transactions can take place?

The above hypothesis was tested with data contains in table 11(question 11). In order to obtain the expected frequency we divided the total frequencies for each response by the number of rows.

Grand Total 85

Number of Rows = 3

Expected Frequency (fe) $\frac{85}{3}$= 28.33

fe = 28.33

Chi-square formula;

(fo -fe)2

fe

chi- square

fo = Observed Frequency

fe = Expected Frequency

The calculation of the chi-square is shown in the table below:

The computed value of the X2 is (83.46). To find the critical value of X2, we used 5% (0.05) as our level of significance.

The degree of freedom is calculated by df = r – 1

Where;

df Degree of Freedom r = Number of Rows c=Number of column Where df = (3-l) (2-1) = 2

(2) (1)

(2}

Df = 2

Using the chi-square table to calculate the critical value, we look for two (2) under the df column and 0.05 along the level of significance. From the X2 table, our critical value is 5.991.

Table 20: The calculation of the chi-square

Variable	Fo	Fe	Fo-fe	$(fo-fe)^2$	(Fo-fe)2/fe
Yes	71	28.33	24.67	608.61	21.48
No	7	28.33	-15.33	235.01	8.3
I don't know	7	28.33	-15.33	235.01	8.3
Total	85				38.08

Decision

Since the calculated value (38.08) is greater than the critical value (5.991), we therefore reject the alternative hypothesis and accept the null hypothesis which stated that fintech app allows BVN and other personal number verification before transactions can take place

Do fintech app has an end-to-end encryption techniques

The above hypothesis was tested with data contains in table 17(question 17)

Do fintech app has an end-to-end encryption techniques?

In order to obtain the expected frequency we divided the total frequencies for each response by the number of rows.

Grand Total 85

Number of Rows 3

Expected Frequency (fe) = $\frac{80}{3}$ = 28.33

fe = 28.33

Chi-square formula;

$\frac{(fo - fe)^2}{fe}$

chi-square

fo Observed Frequency

fe Expected Frequency

The calculation of the chi-square is shown in the table below:

The computed value of the X^2 is (87.19). To find the critical value of X^2, we used 5% (0.05) as our level of significance.

The degree of freedom is calculated by df = r – 1

Where;

df = Degree of Freedom

r = Number of Rows c Number of column

Where

df = (3-l) (2-l) = 2

(2) (l)

(2)

Df = 2

Using the chi-square table to calculate the critical value, we look for two (2) under the df column and 0.05 along the level of significance. From the X^2 table, our critical value is 5.991.

Table 21: The calculation of the chi-square

Variable	Fo	Fe	Fo-fe	$(fo-fe)^2$	$(Fo-fe)^2/fe$
Yes	70	28.33	42.62	1,736.39	61.29
No	7	28.33	-15.33	235.01	8.3
I don't know	6	28.33	-22.33	498.63	17.60
Total	85				87.19

Decision

Since the calculated value (87.19) is greater than the critical value (5.991), we therefore reject the alternative hypothesis and accept the null hypothesis ($H0_5$) which states that fintech app has an end-to-end encryption techniques.

Discussion of Data

Based on the findings revealed from the study, the table 1 showed that 65 of the respondents representing 81.25% were male while 20 respondents representing 18.75% were female. This implies that male are more in number than the female in the selected group of people under study and have the highest percentage of 81.25% respondents.

The table 2 showed that 25 respondents representing 29.41% are married, 50 respondents representing 58.82%are single, while 10 respondents representing 11.77% are divorced. This indicated that those that are Single have the highest percentage of respondents of 58.82% under study in responding to the questionnaire.

The table 3 show that 27 respondents representing 31.73% are between the ages of 15-24 years, 25 respondents representing 29.41% are between the ages of 25-34 years, 20 respondents representing 23.52% are between the ages of 35-44 years while 13 respondents representing 15.29% are ages of 45 and above years. This indicated that those between the ages of 15-24 years are more in number in the survey. The checklist showed a list of fraud and using the fraud assessment matrix, fraudulent activities were ranked based on their likelihood of occurrences and severity.

Table 22: Security Assessment Matrixes

Increasing Likelihood	5	**Happens every day in our Bank**	**5**	**10**	**15**	**20**	**25**	**30**
	4	Happened several times per year in our Bank.	4	8	12	16	20	24
	3	Incident has occurred in our Bank	3	6	9	12	15	18
	2	Heard of incident in the Bank	2	4	6	8	10	12
	1	Never heard of incident in the Bank.	1	2	3	4	5	6
Consequence		Humans	No Effect	Slight trust issue	Minor trust issue	Major trust issue	Fraud	Multiple Fatalities
		App error	No App crash	Slight crash	Minor glitches	Localized error	Major error	Extensive error
	Severity		1	2	3	4	5	6

Table 23: Fraud Rating and Action Priority Key

Fraud level	Action priority
Very high fraud	Immediate action to be completed (required urgently)
High fraud	Action to be completed promptly preferably within 3 months
Medium fraud	Action to be completed, preferably within 6 months (strongly recommended)
Low fraud	Actions to be completed within 12 months (recommended)/No action required.

Table 24: Fraud prevention Performance for awareness campaign

	Authentication	Invasion Risk	Severity	Likelihood	Fraud Rating	% Fraud Rating
1.	Facial recognition	Not Vulnerable	No breach (2)	3	6(M)	20
2.	Password	Not Vulnerable	No breach (2)	4	8(M)	26.7
3.	Email	Not Vulnerable	No breach (2)	3	6(M)	20
4.	Loss of smartphone	vulnerable	Fatality breach (5)	2	10(M)	33.3
5.	Leaked password	Vulnerable	Slight breach(2)	4	8(M)	26.7
6.	No OTP	Vulnerable	Slight effect (2)	3	6(M)	20
7.	Improper display of OTP	Vulnerable	High risk (3)	3	9(M)	30
8.	Frequent Login	Vulnerable	2	5	10(H)	33.3

Total % Fraud rating 210
Average % Fraud rating = 23.3%
Fraud rating = Likelihood x severity
% risk rating x 100
RAM = 6 x 5
Those who are vulnerable
Professionals, Students, Market Women
Numbers employed: Professionals = 30
Student = 500
Market Women = 15
Total 590 persons

IV. Recommendation And Conclusions

To reduce unauthorized access, FinTech firms should implement Multi-Factor Authentication (MFA) using combinations such as device-based verification, biometrics (e.g., fingerprint or facial recognition), and passwordless login options (e.g., magic links or hardware security keys). Biometric systems should include fallback mechanisms and anti-spoofing measures to enhance reliability.

For API security, companies should adopt OAuth 2.0 for secure authorization, enforce TLS encryption for all communication, and deploy real-time traffic monitoring tools such as API gateways with anomaly detection. Additionally, rate limiting and IP whitelisting can help minimize abuse from automated scripts and unauthorized endpoints.

To protect data at rest and in transit, firms must deploy End-to-End Encryption (E2EE) for messaging and transaction data, apply tokenization to sensitive fields (e.g., card numbers), and implement AES-256 encryption for databases. Regular key rotation and access audits should be mandatory.

Adopting a zero-trust security framework involves verifying all access requests regardless of location. Companies should enforce least-privilege access controls, use network segmentation, and implement identity verification for internal users to mitigate insider threats.

AI and Machine Learning models should be trained on large datasets of fraudulent patterns to detect anomalies in transaction behaviour. These systems should support adaptive learning to evolve with emerging fraud techniques and include automated response capabilities (e.g., transaction blocking, and alerts).

For regulators, concrete actions include mandating independent security audits, requiring compliance with global standards such as ISO/IEC 27001, PCI-DSS, and GDPR, and encouraging the use of regulatory sandboxes to test new security technologies. Regulators should also establish incident reporting frameworks and enforce timely disclosure of breaches to affected stakeholders.

By providing these specific technical and policy-based recommendations, the conclusion would more effectively guide both industry players and policymakers in addressing the systemic security risks facing the digital financial ecosystem.

References

[1] Shrier, D. et al., "Global Fintech," *The MIT Press eBooks*, 2022. [Online]. Available: https://doi.org/10.7551/mitpress/13673.001.0001

[2] Allen, F., Gu, X., and Jagtiani, J., "A Survey of Fintech Research and Policy Discussion," *Review of Corporate Finance*, vol. 1, no. 3–4, pp. 259–339, 2021. [Online]. Available: https://doi.org/10.1561/114.00000007

[3] Dwivedi, Y. K. et al., "Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy," *International Journal of Information Management*, vol. 66, p. 102542, 2022. [Online].

Available: https://doi.org/10.1016/j.ijinfomgt.2022.102542
[4] Gill, I. S., Packard, T. G., and Yermo, J., "Keeping the promise of social security in Latin America," *The World Bank eBooks*, 2004. [Online]. Available: https://doi.org/10.1596/0-8213-5817-0
[5] Warner, K. S. and Wäger, M., "Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal," *Long Range Planning*, vol. 52, no. 3, pp. 326–349, 2018. [Online]. Available: https://doi.org/10.1016/j.lrp.2018.12.001
[6] Böhme, R., Christin, N., Edelman, B., and Moore, T., "Bitcoin: Economics, Technology, and Governance," *The Journal of Economic Perspectives*, vol. 29, no. 2, pp. 213–238, 2015. [Online]. Available: https://doi.org/10.1257/jep.29.2.213
[7] Yaacoub, J. A. et al., "Cyber-physical systems security: Limitations, issues and future trends," *Microprocessors and Microsystems*, vol. 77, p. 103201, 2020. [Online]. Available: https://doi.org/10.1016/j.micpro.2020.103201
[8] Bagby, J. and Packin, N., "ReGTech and Predictive Lawmaking: Closing the RegLaG between prospective regulated activity and regulation," *Michigan Business & Entrepreneurial Law Review*, vol. 10, no. 2, p. 127, 2021. [Online]. Available: https://doi.org/10.36639/mbelr.10.2.regtech
[9] Beaman, C. et al., "Ransomware: Recent advances, analysis, challenges and future research directions," *Computers & Security*, vol. 111, p. 102490, 2021. [Online]. Available: https://doi.org/10.1016/j.cose.2021.102490
[10] Corbet, S., Lucey, B., Urquhart, A., and Yarovaya, L., "Cryptocurrencies as a financial asset: A systematic analysis," *International Review of Financial Analysis*, vol. 62, pp. 182–199, 2018. [Online]. Available: https://doi.org/10.1016/j.irfa.2018.09.003
[11] Treleaven, P. et al., "The future of cybercrime: AI and emerging technologies are creating a cybercrime tsunami," *SSRN Electronic Journal*, 2023. [Online]. Available: https://doi.org/10.2139/ssrn.4507244
[12] Daah, C., Qureshi, A., Awan, I., and Konur, S., "Enhancing Zero Trust Models in the Financial Industry through Blockchain Integration: A Proposed Framework," *Electronics*, vol. 13, no. 5, p. 865, 2024. [Online]. Available: https://doi.org/10.3390/electronics13050865
[13] Faotu, H., Asheshemi, O. N., and Jeremiah, E. T., "Human Vulnerabilities in Cybersecurity: Analyzing Social Engineering Attacks and AI-Driven Machine Learning Countermeasures," *Journal of Science and Technology*, vol. 30, no. 1, pp. 72–84, 2024. [Online]. Available: https://doi.org/10.20428/jst.v30i1.2597
[14] Yash, R., "Beyond the code: exploring the human factor in cybersecurity through social engineering," 2023.
[15] Solove, D. J., *The Digital Person: Technology and Privacy in the Information Age*, *Choice Reviews Online*, vol. 42, no. 09, p. 42–5512, 2005. [Online]. Available: https://doi.org/10.5860/choice.42-5512
[16] Hileman, G. and Rauchs, M., "2017 Global Blockchain Benchmarking Study," *SSRN Electronic Journal*, 2017. [Online]. Available: https://doi.org/10.2139/ssrn.3040224
[17] Tobias, A., "Cryptocurrencies and Decentralized Finance," *International Monetary Fund*, 2022. [Online]. Available: https://www.imf.org/en/News/Articles/2022/06/24/sp083022-crptocurrencies-and-decentralized-finance
[18] Eli, D., "Cryptocurrency," 2014. [Online]. Available: https://www.researchgate.net/publication/29872075_Cryptocurrency
[19] Wolfgang, K. H., Campbell, R. H., and Raphael, C. G., *Understanding Cryptocurrencies*, 2019.
[20] Conti, M., Kumar, E. S., Lal, C., and Ruj, S., "A survey on security and privacy issues of Bitcoin," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 4, pp. 3416–3452, 2018. [Online]. Available: https://doi.org/10.1109/comst.2018.2842460
[21] Anagnostopoulos, I., "Fintech and regtech: Impact on regulators and banks," *Journal of Economics and Business*, vol. 100, pp. 7–25, 2018. [Online]. Available: https://doi.org/10.1016/j.jeconbus.2018.07.003
[22] Wang, Y. et al., "A survey on metaverse: fundamentals, security, and privacy," *IEEE Communications Surveys & Tutorials*, vol. 25, no. 1, pp. 319–352, 2022. [Online]. Available: https://doi.org/10.1109/comst.2022.3202047
[23] Rose, S., Borchert, O., Mitchell, S., and Connelly, S., "Zero Trust Architecture," *NIST Special Publication 800-207*, 2020. [Online]. Available: https://doi.org/10.6028/nist.sp.800-207
[24] Faotu, H. and Jeremiah, E. T., "AI and SaaS Embedded System: Enhancing Content Creation Through Contextual Language," *Journal of Science and Technology*, vol. 29, no. 2, pp. 57–66, 2024. [Online]. Available: https://doi.org/10.20428/jst.v29i2.2447
[25] Gill, S. S. et al., "AI for next generation computing: Emerging trends and future directions," *Internet of Things*, vol. 19, p. 100514, 2022. [Online]. Available: https://doi.org/10.1016/j.iot.2022.100514
[26] Zou, Y., Zhu, J., Wang, X., and Hanzo, L., "A survey on wireless security: technical challenges, recent advances, and future trends," *Proceedings of the IEEE*, vol. 104, no. 9, pp. 1727–1765, 2016. [Online]. Available: https://doi.org/10.1109/jproc.2016.2558521

أثر تصميم منصة تعليمية محلية على رضا طلبة برنامج نظم المعلومات في كلية الحاسوب وتكنولوجيا المعلومات بجامعة عدن

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الملخص:

في ظل التطور السريع للتكنولوجيا والتحول الرقمي في التعليم العالي، أصبحت المنصات التعليمية الإلكترونية عنصرًا أساسيًا في دعم العملية التعليمية. ومع ذلك، تواجه العديد من الدول النامية، بما في ذلك اليمن، تحديات كبيرة بسبب ضعف البنية التحتية للإنترنت، مما يعيق الاستفادة من المنصات التعليمية العالمية. تهدف هذه الدراسة إلى تصميم منصة تعليمية محلية تعتمد على الشبكات المحلية (Intranet) في كلية الحاسوب وتكنولوجيا المعلومات بجامعة عدن، وتحليل مدى تأثيرها على رضا الطلاب. تم استخدام المنهج شبه التجريبي، حيث تم اختبار المنصة مع مجموعة من طلاب برنامج نظم المعلومات، وتم جمع البيانات من خلال استبيانات وتحليلها باستخدام الأساليب الإحصائية. أظهرت النتائج أن استخدام المنصة التعليمية المحلية أسهم بشكل ملحوظ في تحسين رضا الطلاب عن التجربة التعليمية، حيث وفرت بيئة تعلم أكثر تفاعلية ومرونة. توصي الدراسة بتوسيع نطاق استخدام المنصات التعليمية المحلية في المؤسسات الأكاديمية التي تواجه تحديات تقنية مماثلة، وتعزيز البنية التحتية الرقمية لدعم التعليم الإلكتروني المستدام.

الكلمات المفتاحية *التعليم الإلكتروني، المنصات التعليمية المحلية، الرضا.*

The Impact of Designing a Local Educational Platform on the Satisfaction of Students in the Information Systems Program at the Faculty of Computer and Information Technology, University of Aden

***Abstract*— With the rapid advancement of technology and the digital transformation in higher education, educational platforms have become a crucial element in supporting the learning process. However, many developing countries, including Yemen, face significant challenges due to weak internet infrastructure, limiting their ability to benefit from global e-learning platforms. This study aims to design a local educational platform based on intranet networks at the Faculty of Computer and Information Technology, University of Aden, and analyze its impact on student satisfaction. A quasi-experimental approach was adopted, where the platform was tested with a group of Information Systems students, and data was collected through surveys and analyzed using statistical methods. The results indicated that the use of the local educational platform significantly improved students' satisfaction with their learning experience by providing a more interactive and flexible environment. The study recommends expanding the use of local educational platforms in academic institutions facing similar technological challenges and enhancing digital infrastructure to support sustainable e-learning.**

Keywords— *E-learning, Local Educational Platforms, Satisfaction.*

I. المقدمة

في ظل التقدم التكنولوجي السريع والتحول الرقمي الذي يشهده التعليم العالي، أصبحت المنصات التعليمية ركيزة أساسية لدعم العملية التعليمية، مما ساهم في تغيير طرق التدريس التقليدية نحو أساليب أكثر تفاعلية ومرونة. ومع ذلك، لا تزال العديد من الدول ، ومنها اليمن، تواجه تحديات كبيرة تتعلق بالبنية التحتية التقنية وضعف الاتصال بشبكة الإنترنت، مما يعيق استفادة المؤسسات التعليمية من المنصات العالمية والتقنيات الحديثة.

في هذا السياق، تبرز الحاجة إلى تطوير منصات تعليمية محلية يمكنها العمل بكفاءة في ظل هذه القيود التقنية. تعتمد المنصات المحلية على الشبكات المحلية (Intranet) لتقديم المحتوى التعليمي، مما يجعلها حلاً عمليًا وفعالًا يتيح للطلاب الوصول إلى موارد التعليم دون الحاجة إلى اتصال دائم بالإنترنت. توفر هذه المنصات بيئة تعليمية تفاعلية تدعم التعلم الفردي والجماعي، وتُسهم في تقليل الفجوة الرقمية بين الطلاب في المناطق الحضرية والريفية.

يعد رضا الطلاب عن المنصات التعليمية أحد المؤشرات الأساسية لقياس نجاح العملية التعليمية. فالطلاب الذين يشعرون بالرضا عن المنصة التي يستخدمونها يظهرون تفاعلًا أكبر مع المحتوى التعليمي، مما يؤدي إلى تحسين مستواهم الأكاديمي وزيادة اندماجهم في العملية

التعليمية. وعلى الرغم من التوسع في استخدام المنصات التعليمية عالميًا، إلا أن هناك نقصًا ملحوظًا في الدراسات التي تركز على المنصات المحلية في البيئات ذات الموارد المحدودة، مثل اليمن.

تهدف هذه الدراسة إلى سد هذه الفجوة من خلال تصميم منصة تعليمية محلية لطلاب برنامج نظم المعلومات في كلية الحاسوب وتكنولوجيا المعلومات بجامعة عدن، وتحليل مدى تأثيرها على رضا الطلاب. تُركز الدراسة على تقييم الجوانب التفاعلية والتقنية للمنصة، مع تسليط الضوء على التجربة التعليمية التي تقدمها ومدى ملاءمتها لاحتياجات الطلاب في بيئة تعليمية تواجه قيودًا تقنية واقتصادية.

إن نتائج هذه الدراسة ليست مهمة فقط لتحسين جودة التعليم في جامعة عدن، ولكنها توفر أيضًا نموذجًا قابلًا للتطبيق على نطاق واسع في البيئات المماثلة، مما يساهم في تعزيز التعليم العالي باستخدام تقنيات مبتكرة تركز على الاستدامة والفاعلية.

II. مشكلة الدراسة

تعاني جامعة عدن، وخاصة كلية الحاسوب وتكنولوجيا المعلومات، من تحديات كبيرة في تفعيل التعليم الإلكتروني والمدمج بسبب ضعف البنية التحتية للإنترنت، وعدم توفر شبكة اتصالات مستقرة، مما أدى إلى محدودية استخدام المنصات التعليمية الحالية (مثل نظام مودل). هذا الوضع أثر سلبًا على جودة العملية التعليمية، حيث يواجه الطلاب صعوبات في الوصول إلى المحتوى التعليمي، مثل:

- نقص أجهزة الكمبيوتر في المختبرات، واعتمادهم على وسائط قابلة للنقل (مثل الفلاش ديسك) التي تنقل الفيروسات وتُبطئ عملية نقل البيانات.
- غياب التفاعل الفعّال بين المدرسين والطلاب عبر المنصات الحالية، مما يُضعف التواصل المباشر وتلقي التغذية الراجعة.
- عدم توفر بيئة تعليمية مرنة تُلائم الظروف المحلية، مثل الحروب والأزمات التي تُعطل البنية التحتية وتُحد من إمكانية الاعتماد الكلي على الإنترنت.

لذلك، تبرز الحاجة إلى تصميم منصة تعليمية محلية تعمل عبر شبكة محلية لاسلكية داخل الكلية وقابلة للعمل في نطاق اوسع، دون الاعتماد على الإنترنت، لتحسين وصول الطلاب إلى المحتوى التعليمي، وتعزيز التفاعل بين المدرسين والطلاب، ورفع مستوى الرضا الأكاديمي في ظل التحديات التقنية واللوجستية التي تواجهها الجامعة.

III. أسئلة الدراسة

في ضوء مشكلة الدراسة المتمثلة في عدم وجود منصة تعليمية محلية، يمكن صياغة أسئلة الدراسة على النحو التالي:

1 السؤال الرئيسي:

- ما اثر تصميم منصة تعليمية محلية على رضا طلاب برنامج نظم المعلومات في كلية الحاسوب وتكنولوجيا المعلومات بجامعة عدن

2 الأسئلة الفرعية:

- ما الخصائص والمكونات الأساسية للمنصة التعليمية المحلية؟
- ما المعايير المستخدمة لتقييم أداء المنصة التعليمية المحلية؟
- ما مدى فاعلية المنصة التعليمية المحلية في تقديم المحتوى التعليمي في ظل ضعف أو عدم توفر خدمة الإنترنت؟

IV. أهداف الدراسة

تهدف الدراسة إلى تحقيق الأهداف التالية:

1 الهدف الرئيسي:

- تصميم منصة تعليمية محلية تعتمد على شبكة الانترانت المحلية في جامعة عدن، وتقييم مدى رضا الطلاب عليها.

2 الأهداف الفرعية:

- تحليل المنصات التعليمية وأنواعها ومجالاتها.
- تصميم وتطوير عمل المنصة التعليمية المحلية في ظل ضعف أو عدم توفر خدمة الإنترنت.
- تقييم المنصة التعليمية المحلية باستخدام طرق التحليل الإحصائي.

V. فرضيات الدراسة

1. لا توجد فروق ذات دلالة احصائية عند مستوى دلالة (α=0.05)بمستوى رضا الطلبة الذين يدرسون باستخدام البيئة التعليمية القائمة على المنصات التعليمية المحلية في التطبيق القبلي والبعدي.
2. لا توجد فروق ذات دلالة احصائية عند مستوى الدلالة (α=0.05) بمستوى رضاء الطلبة الذين يدرسون باستخدام البيئة التعليمية القائمة على المنصات التعليمية المحلية بين الذكور والإناث، أي يعزى الفرق إلى الجنس.

VI. أهمية الدراسة

تنبع أهمية الدراسة من عدة نقاط رئيسية، منها:

1. تسليط الضوء على تطبيق التعليم المدمج في التعليم الجامعي لتوفير بيئة تعليمية مرنة تتكيف مع الزيادة السريعة في أعداد الطلاب والبنية التحتية المحدودة.
2. تقديم حل فعال للتحديات الناتجة عن الأوبئة والكوارث والحروب التي تؤثر على استمرارية العملية التعليمية.
3. تزويد الجهات المعنية مثل وزارة التعليم العالي والبحث العلمي ووزارة التربية والتعليم برؤية واضحة حول تجربة التعليم المدمج، الإمكانيات التي يوفرها والمتطلبات والتحديات التي تواجه تطبيقه.
4. رسم خريطة تعليم بديلة لمواجهة المشاكل التقليدية مثل الزيادة في عدد الطلاب، النقص في الكادر التدريسي وضعف الخدمات اللوجستية، مع الاستفادة من تطبيقات التعليم الإلكتروني.

VII. حدود الدراسة

- *الحدود الموضوعية:* فاعلية استخدام المنصات التعليمية المحلية (سيتم تطبيق الدراسة بشقها التجريبي في مساق "هياكل البيانات")
- *الحدود المكانية:* كلية الحاسوب وتكنولوجيا المعلومات، جامعة عدن.
- *الحدود الزمانية:* الفصل الدراسي الاول من العام الجامعي 2024-2023م.
- *الحدود البشرية:* طلبة برنامج بكالوريوس نظم المعلومات بكلية الحاسوب وتكنولوجيا المعلومات، المستوى الثاني.

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VIII. مصطلحات الدراسة

المنصات التعليمية

هي بيئات إلكترونية تعتمد على تقنيات الويب لتقديم محتوى تعليمي متكامل، حيث توفر أدوات تفاعلية تساعد المتعلمين والمعلمين على الوصول إلى المواد التعليمية في أي وقت ومكان، بشرط توفر اتصال بالإنترنت. تتيح هذه المنصات تحميل الكتب والمقالات العلمية، مشاهدة المحاضرات المسجلة، إجراء الاختبارات الإلكترونية، والمشاركة في المناقشات والأنشطة التفاعلية، مما يسهم في تعزيز التعلم الذاتي والتعاوني وفق استراتيجيات التعليم الحديثة.

المنصات التعليمية المحلية

هي أنظمة تعليمية رقمية مخصصة للمؤسسات الأكاديمية، تعمل ضمن نطاق الشبكة المحلية للجامعة أو المؤسسة التعليمية، مما يتيح للطلاب وأعضاء هيئة التدريس الوصول إلى المحتوى التعليمي دون الحاجة إلى اتصال بالإنترنت. تشمل هذه المنصات ميزات مثل تحميل المحاضرات، الوصول إلى الموارد التعليمية، إجراء الاختبارات الإلكترونية، والتفاعل بين الطلاب والمعلمين من خلال أدوات تعليمية مدمجة تدعم استمرارية العملية التعليمية في البيئات ذات الاتصال المحدود بالإنترنت

رضا الطلاب في العملية التعليمية

يشير إلى مدى استجابة الطلاب إيجابيًا للتجربة التعليمية التي يتلقونها، وهو مؤشر على جودة التعليم من منظور المتعلمين. يتم قياسه عبر أدوات مثل الاستبيانات والمقابلات، ويشمل عدة أبعاد مثل جودة التدريس، توفر الموارد التعليمية، سهولة استخدام المنصات التعليمية، مدى التفاعل مع أعضاء هيئة التدريس، ومستوى الدعم الأكاديمي والإداري المقدم. يتم قياسه باستخدام مقاييس كمية مثل مقياس ليكرت أو تحليل البيانات النوعية المستخلصة من ملاحظات الطلاب وانطباعاتهم حول العملية التعليمية.

IX. الإطار النظري والدراسات السابقة

الإطار النظري

شهد التعليم في العصر الحديث تطورًا كبيرًا بفضل الثورة المعلوماتية والتكنولوجيا الرقمية، مما أدى إلى ظهور أنماط جديدة من التعليم، مثل التعليم الإلكتروني والتعلم المدمج، التي تسهم في تحسين جودة العملية التعليمية وزيادة مرونتها. ومع ذلك، فإن تطبيق هذه الأنظمة يواجه تحديات خاصة في البيئات ذات البنية التحتية المحدودة، مثل جامعة عدن. لذا، تبرز أهمية دراسة أثر تصميم منصات تعليمية محلية على رضا الطلاب وتحسين أدائهم الأكاديمي.

التعليم الإلكتروني والتعليم المدمج

التعليم الوجاهي: يعتمد على التفاعل المباشر بين المعلم والطلاب في قاعات الدراسة التقليدية.

التعليم الإلكتروني: يتيح الوصول إلى المحتوى التعليمي عبر الإنترنت أو الشبكات المحلية، مما يوفر مرونة في التعلم.

التعليم المدمج: يجمع بين التعليم التقليدي والتعليم الإلكتروني، مما يساعد على تحقيق التفاعل المباشر مع الاستفادة من الموارد الرقمية.

مفهوم المنصات التعليمية

تُعرف المنصات التعليمية بأنها أدوات تقنية تعمل على تسهيل العملية التعليمية من خلال تقديم مواد تعليمية عبر الإنترنت أو الشبكات المحلية. وتتميز المنصات بقدرتها على التفاعل مع المستخدمين، مما يتيح لهم الوصول إلى المعلومات وتنظيم عملية التعلم بطريقة تناسب احتياجاتهم الفردية [1] .

معايير تصميم المنصات التعليمية

تم اقتباس المعايير التالية من دراسات متعددة في مجال تصميم المنصات التعليمية، مثل دراسة "معايير تصميم المنصات التعليمية الإلكترونية" للباحثين محمد أحمد ومحمد علي [2]، والتي نُشرت في مجلة التعليم الإلكتروني.

بالإضافة إلى ذلك، توصي منظمة الأمم المتحدة للتربية والعلم والثقافة (اليونسكو) في تقريرها لعام 2019 بعنوان "إرشادات لتصميم منصات التعلم الرقمي" بمراعاة هذه المعايير لضمان جودة التعليم الإلكتروني [3].

1. سهولة الاستخدام (Usability): يجب أن تكون المنصة بديهية وسهلة التنقل، مما يتيح للمتعلمين الوصول إلى المحتوى والموارد بسهولة.
2. التصميم التفاعلي (Interactivity): تشجيع التفاعل بين المتعلمين والمحتوى، وبين المتعلمين أنفسهم، من خلال أدوات مثل المنتديات، والدردشات، والاختبارات التفاعلية.
3. التوافقية (Compatibility): ضمان عمل المنصة عبر مختلف الأجهزة وأنظمة التشغيل، بما في ذلك الهواتف الذكية والأجهزة اللوحية.
4. الأمان والخصوصية (Security and Privacy): حماية بيانات المستخدمين وضمان سرية المعلومات الشخصية.
5. إدارة المحتوى (Content Management): توفير نظام فعال لإدارة المحتوى التعليمي، يسمح بإضافة وتحديث المواد بسهولة.
6. التقييم والتغذية الراجعة (Assessment and Feedback): تضمين أدوات لتقييم أداء المتعلمين وتقديم تغذية راجعة فورية.
7. الدعم الفني (Technical Support): توفير دعم فني مستمر للمستخدمين لحل المشكلات التقنية التي قد تواجههم.

المنصات التعليمية المحلية

المنصات التعليمية المحلية تعتمد على الشبكات الداخلية (Intranet) وتتميز بالقدرة على العمل دون الحاجة إلى اتصال دائم بشبكة الإنترنت. تعد هذه المنصات حلاً مثاليًا للتعليم في المناطق التي تعاني من ضعف البنية التحتية التقنية أو انقطاع الخدمات. وأشار الخطيب [4] ان المنصات المحلية توفر بيئة تعليمية مستقرة تعزز من جودة التعلم وتقلل من تكاليف الاتصال، مما يجعلها خيارًا مستدامًا للجامعات في الدول ذات البنية التقنية المتدنية.

مميزات المنصات التعليمية المحلية

- توفير بيئة تعلم مستقرة حتى في ظل ضعف الإنترنت.
- تقليل تكاليف البنية التحتية، مثل الطباعة والنقل.
- تعزيز التفاعل بين الطلاب وأعضاء هيئة التدريس.
- تحسين إمكانية الوصول إلى المحتوى التعليمي في أي وقت ومكان.

رضا الطلاب في العملية التعليمية

يشير رضا الطلاب إلى مستوى قبولهم وتفاعلهم مع الأدوات والمنهجيات التعليمية المستخدمة. يرتبط هذا المفهوم بجودة التصميم وسهولة الاستخدام ومستوى التفاعل الذي تقدمه المنصات التعليمية. دراسة Puri [5] أكدت أن المنصات التي تقدم تجارب تفاعلية وسلسة تسهم في زيادة رضا الطلاب وتحسين أدائهم الأكاديمي.

أثر تصميم المنصات التعليمية على رضا الطلاب

- تسهم المنصات المحلية في تقليل الصعوبات التي يواجهها الطلاب في الوصول إلى المواد الدراسية.
- توفر تجربة تعلم أكثر تفاعلية من خلال أدوات المحاكاة والاختبارات الإلكترونية.
- تساعد على قياس مستوى رضا الطلاب من خلال استبيانات وتحليلات أداء المستخدمين.

التعليم في جامعة عدن والتحديات التي تواجهه

نظرًا لضعف البنية التحتية للإنترنت في اليمن، يواجه الطلاب صعوبات في الوصول إلى التعليم الإلكتروني. ومن هنا، تبرز الحاجة إلى تصميم منصات تعليمية محلية تعتمد على الشبكات الداخلية، مما يتيح للطلاب الوصول إلى المحتوى التعليمي بسهولة وبتكلفة منخفضة.

التقييم الإحصائي لأداء المنصة

تعتمد الدراسة على تحليل بيانات الطلاب باستخدام أدوات التحليل الإحصائي لقياس مدى فاعلية المنصة وتأثيرها على مستوى رضاهم الأكاديمي.

معايير تقييم المنصات التعليمية الالكترونية :

ذكرت دارسة جادالله **[6]** عدة معايير لتقييم المنصات التعليمية الالكترونية وهي:

1 -التوصيف العام للمنصة التعليمية الإلكترونية.
2 -اهداف التعلم ومخرجات المنصة التعليمية الإلكترونية.
3 -محتوى المنصة التعليمية الإلكترونية.
4 -استراتيجيات وانشطة تعلم المنصة التعليمية الإلكترونية.
5 -التصميم الفني للمنصة الالكترونية.
6- اداء المتعلم.

الدراسات السابقة

تم استعراض عدد من الدراسات السابقة المتعلقة بالمنصات التعليمية وتأثيرها على التعليم الإلكتروني، وتم ترتيبها من الأقدم إلى الأحدث كما يلي:

اولاً: تأثير المنصات التعليمية على التحصيل الدراسي:

دراسة الباوي وغازي ***[7] :***

هدفت إلى قياس أثر استخدام منصة Google Classroom على تحصيل طلبة قسم الحاسبات.
أظهرت النتائج أن المنصة ساهمت في تحسين تحصيل المجموعة التجريبية مقارنة بالمجموعة الضابطة.

دراسة الميلبي [8] :

استخدمت المنهج التجريبي لقياس تأثير المنصات الإلكترونية على مستوى تحصيل الطلاب.
أشارت النتائج إلى وجود فرق دال إحصائيًا لصالح المجموعة التي استخدمت المنصات التعليمية.

دراسة الذهلي [9] :

درست أثر المنصات التعليمية على تحصيل طلاب مادة الرياضيات.
أثبتت النتائج وجود تحسن ملحوظ في تحصيل الطلاب عند استخدام المنصة.

ثانيًا: رضا الطلاب عن استخدام المنصات التعليمية:

دراسة F. Amiri [10]:

تناولت رضا الطلاب عن استخدام المنصات التعليمية الإلكترونية.
أظهرت الدراسة مستويات عالية من الرضا، حيث وجد الطلاب أن المنصات سهلة الاستخدام وفعالة.

دراسة الصيداوي [11] :

استخدمت استبيانات لقياس اتجاهات الطلاب نحو التعلم الإلكتروني.
أشارت النتائج إلى أن معظم الطلاب لديهم اتجاهات إيجابية نحو استخدام المنصات التعليمية.

ثالثًا: تحديات تطبيق المنصات التعليمية:

دراسة الدوسري [12] **:**

تناولت تقييم استخدام أعضاء هيئة التدريس للمنصات التعليمية في تدريس اللغة الإنجليزية.
أظهرت النتائج أن درجة استخدام المنصات كانت متوسطة بسبب بعض التحديات التقنية.

دراسة أبو شخيدم [13] :

درست فاعلية التعليم الإلكتروني أثناء جائحة كورونا من وجهة نظر المدرسين في جامعة فلسطين التقنية خضوري.
أظهرت النتائج أن التعليم الإلكتروني كان له أثر إيجابي لكنه واجه صعوبات مثل ضعف البنية التحتية وقلة التدريب للمعلمين.

رابعًا : تأثير المنصات التعليمية على التفاعل بين الطلاب والمعلمين:

دراسة تمارا ومحمد ويوسف ومجدلاوي [14] :

تناولت دور المنصات الإلكترونية في تعزيز التفاعل بين الطلبة في الجامعة الأردنية.
أكدت النتائج أن المنصات حسّنت من مستوى التواصل بين الطلاب والمعلمين.

دراسة شريف والدولات [15] :

أوصت بضرورة استخدام المنصات التعليمية في تدريس العلوم لزيادة تفاعل الطلاب داخل البيئة التعليمية.

خامسًا : تقييم أداء المنصات التعليمية:

دراسة جمانة أبو قتب [16] :

بحثت في مدى استخدام معلمي الرياضيات للمنصات التعليمية.
أظهرت النتائج أن الاستخدام كان بدرجة متوسطة، مع الحاجة إلى تدريب إضافي للمعلمين.

دراسة الصيداوي [17] :

استخدمت اختبار التحصيل لقياس تأثير المنصات على اتجاهات الطلاب.
أكدت الدراسة أن المنصات ساعدت في تحسين تجربة التعلم وزيادة دافعية الطلاب.

تعقيب على الدراسات السابقة

أولًا: تأثير المنصات التعليمية على التحصيل الدراسي

أوجه التشابه:

جميع الدراسات استخدمت مناهج تجريبية لمقارنة أداء الطلاب في المجموعات التجريبية والضابطة.

أوجه الاختلاف:

لم تتناول هذه الدراسات المنصات التعليمية المحلية تحديدًا، وهو ما يميز الدراسة الحالية التي تركز على منصة تعمل داخل نطاق شبكة الجامعة.
تختلف معظم الدراسات مثل الباوي وغازي ، الميلبي ، والذهلي مع الدراسة الحالية في البحث عن تأثير المنصات التعليمية على التحصيل الدراسي بينما الدراسة الحالية تختبر الرضا.
بعض الدراسات ركزت على مواد دراسية محددة مثل الرياضيات، بينما تستهدف الدراسة الحالية طلاب نظم المعلومات، مما قد يؤثر على تعميم النتائج.

ثانيًا: رضا الطلاب عن استخدام المنصات التعليمية

أوجه التشابه:

دراستا Frishta Amiri والصيداوي تتفقان مع الدراسة الحالية في قياس رضا الطلاب عن المنصات التعليمية، حيث اعتمدت كلتاهما على الاستبيانات لقياس الاتجاهات والمستويات المختلفة للرضا.
النتائج في الدراسات السابقة تشير إلى ارتفاع مستوى الرضا، وهو ما قد يكون متوقعًا في الدراسة الحالية، ولكن مع إمكانية وجود اختلاف في مستوى الرضا بسبب الطبيعة المحلية للمنصة المدروسة.

أوجه الاختلاف:

لم توضح الدراسات السابقة مدى تأثير ضعف الاتصال بالإنترنت على رضا الطلاب، في حين أن الدراسة الحالية تركز على المنصة المحلية التي تعمل في ظل ضعف الإنترنت، مما يضيف بُعدًا جديدًا للتحليل.

https://doi.org/10.20428/jst.v30i5.2833

ثالثًا: تحديات تطبيق المنصات التعليمية

أوجه التشابه:

دراستا الدوسري وأبو شخيدم تناولتا التحديات التي تواجه تطبيق المنصات التعليمية، وهو محور مهم في الدراسة الحالية.

كلا الدراستين أشارتا إلى أن المشكلات التقنية وقلة تدريب المعلمين تشكل عوائق رئيسية في تبني المنصات، وهو ما قد يكون مشابهًا للتحديات التي تواجهها المنصة المحلية في الدراسة الحالية.

أوجه الاختلاف:

ركزت الدراسات السابقة على أعضاء هيئة التدريس والمعلمين في تقييم التحديات، بينما تركز الدراسة الحالية على تجربة الطلاب، مما يمنح منظورًا مختلفًا حول التحديات التي يواجهها المستخدمون النهائيون.

الدراسة الحالية تدرس منصة تعمل دون الحاجة إلى اتصال بالإنترنت، وهو تحدٍ لم تتطرق إليه معظم الدراسات السابقة.

رابعًا: تأثير المنصات التعليمية على التفاعل بين الطلاب والمعلمين

أوجه التشابه:

دراستا تمارا وآخرون وشريف والدولات تناولتا تأثير المنصات التعليمية على تعزيز التفاعل بين الطلاب والمعلمين، وهو أحد الأهداف الأساسية للدراسة الحالية.

النتائج في هذه الدراسات أكدت أن المنصات عززت التفاعل، وهو ما قد يدعم فرضية الدراسة الحالية حول أهمية المنصات التعليمية المحلية في تعزيز التواصل بين الطلاب وأساتذتهم.

أوجه الاختلاف:

لم تناقش الدراسات السابقة التفاعل في بيئة ذات اتصال محدود بالإنترنت، وهو ما يجعل الدراسة الحالية فريدة في بحث تأثير الشبكة المحلية على التواصل والتفاعل.

الدراسة الحالية قد تتطرق إلى أدوات محددة داخل المنصة (مثل المنتديات أو الرسائل الداخلية) لقياس مستوى التفاعل، وهو ما لم يتم تناوله بالتفصيل في الدراسات السابقة.

خامسًا: تقييم أداء المنصات التعليمية

أوجه التشابه:

دراستا جمانة أبو قتب والصيداوي تناولتا تقييم أداء المنصات التعليمية بناءً على مدى استخدامها ومدى تأثيرها على اتجاهات الطلاب ودافعيتهم، وهي نقاط تتقاطع مع الدراسة الحالية.

أوجه الاختلاف:

الدراسة الحالية لا تركز فقط على تقييم الأداء العام، بل تهتم أيضًا بمدى فعالية المنصة المحلية مقارنة بالمنصات التقليدية المتصلة بالإنترنت.

الدراسات السابقة ركزت على تقييم الأداء من منظور المعلمين أو الطلاب، بينما تسعى الدراسة الحالية إلى تحليل الأداء بشكل أكثر تكاملًا من حيث الكفاءة، سهولة الاستخدام، ومدى تحقيق الأهداف التعليمية.

الاستنتاج العام

تتوافق الدراسة الحالية مع العديد من الدراسات السابقة في الموضوعات الأساسية مثل تأثير المنصات على التحصيل الدراسي، رضا الطلاب، والتفاعل التعليمي.

تتميز الدراسة الحالية بتركيزها على منصة تعليمية محلية تعمل بدون إنترنت، وهو عنصر جديد لم تتم دراسته بعمق في الأبحاث السابقة.

تضيف الدراسة الحالية بُعدًا جديدًا من حيث تحليل التحديات التقنية والعملية للمنصات المحلية وتأثيرها على التعليم في البيئات ذات البنية التحتية الضعيفة.

هذه الدراسات تقدم أساسًا علميًا قويًا لدراسة تأثير تصميم المنصات التعليمية المحلية على رضا طلاب جامعة عدن وتحقيق أهداف البحث بشكل منهجي.

X. إجراءات البحث

المنهجية

اعتمد البحث على المنهج شبه التجريبي لتقييم تأثير المنصة التعليمية المحلية على رضا الطلاب. تم تصميم المنصة باستخدام شبكة محلية (LAN)تتيح للطلاب الوصول إلى الموارد التعليمية دون الحاجة إلى الإنترنت.

عينة الدراسة

تم اختيار عينة قصدية من تلاميذ المستوى الثاني مكونة من (40) طالب وطالبة ممن لديهم رغبة المشاركة في التجربة، بالإضافة إلى توفر المصادر اللازمة لتنفيذ التجربة (جهاز حاسوب محمول، هاتف اندرويد، هاتف ايفون، امتلاك مهارات استخدام متصفحات الانترنت المختلفة والمشاركة التفاعلية) و التعلم من خلال بيئة التعلم من خلال المنصة التعليمية المحلية.

المجتمع المستهدف: جميع طلاب كلية الحاسوب وتكنولوجيا المعلومات – جامعة عدن ، وعند اكتمال وتشغيل الشبكة المحلية ستغطي المنصة جميع طلاب جامعة عدن.

خصائص العينة: تنوعت العينة من حيث الجنس، الخلفية التقنية، ومستوى الرضا المبدئي عن التعليم الإلكتروني

اجراءات البحث

تم تنفيذ البحث وفق الخطوات التالية:

إعداد المنصة التعليمية المحلية:

اولاً :جمع البيانات:

يعد جمع البيانات هو الخطوة الأساسية والأكثر أهمية للبحث ، و هو إجراء لجمع وقياس وتحليل الرؤى الدقيقة للبحث باستخدام التقنيات القياسية المعتمدة.

في هذا البحث سوف يتم تبني طريقة المقابلة لجمع البيانات لغرض تصميم المنصة التعليمية المحلية في كلية الحاسوب وتكنولوجيا المعلومات.

من خلال النزول إلى كلية الحاسوب وتكنولوجيا المعلومات – جامعة عدن تم التعرف على طريقة التعلم باستخدام التعليم المدمج وتبين انه لا توجد منصة حالية خاصة بالكلية وذلك بسبب ضعف شبكة الإنترنت في البلاد، كما تبين ان هناك كادر قادر على التعامل مع انظمة او منصات الكمبيوتر المختلفة وهذا يوفر الجهد والوقت في عملية التدريب ونقلهم إلى العمل بواسطة المنصة المقترحة، كما تبين وجود بعض المشكلات التي تواجه الطلبة من اجل الحصول على المادة التعليمية أهمها:

1 -قلة عدد اجهزة الكمبيوتر في الكلية.

2 -انتقال الفيروسات بسبب استخدام الفلاش ديسك.

3 -بطيء عملية نقل المحاضرات من سيرفر الكلية إلى الفلاش.

4- عدم وجود اي تفاعل بين المدرس والطلبة .

ثانيًا: توصيف البيانات:

ان البيانات المستخدمة في المنصة المقترحة لغرض الاختبار تم تصنيفها كالتالي:

1.بيانات الطلاب : ويحتوي على بيانات الطلاب الاساسية مثل (رقم القيد – اسم الطالب – كلمة السر).

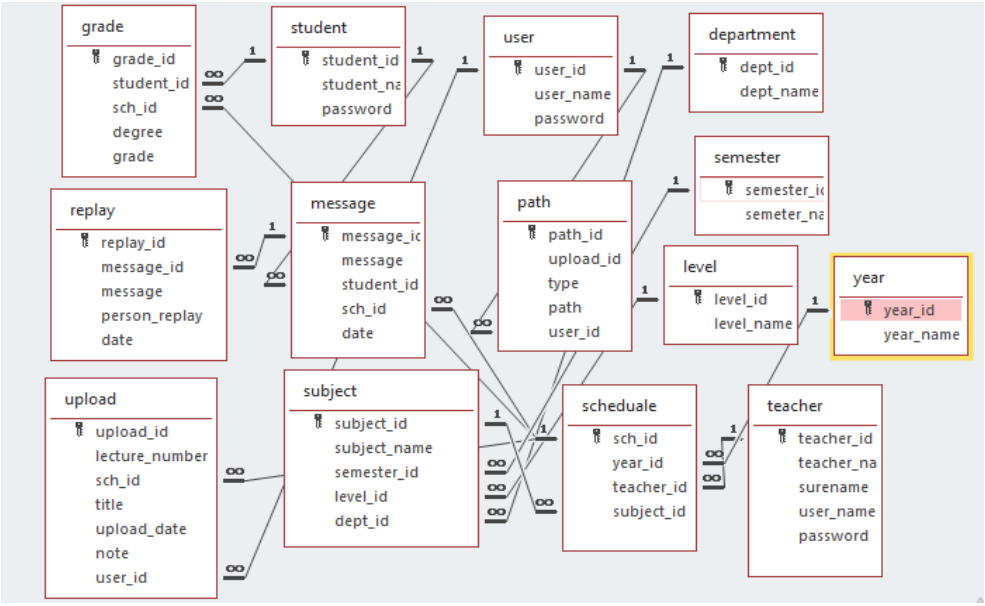
2.بيانات الهيئة التدريسية: يحتوي على بيانات اعضاء هيئة التدريس مثل (رقم المدرس – اسم المدرس – اللقب العلمي – اسم المستخدم – كلمة السر).

3.بيانات الاقسام: يحتوي على بيانات الاقسام العلمية مثل (رقم القسم – اسم القسم – رمز القسم – رئيس القسم).

4.بيانات المواد: يحتوي على بيانات المواد الدراسية مثل (رقم المادة – رمز المادة – اسم المادة – القسم العلمي – المدرس).

5.بيانات المستويات والفصول: يحتوي على المستويات الدراسية والفصول الدراسية.
6.بيانات المادة العلمية: يحتوي على بيانات المادة المرفوعة للمنصة (اسم المادة – رقم المحاضرة – عنوان المحاضرة – نوع الملف المرفق- الملف المرفق).

يوضح الشكل (1) التالي مخطط ربط قاعدة البيانات المقترحة حيث تتوزع بيانات المنصة التعليمية المحلية المقترحة على مجموعة من الجداول كما هو موضح في المخطط التالي:

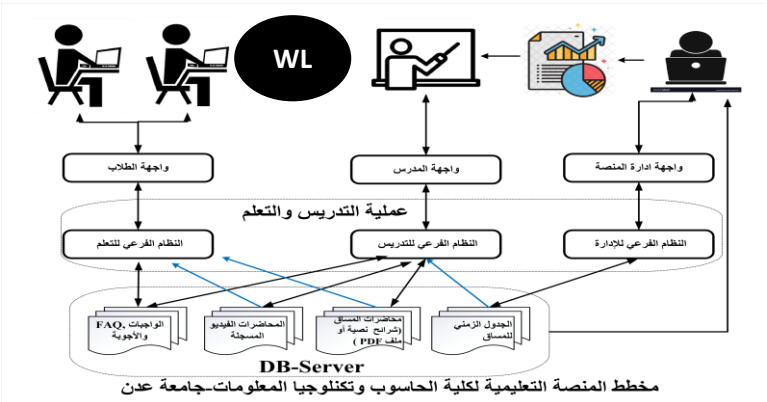


شكل 1: مخطط ربط قاعدة البيانات المقترحة

ثالثًا: تصميم المنصة:

ان المنصة التعليمية المحلية المقترحة لكلية الحاسوب وتكنولوجيا المعلومات هي منصة مستلهمة من منصتي:

1. Google classroom: هي خدمة ويب مجانية يتم تطويرها من قبل جوجلGoogle ، للمدارس، والجامعات، وهي أداة، بسيطة، وسهلة الاستخدام تساعد المُعلمين، على إدارة مهام العملية التعليمية. والهدف منها تسهيل إنشاء الواجبات، وتوزيعها، وتصنيفها، وتصنيفها بشكل غير ورقي، وقد تم إصدار (قاعة دراسة جوجل)، علنًا في 12 أغسطس 2014.
2. Edmodo: هي منصة تكنولوجيا تعليمية للمدارس والمعلمين من رياض الأطفال وحتى الصف الثاني عشر. يقع مقرها في سان ماتيو بكاليفورنيا. تمكن المنصة المعلمين من مشاركة المحتوى وتوزيع الاختبارات والواجبات والتواصل مع الطلاب والزملاء وأولياء الأمور،وقد تم انشاء المنصة في 2008، وإغلقت المنصة في 22 سبتمبر 2022.



شكل 2 :تفاصيل المنصة التعليمية المحلية المقترحة

رابعًا: الالية المتبعة في تنفيذ المنصة التعليمية المحلية:

1) اعداد البيانات الاساسية للمنصة التعليمية المحلية

اولًا: بيانات يتم ادخالها مسبقاً قبل بدء العملية التعليمية، وهي:

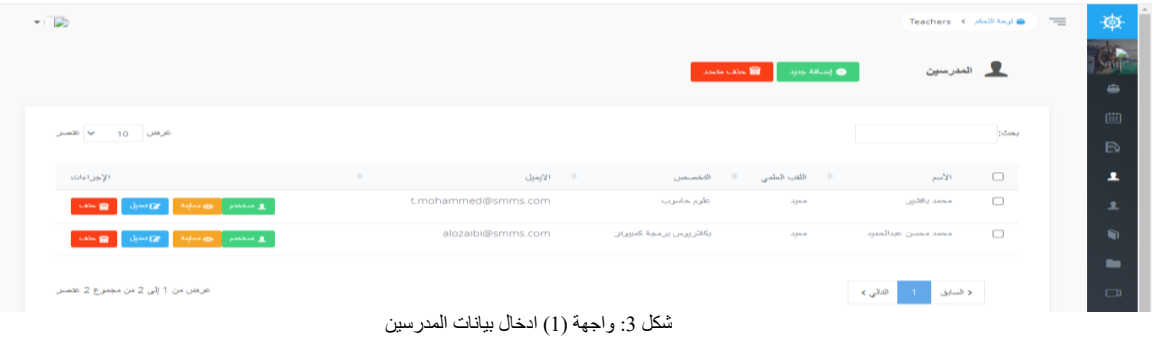
1- بيانات المدرسين (اعضاء هيئة التدريس وهيئة التدريس المساعدة):

وهي البيانات الشخصية لأعضاء هيئة التدريس وهيئة التدريس المساعدة حيث يتم الحصول على هذه البيانات من خلال نيابة الشؤون الأكاديمية والأقسام العلمية في الكلية, الجدول (1) يوضح بيانات المدرسين.

جدول (1) بيانات المدرسين

رقم المدرس	الاسم	التخصص	اللقب العلمي	البريد الالكتروني

يلي الحصول على هذه البيانات عملية ادخالها للمنصة التعليمية المحلية من خلال الواجهة المخصصة لذلك كما هو موضح بالواجهة (1).



شكل 3: واجهة (1) ادخال بيانات المدرسين

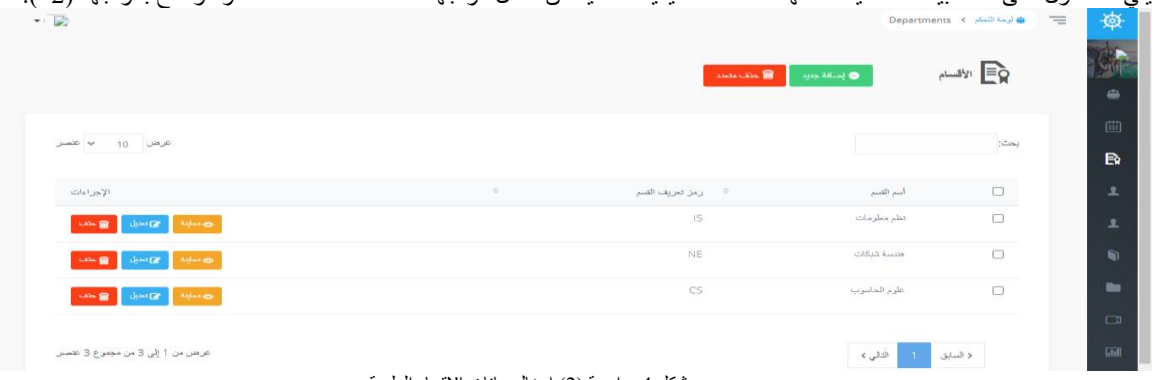
2- بيانات الاقسام العلمية:

وهي البيانات العامة لكل قسم علمي في الكلية، حيث تم الحصول على عليها من خلال نيابة الشؤون الأكاديمية في الكلية، الجدول (2) يوضح بيانات الاقسام العلمية.

جدول (2) بيانات الاقسام العلمية

رقم القسم	اسم القسم	الرمز

يلي الحصول على هذه البيانات عملية ادخالها للمنصة التعليمية المحلية من خلال الواجهة المخصصة لذلك كما هو موضح بالواجهة (2).



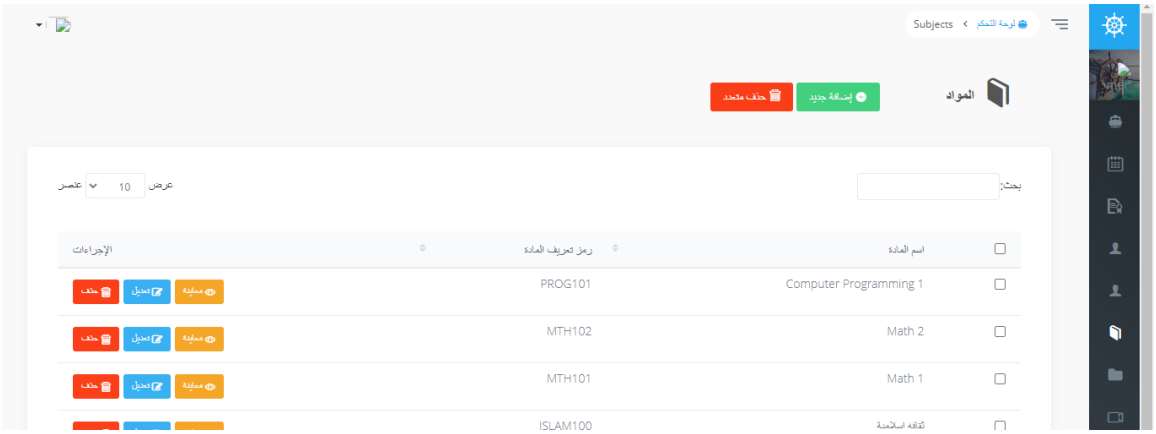
شكل 4: واجهة (2) ادخال بيانات الاقسام العلمية

3- بيانات المواد الدراسية:
وهي البيانات المتعلقة بالخطة الدراسية للأقسام العلمية، يتم الحصول على هذه البيانات بحسب الخطة الدراسية لكل قسم علمي من خلال الاقسام العلمية في الكلية.

جدول (3) يوضح بيانات المواد الدراسية

رقم المادة	اسم المادة	رمز المادة

يلي الحصول على هذه البيانات عملية ادخالها للمنصة التعليمية المحلية من خلال الواجهة المخصصة لذلك كما هو موضح بالواجهة (3) .



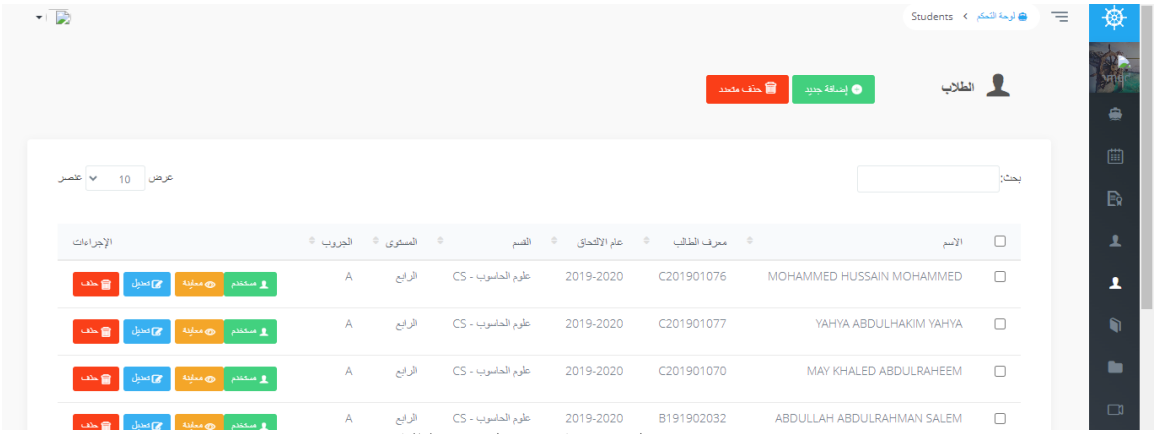
شكل 5: واجهة (3) ادخال بيانات المواد الدراسية

4- بيانات الطلاب:
وهي البيانات الشخصية لكل طالب وطالبة بعد عملية القيد والتسجيل في الكلية، يتم الحصول على هذه البيانات من خلال نيابة شؤون الطلاب.

جدول (4) يوضح بيانات الطلاب

رقم الطالب	الاسم	رقم القيد(المعرف)	عام الالتحاق	القسم	المستوى	المجموعة

يلي الحصول على هذه البيانات عملية ادخالها للمنصة التعليمية المحلية من خلال الواجهة المخصصة لذلك بشكل يدوي او من خلال ادراج ملف اكسل Excel يحتوي بيانات الطلبة.



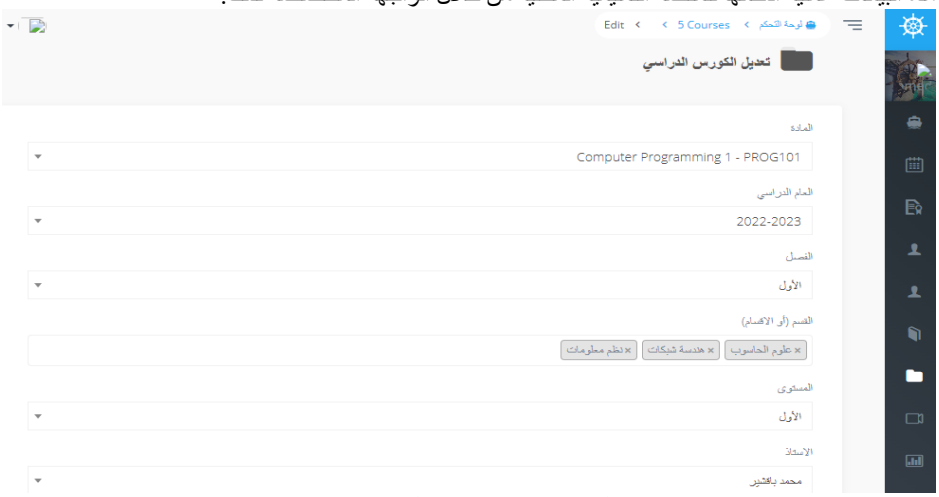
شكل 6: واجهة (4) ادخال بيانات الطلبة

5- بيانات المواد الفصلية للفصل الحالي مع تحديد مدرس كل مادة:
يتم الحصول عليها من خلال الاقسام العلمية في الكلية.

جدول (5) يوضح بيانات المواد الفصلية

رقم المادة	اسم المادة	اسم المدرس	المستوى الدراسي	الفصل الدراسي	القسم العلمي	العام الدراسي

يلي الحصول على هذه البيانات عملية ادخالها للمنصة التعليمية المحلية من خلال الواجهه المخصصة لذلك.

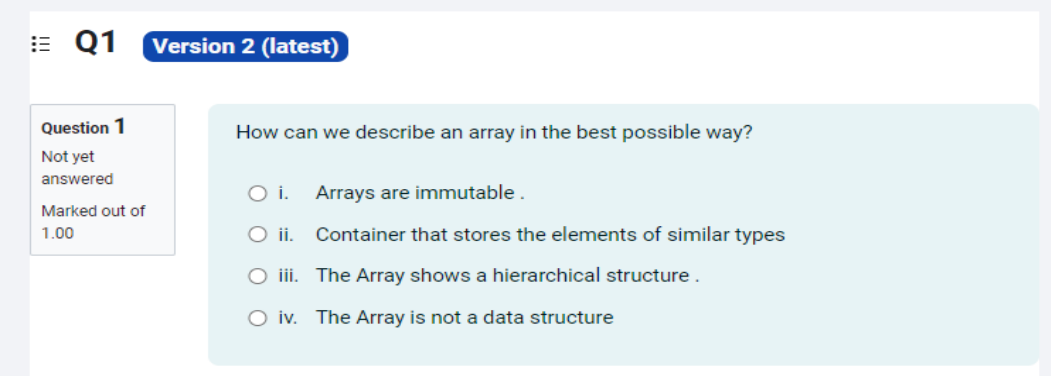


شكل 7: واجهة (5) واجهة ادخال المواد الفصلية

ثانيًا : بيانات يتم تغذية المنصة بها أثناء الفصل الدراسي:
1- *البيانات الدورية اللازمة للعمل:*
وهي بيانات المحاضرات التي يوفرها مدرس المادة العلمية، والذي يقوم بتغذيتها للمنصة التعليمية المحلية مباشرة او من خلال الموظف المختص.

شكل 8: واجهة (6) يوضح نموذج البيانات الدورية اللازمة للعمل

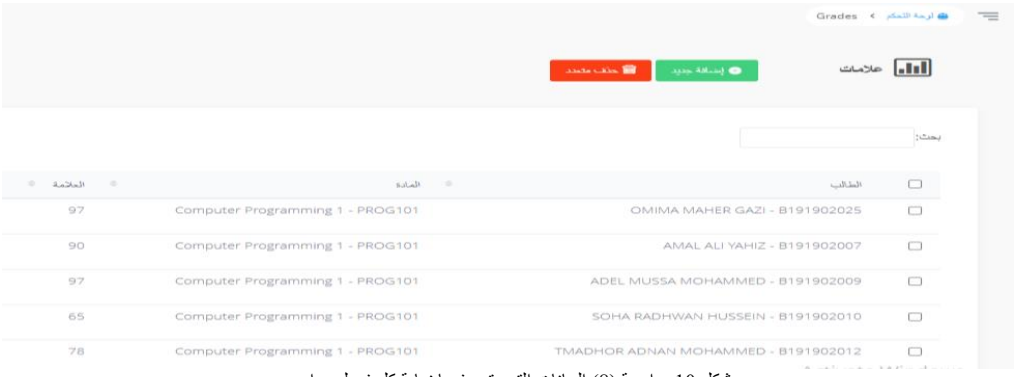
2- بيانات الاختبارات الفصلية او التمارين الاسبوعية:
هي بيانات التمارين والاختبارات التي يعدها المدرس للطلاب لإجراء عملية التقييم للطالب بصورة الكترونية حيث يقوم بتخزين الاسئلة في بنك الاسئلة الخاص بالمنصة وبعد ذلك تقوم المنصة باختيار الاسئلة لكل طالب بشكل عشوائي.



شكل 9: واجهة (7) نموذج الاختبارات الاليكتروني

ثالثًا: البيانات التي يتم رفعها للمنصة بعد نهاية كل فصل دراسي:

وهي بيانات درجات الطلبة حيث يقوم الموظف المختص برفعها للمنصة بشكل كامل عن طريق ملف اكسل Excel يحصل علية من نيابة شؤون الطلاب في الكلية.



شكل 10: واجهة (8) البيانات التي يتم رفعها نهاية كل فصل دراسي

2) البيئة التعليمية الافتراضية التفاعلية (الدردشات):

تعتبر المنصة التعليمية لكلية الحاسوب وتكنلوجيا المعلومات بيئة تعليمية افتراضية تفاعلية لمحيط يوظف اليات واساليب مختلفة من التفاعل بين المعلم والطالب وبين الطلاب أنفسهم من خلال الشبكة اللاسلكية المحلية وبواسطة مجموعة من التقنيات. من حيث انه توجد واجهة الاستفسار القائم على المحادثة المباشرة بين الطلاب من جهة ومع اعضاء هيئة التدريس من جهة اخرى. ومن الوظائف التي تقوم بها المنصة التعليمية لكلية الحاسوب وتكنلوجيا المعلومات والمتمثلة في:

- بناء الوسائط والمواد التعليمية وتوفيرها للطلاب لاستخدامها في اي وقت واي مكان.
- توفير الروابط العملية اللازمة لبناء محتوى المقرر.
- كسر الحواجز النفسية بين المعلم والطالب والتي يعاني منها الطالب داخل القاعة الدراسية.
- التفاعل مع المحتوى التعليمي بدون اي عائق نفسي مما يساعده على استقاء المعلومات والحوار والمناقشة بينة وبين المعلم.
- التفاعل بين مجموعة الطلاب يعطي الفرصة لمختلف الطلاب لإظهار أنفسهم ومشاركة الافكار والآراء واتاحة الفرصة لكل طالب بأجراء المحادثات والمناقشات بينة وبين اقرأنه دون التقيد بمواعيد محددة.

شكل 11: واجهة (9) الدردشات

3) مخرجات المنصة التعليمية المحلية:

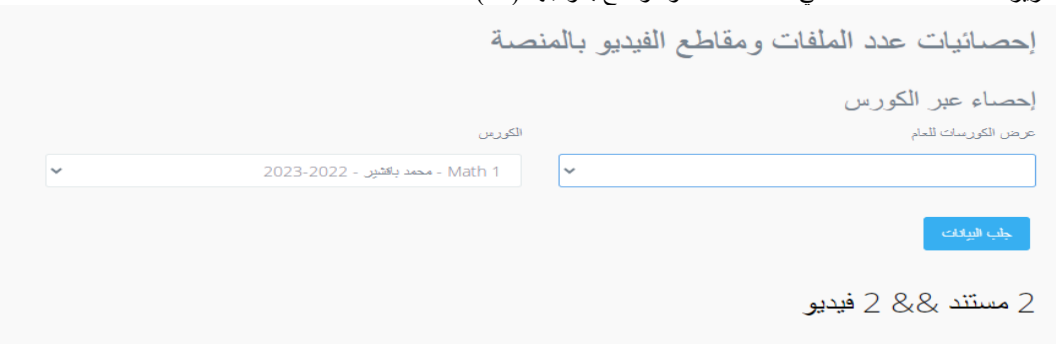
توفر المنصة التعليمية المحلية مجموعة متنوعة من التقارير والاحصائيات وهي على النحو التالي:

1- تقارير احصائية: تعرض مجموعة من الاحصائيات الخاصة بالعمل داخل المنصة:

a. تقرير الدخول اليومي والشهري للمنصة كما هو موضح بالواجهة (10).

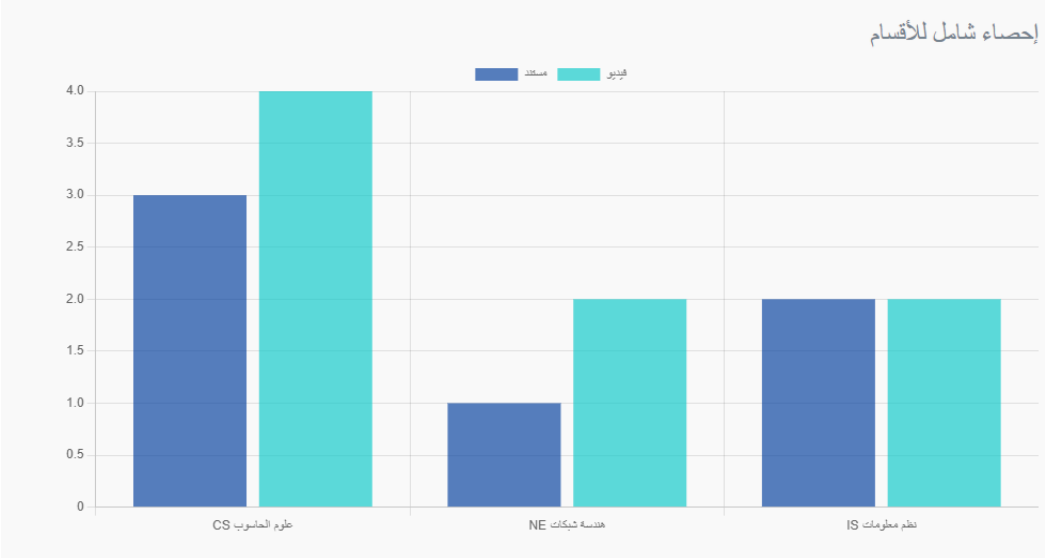
شكل 12: واجهة (10) احصائيات دخول المنصة

b. تقرير عدد الملفات لكل مادة في المنصة كما هو موضح بالواجهة (11).



شكل 13: واجهة (11) احصائيات الملفات المرفوعة إلى المنصة

c. مخطط بياني يبين عدد الملفات في كل قسم علمي، كما هو موضح بالواجهة (12).



شكل 14: واجهة (12) مخطط عدد الملفات لكل قسم علمي

2- تقارير بيانات الطلاب: توفر المنصة التعليمية المحلية مجموعة من التقارير الخاصة ببيانات الطلاب الشخصية والاكاديمية وهي على النحو الموضح بالواجهة (13).

شكل 15: واجهة (13) بيانات الطلبة الشخصية والأكاديمية

4) دليل تفصيلي حول إدارة المنصة:

اولًا: الفئات العاملة على المنصة التعليمية المحلية:

تتمتع المنصة التعليمية المحلية ببيئة عمل أمنه حيث تشتمل على مجموعة من الضوابط والصلاحيات للوصول للبيانات، لذا فإن الوصول والعمل على المنصة التعليمية المحلية يتم وفقاً للصلاحيات الممنوحة للمستخدم من قبل ادارة المنصة. ووفقاً لذلك يصنف مستخدمو المنصة التعليمية المحلية وفق الصلاحيات الممنوحة لهم إلى ثلاثة أقسام وهم مدير المنصة التعليمية المحلية، المدرسون، الطلبة.

1. مدير المنصة التعليمية المحلية:

يتولى مدير المنصة مهام إدخال او تعديل البيانات الاساسية للمنصة وهو الوحيد المخول بذلك :

- ادخال بيانات الكلية الاساسية : يحصل مدير النظام على البيانات من عمادة الكلية ثم يدخلها الى النظام .
- عمل التحديثات اللازمة لعمل المنصة : يقوم مدير النظام بالدخول لهذه الصفحة عند حصول اي تعديلات على البيانات الاساسية للمنصة او تحديثات عليها .

- ادخال وتعديل بيانات الاقسام العلمية : يقوم مدير النظام بادخال او تعديل بيانات الاقسام العلمية ويحصل على البيانات من نيابة الشؤون الاكاديمية .
- ادخال وتعديل بيانات رؤساء الاقسام العلمية : ويحصل على قرارات تعيين رؤساء الاقسام العلمية من مدير مكتب عميد الكلية وشؤون السكرتارية.
- ادخال بيانات المدرسين الاساسية مع اللقب العلمي : يقوم مدير المنصة بادخال البيانات بعد الحصول عليها من نيابة الشؤون الاكاديمية .
- صفحة تحديد المواد التي يدرسها المدرس في الفصل الحالي : يقوم مدير المنصة بادخال البيانات بعد الحصول عليها من نيابة الشؤون الاكاديمية .
- رفع بيانات الطلاب و العلامات من ملفات اكسل Excel : يقوم مدير المنصة برفع البيانات من ملف اكسل Excel أو ادخالها بشكل يدوي، وذلك بعد الحصول عليها من نيابة شؤون الطلاب .
- تعديل المحاضرات والاشراف عليها : يقوم مدير المنصة برفع المحاضرات بعد الحصول عيها من المدرسين او التعديل على الملفات في حالة حصول تعديل عليها .
- الدرجات: صفحة لعرض درجات الطلبة لكل مادة ، يقوم مدير المنصة برفع البيانات من ملف اكسل Excel بعد الحصول عليها من نيابة شؤون الطلاب .

يملك مدير المنصة صلاحيات كاملة للعمل داخل المنصة ويشترط في مدير المنصة ان يكون ذو معرفة كافية في تقنية لمعلومات وإدارة مواقع الويب والشبكات وكذلك يملك قدرة للتعامل مع برامج الوسائط المتعددة والعمل عليها .

2. المدرسون:

ويشكلوا العنصر الاساسي الآخر في المنصة لكي تستقيم العملية التعليمية ويقوم مدرس كل مساق علمي بالتالي:

- ادخال المحاضرات (فيديو – شرائح – ملفات PDF - ...) : في هذه الصفحة يقوم مدرس المساق برفع المحاضرات وكذلك التمارين الخاصة بالمادة الدراسية الخاصة به.
- صفحة النقاشات العلمية بين الطلبة ومدرسيهم : صفحة للشات حيث توجد لكل مادة صفحة للنقاش بين الطلبة ومدرس المادة بحيث يقوم المدرس بالاجابة على استفسارات الطلبة .

3. الطلبة :

ويشكل العنصر الاساسي الاخر وهم محور العملية التعليمية في المنصة، ويتمكن كل طالب من التالي:

- عرض مواد الفصل الحالي مع المدرسين : يعرض في هذه الصفحة المواد التي يدرسها الطالب في الفصل الحالي مع المدرسين لكل مادة، مع امكانية عرض مواد الفصول الماضية، يتم ادخال البيانات عن طريق مدير النظام او مدرسوا المواد .
- المحاضرات : تعرض هذه الصفحة محاضرات (فيديو- عرض تقديمي – PDF) لكل مادة بعد ان يقوم مدير النظام او مدرس المادة بادخال البيانات .
- النقاشات العلمية بين الطلبة ومدرسيهم : صفحة للشات حيث توجد لكل مادة صفحة للنقاش بين الطلبة ومدرس المادة بحيث يقوم المدرس بالاجابة على استفسارات الطلبة .
- العلامات : صفحة لعرض درجات الطلبة لكل مادة ، يقوم مدير النظام برفع البيانات من ملف اكسل Excel بعد الحصول عليها من نيابة شؤون الطلاب .

ثانيًا: بيئة التنفيذ للمنصة التعليمية المحلية:

تم تنفيذ المنصة التعليمية المحلية في رحاب كلية الحاسوب وتكنولوجيا المعلومات حيث تم وضع السيرفر الخاص بالمنصة في مكتب ادارة امن المعلومات والشبكات وتم ربط الشبكة بين الادارة والمختبرات وكذلك وضع نقطة اتصال لاسلكية للوصول اللاسلكي للشبكة ثم الدخول للمنصة. وعليه فانه قبل الشروع في تنفيذ المنصة التعليمية المحلية ينبغي ان تتوفر متطلبات التنفيذ التالية:

المتطلبات المادية Hardware:

- سيرفر للمنصة التعليمية المحلية (Intel Xeon Processor – RAM 16 GB- NIC 10/100/1000- Hard Disk 2TB SSD).
- Switch لتوصيل الشبكة المحلية.
- اسلاك شبكة UTP .
- Access pointللشبكة اللاسلكية ذا سرعة عالية 300mbps او أعلى.

المتطلبات البرمجية Software:

- ويندوز سيرفر 2012 او اعلى .
- الخادم المحلي لاراغون Laragon : لصناعة سيرفر محلي افتراضي . تحتوي حزمة البرامج على خادم الويب Apache ونظام إدارة قواعد البيانات MySQL (أو MariaDB) ولغتي البرمجة Perl و PHP. ويدعم جميع انظمة التشغيل .
- نظام إدارة قواعد البيانات MySQL : يتم تخزين البيانات فيها.

المتطلبات البيئية:

- كابينة للسيرفر ومتطلبات الشبكة من سويتش وأسلاك شبكة UTP .
- تكييف لغرفة السيرفر .
- مصدر تيار كهربائي متردد غير منقطع .
- منظم كهربائي .
- توصيلات كهربائية .

المتطلبات البشرية:

فني كمبيوتر واحد على الاقل يكون ذو معرفة تقنية ومعرفة في الوسائط المتعددة ليتمكن من فحص الملفات المقدمة من أعضاء هيئة التدريس ورفعها للمنصة.

تحديد أفراد عينة الدراسة:

- اختيار عينة من طلاب برنامج نظم المعلومات في كلية الحاسوب وتكنولوجيا المعلومات بجامعة عدن.
- تمثيل متوازن للعينة وفقًا للجنس .

إجراء الاختبارات القبلية والبعدية:

- تنفيذ اختبار تحصيلي قبل استخدام المنصة لقياس المستوى المعرفي الأولي للطلاب.
- تنفيذ اختبار بعدي بعد استخدام المنصة لتقييم مدى تأثيرها على التحصيل العلمي.

تحكيم الاستبانة الخاصة باتجاهات الطلاب:

- تصميم استبانة لقياس رضا الطلاب عن استخدام المنصة التعليمية المحلية.
- عرض الاستبانة على محكمين متخصصين لضمان دقتها وموضوعيتها.

توزيع الأداة الإلكترونية:

- إرسال الاستبانة إلى الطلاب إلكترونيًا وجمع الاستجابات.
- تم استرجاع (40) استبانة صالحة للتحليل الإحصائي.

إدخال البيانات وتحليلها إحصائيًا:

- إدخال البيانات في برنامج التحليل الإحصائي.SPSS
- استخدام التكرارات، المتوسطات الحسابية، النسب المئوية، والانحرافات المعيارية لتحليل البيانات.

مقارنة النتائج مع الدراسات السابقة:

- تحليل البيانات ومقارنتها بنتائج الدراسات السابقة لتحديد أوجه التشابه والاختلاف.
- استخلاص التوصيات بناءً على النتائج المتحصل عليها.

المعالجات الإحصائية المستخدمة:

- التكرارات، المتوسطات الحسابية، النسب المئوية، والانحرافات المعيارية.
- اختبار "ت" لعينتين مستقلتين.(Independent t-test)
- اختبار "ت" لعينتين مرتبطتين.(Dependent t-test)
- معامل ارتباط بيرسون لقياس قوة العلاقة بين المتغيرات.
- معامل ألفا كرونباخ (Cronbach's Alpha) لقياس ثبات الاستبانة.

XI. النتائج:

تمت الإجابة عن سؤال البحث الرئيسي عن طريق الإجابة عن أسئلة البحث الفرعية الثلاثة، حيث بعد الانتهاء من كتابة الإطار النظري للبحث وأيضًا بعد الانتهاء من بناء المنصة وضبط المعايير يكون قد تم الإجابة على السؤال الفرعي الأول والثاني، وبعد تنفيذ التجربة واستخدام المنصة التعليمية المحلية من قبل عينة الدراسة (طلاب المستوى الثاني في برنامج نظم المعلومات بكلية الحاسوب وتكنولوجيا المعلومات بجامعة عدن)، تم جمع البيانات وتحليلها باستخدام أدوات التحليل الإحصائي تمت الإجابة على السؤال الفرعي الثالث عبر اختبار صحة فرضيات البحث، حيث أظهرت النتائج أن المنصة التعليمية أثرت إيجابًا على رضا الطلاب ومستوى تفاعلهم مع المحتوى التعليمي، مما ساهم في تحسين تجربتهم التعليمية بشكل ملحوظ.

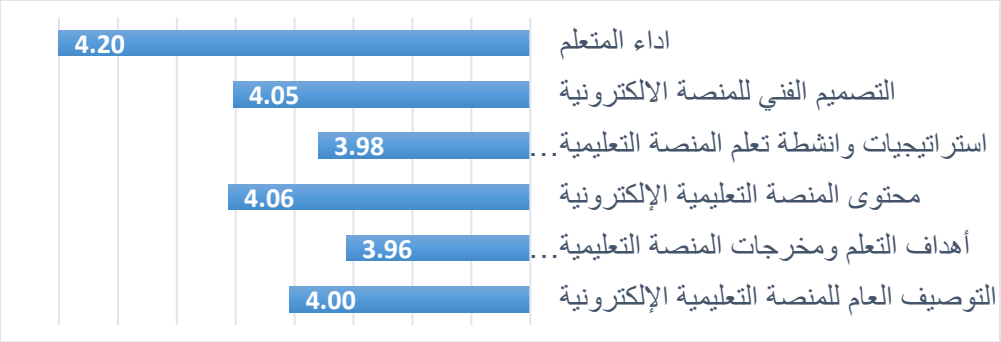
اولاً: تحليل الفرض الأول

لاختبار صحة الفرض الأول تم تحليل الإستبيان ، حيث أظهر تحليل استجابات الاستبيانات ارتفاعًا ملحوظًا في رضا الطلاب بعد استخدام المنصة مقارنةً بما قبلها، كما هو موضح :

محاور الاستبانة:

جدول (6) مخطط محاور الاستبانة:

الموضوع	حجم العينة	المتوسط الحسابي	الانحراف المعياري	النسبة المئوية	اختبار (t)	مستوى الدلالة	الاتجاه
المحور الأول: التوصيف العام للمنصة التعليمية الإلكترونية	40	4.00	.606	80.08	10.486	0.000	اوافق
المحور الثاني: أهداف التعلم ومخرجات المنصة التعليمية الإلكترونية		3.96	.622	79.13	9.857	0.000	اوافق
المحور الثالث: محتوى المنصة التعليمية الإلكترونية		4.06	.661	81.13	9.716	0.000	اوافق
المحور الرابع: استراتيجيات وانشطة تعلم المنصة التعليمية الإلكترونية		3.98	.682	79.60	9.712	0.000	اوافق
المحور الخامس: التصميم الفني للمنصة الالكترونية		4.05	.685	81.05	10.109	0.000	اوافق
المحور السادس: اداء المتعلم		4.20	.609	84.00	9.087	0.000	اوافق



شكل 16: للمتوسط الحسابي لمحاور الاستبانة

مما سبق نجد ان نسبة (80.83%) من افراد عينة الدراسة راضين على محاور الدراسة التي تحقق فرضية الدراسة حيث بلغ المتوسط الحسابي للموافقين (4.04) وهو يعتبر قيمة كبيرة، وكذلك من الجدول السابق نجد أن قيمة (t) المحسوبة لجميع المحاور حيث بلغت اقل قيمة (9.087) وهي اكبر من قيمة (t) الجدولية (2.021) عند مستوى دلالة (0.05)، وتساوي (3.551) عند مستوى دلالة (0.001) عند درجة الحرية (40).

مما سبق يتضح ان قيمة (t) المحسوبة أكبر من قيمة (t) الجدولية مما يدل على وجود فرق ذو دلالة إحصائية لصالح التطبيق البعدي. وبذلك تم التحقق من عدم صحة الفرض الأول وقبول الفرض البديل، ونصه:

"توجد فروق ذات دلالة احصائية عند مستوى دلالة (α=0.05) بمستوى رضا الطلبة الذين يدرسون باستخدام البيئة التعليمية القائمة على المنصات التعليمية المحلية في التطبيق القبلي والبعدي."

تحليل الفرض الثاني

لاختبار صحة الفرض الثاني اعتمد البحث على الاستبيان السابق، ولكن تم تفصيل الاجابات على مستوى الذكور والاناث، وبما اننا نبحث على رضا الطلبة على مستوى الأداء تم تحليل محاور الاستبيان كالتالي:

جدول (7) تحليل محاور الاستبيان بحسب الجنس

الجنس	N حجم العينة	المتوسط الحسابي Mean	اتجاه المحور	الانحراف المعياري Std. Deviation	درجة الحرية df	قيمة T	Sig (2-tailed).	الدلالة الإحصائية	
المحور الأول	ذكر	13	3.83	اوافق	.923	38	1.247	.220	غير دال إحصائياً عند مستوى α=0.05
	أنثى	27	4.09	اوافق	.368				
المحور الثاني	ذكر	13	3.94	اوافق	.908		.097	.923	غير دال إحصائياً عند مستوى α=0.05
	أنثى	27	3.96	اوافق	.448				
المحور الثالث	ذكر	13	3.84	اوافق	.882		1.481	.147	غير دال إحصائياً عند مستوى α=0.05
	أنثى	27	4.16	اوافق	.510				
المحور الرابع	ذكر	13	3.89	اوافق	.958		.559	.579	غير دال إحصائياً عند مستوى α=0.05
	أنثى	27	4.02	اوافق	.518				
المحور الخامس	ذكر	13	3.83	اوافق	1.002		1.476	.148	غير دال إحصائياً عند مستوى α=0.05
	أنثى	27	4.16	اوافق	.450				
المحور السادس	ذكر	13	4.02	اوافق	1.078		1.054	.299	غير دال إحصائياً عند مستوى α=0.05
	أنثى	27	4.29	اوافق	.572				

من الجدول السابق نلاحظ ان عدد الذكور (13) وعدد الاناث (27) والمتوسطات الحسابية للمحاور الستة بين الذكور والاناث جميعها في الاتجاه (موافق)، تم إجراء اختبار (t) لعينتين مستقلتين لمقارنة [مستوى رضاء الطلبة الذين يدرسون باستخدام البيئة التعليمية القائمة على المنصات التعليمية المحلية] بين [الذكور] و[الإناث]؛ وليس هناك فروق ذات دلالة إحصائية عند مستوى الدلالة (α=0.05) في [مستوى الرضا] بين [الذكور] و [الإناث]

وبهذا نقبل الفرض الصفري الذي نصه "لا توجد فروق ذات دلالة احصائية عند مستوى الدلالة (α=0.05) بمستوى رضا الطلبة الذين يدرسون باستخدام البيئة التعليمية القائمة على المنصات التعليمية المحلية بين الذكور والإناث، أي يعزى الفرق إلى الجنس"، ونرفض الفرض البديل.

وبهذا وجدنا ان استخدام المنصة التعليمية المحلية لا تتأثر بمتغير الجنس على مستوى رضا الطلبة، وكلا الجنسين (الذكور والاناث) كانت اتجاهات اجاباتهم في الاستبانة إلى الاتجاه (موافق) وهذا يدل ان المنصة التعليمية المحلية تحضى بقبول كلا الجنسين، وصالحة للإستخدام بالنسبة للذكور والاناث على حدٍ سواء.

تحليل النتائج

- فاعلية المنصة: النتائج تؤكد أن المنصة التعليمية المحلية كانت فعالة في تحسين تجربة التعلم وزيادة رضا الطلاب، مما يعكس أهمية تصميم أدوات تعليمية تتماشى مع احتياجات السياق المحلي.
- أثر التفاعل: التفاعل المتزايد داخل المنصة بين الطلاب وأعضاء هيئة التدريس ساهم في تعزيز دافعيتهم للتعلم.
- التغلب على التحديات: أثبتت المنصة جدواها في تقديم حلول للتحديات التقنية التي تعاني منها البيئة التعليمية في اليمن، مثل ضعف البنية التحتية للإنترنت.

تحليل النتائج والمناقشة

1. *تحليل النتائج*

- أثر التفاعل داخل المنصة:

أكدت النتائج أن المنصة ساعدت في زيادة التفاعل بين الطلاب وأعضاء هيئة التدريس، مما ساهم في تعزيز دافعيتهم للتعلم.

تتفق هذه النتيجة مع دراسة تمارا وآخرون، التي أوضحت أن المنصات التعليمية الرقمية في الجامعة الأردنية عززت التفاعل بين الطلبة والمعلمين.

كما تتماشى مع توصيات دراسة شريف والدولات، التي أكدت على ضرورة استخدام المنصات التعليمية في تدريس العلوم لتعزيز تفاعل الطلاب داخل البيئة التعليمية.

- التغلب على التحديات التقنية:

أثبتت الدراسة أن المنصة المحلية ساهمت في التغلب على بعض التحديات التقنية التي تعاني منها البيئة التعليمية في اليمن، مثل ضعف البنية التحتية للإنترنت.

هذه النتيجة تدعم نتائج دراسة الدوسري، التي أشارت إلى أن بعض المنصات التعليمية تواجه تحديات في الاستخدام بسبب المشكلات التقنية.

كما تتوافق مع نتائج أبو شخيدم، التي أكدت أن التعليم الإلكتروني خلال جائحة كورونا واجه صعوبات مثل قلة التدريب وضعف البنية التحتية، وهو ما تحاول الدراسة الحالية معالجته من خلال تطوير منصة محلية يمكن تشغيلها دون الحاجة إلى اتصال مستمر بالإنترنت.

2. *مناقشة النتائج*

- رضا الطلبة عن التعليم الإلكتروني عبر المنصة المحلية

أظهرت الدراسة أن الطلبة أبدوا استجابة إيجابية تجاه التعليم الإلكتروني باستخدام المنصة المحلية، وهو ما يتوافق مع:

دراسةFrishta Amiri ، التي وجدت أن الطلاب يرون المنصات التعليمية سهلة الاستخدام وفعالة في تحسين التعلم.

دراسة الصيداوي، التي استخدمت استبيانات لقياس اتجاهات الطلاب نحو التعلم الإلكتروني، ووجدت أن معظم الطلاب لديهم مواقف إيجابية تجاه استخدام المنصات الرقمية.

كما تتماشى مع نتائج دراسة الغامدي، التي أشارت إلى أن المنصات التعليمية تعزز التفاعل بين الطلاب والمعلمين، مما يزيد من اهتمام الطلاب بالمحتوى التعليمي.

XII. التوصيات

أشارت نتائج الدراسة إلى أن المنصة التعليمية المحلية مهمه جداً في العملية التعليمية حيث ان اتجاهات الطلبة نحو المنصة التعليمية المحلية هو باتجاه (راض)، لذلك يوصي البحث بما يلي:

1 تحسين البنية التحتية التقنية للمنصة التعليمية:

توسيع نطاق الشبكة المحلية: يُوصى بتوسيع نطاق الشبكات المحلية اللاسلكية لتغطية المزيد من المناطق في الكليات المختلفة لضمان الوصول السلس إلى المنصة التعليمية من أي مكان داخل الجامعة.

تحسين الأجهزة والمعدات: من الضروري تحسين البنية التحتية التقنية مثل أجهزة الحواسيب وأجهزة الشبكات في الجامعة لضمان قدرة المنصة على استيعاب أعداد كبيرة من الطلاب.

2 توفير التدريب المستمر للمعلمين والطلاب:

تدريب المعلمين: يُوصى بتنظيم ورش عمل دورية لتدريب المعلمين على استخدام المنصة بشكل فعال، بما في ذلك تصميم المحتوى التفاعلي، إدارة الفصول الافتراضية، واستخدام الأدوات التحليلية لمتابعة أداء الطلبة.

تدريب الطلبة: يجب توفير دورات تعريفية للطلاب حول كيفية استخدام المنصة بفعالية، والاعتماد على مواردها المتاحة، لضمان الاستفادة القصوى منها.

3 زيادة دعم المحتوى التفاعلي:

إثراء المحتوى التعليمي: يجب على الكليات تقديم مزيد من المحتوى التعليمي التفاعلي مثل الفيديوهات التعليمية، والمحاضرات المسجلة، والاختبارات القصيرة. هذا من شأنه أن يجعل العملية التعليمية أكثر تشويقًا ويحفز الطلاب على التفاعل مع المواد التعليمية.

استخدام التعليم المدمج: يُوصى بتعزيز نمط التعليم المدمج الذي يجمع بين التعليم التقليدي والرقمي. يمكن استخدام الفصول الافتراضية إلى جانب الحضور الجسدي في بعض المواد العملية التي تحتاج إلى التجربة العملية.

4 الإستفادة من التغذية الراجعة وتحليل البيانات:

تحليل أداء الطلبة: يُوصى بتطبيق أدوات تحليل أداء الطلبة على المنصة لمتابعة تقدمهم الأكاديمي بشكل دوري، وتحديد المشكلات التي تواجههم في استخدام المنصة، مما يساعد على تحسينها باستمرار.

تحسين التقييمات الإلكترونية: من الضروري تطوير أدوات التقييم الإلكتروني لتكون أكثر شمولًا ومرونة، مثل توفير اختبارات موجهة وواجبات تفاعلية على المنصة.

5 إستمرارية الدعم الفني للمنصة:

توفير دعم فني مستمر: يُوصى بإنشاء فريق دعم فني متخصص لحل المشكلات التقنية التي قد تواجه الطلبة والمعلمين أثناء استخدام المنصة. يجب أن يكون الفريق متاحًا على مدار الساعة لضمان استمرارية التعليم دون انقطاع.
تحسين سرعة الاستجابة: يجب تحسين سرعة استجابة المنصة وتجنب الأعطال التقنية لضمان تجربة تعليمية سلسة للطلاب والمعلمين.

6 تعزيز ثقافة التعليم الإلكتروني في الجامعة:
تشجيع تبني التعليم الإلكتروني: يجب على إدارة الجامعة تشجيع أعضاء هيئة التدريس على تبني التعليم الإلكتروني واستخدام المنصات المحلية بفاعلية. يمكن تقديم مكافآت أو حوافز للمعلمين الذين يطورون محتوى تعليمي إلكتروني مميز.
زيادة الوعي بأهمية التعليم الإلكتروني: ينبغي القيام بحملات توعية موجهة للطلبة وأولياء الأمور حول أهمية التعليم الإلكتروني ودوره في تحسين جودة التعليم.

7 تعميم التجربة على الكليات الأخرى:
توسيع نطاق المنصة: بناءً على النتائج الإيجابية التي تم التوصل إليها في كلية الحاسوب وتكنولوجيا المعلومات، يُوصى بتوسيع استخدام المنصة لتشمل جميع الكليات والتخصصات في الجامعة. هذا يمكن أن يساعد في تحقيق تحسن شامل في التحصيل الأكاديمي للطلبة في مختلف التخصصات.

8 إجراء أبحاث إضافية حول تأثير التعليم الإلكتروني على مهارات الطلبة:
يُوصى بإجراء دراسات مستقبلية حول تأثير التعليم الإلكتروني باستخدام المنصة المحلية على مهارات الطلبة في جوانب متعددة، مثل التفكير النقدي، والعمل الجماعي، ومهارات حل المشكلات، لمعرفة مدى تأثير هذا النمط من التعليم على المهارات الحياتية والشخصية للطلبة.

9 تحسين الجانب العملي للتعليم الإلكتروني:
تعزيز التعليم العملي الافتراضي: بالنسبة للتخصصات التي تعتمد على الجانب العملي مثل الحاسوب والهندسة، يُوصى بتطوير مختبرات افتراضية على المنصة، بحيث يتمكن الطلبة من تنفيذ التجارب والمحاكاة العلمية بشكل افتراضي.

XIII. المراجع

[1] ر. الغامدي، "تأثير المنصات التعليمية على تفاعل الطلاب مع المعلمين والمحتوى التعليمي"، *مجلة التعليم الإلكتروني*، م. 7، ع. 2، ص. 55–70، 2019.
[2] أ. محمد و م. علي، "معايير تصميم المنصات التعليمية الإلكترونية"، *مجلة التعليم الإلكتروني*، م. 8، ع. 1، ص. 50–65، 2020.
[3] منظمة الأمم المتحدة للتربية والعلم والثقافة (اليونسكو)، *إرشادات لتصميم منصات التعلم الرقمي*، اليونسكو، 2019.
[4]م. الخطيب، "فاعلية المنصات التعليمية المحلية في تحسين جودة التعلم في البيئات ذات البنية التحتية الضعيفة"، *مجلة دراسات تكنولوجيا التعليم*، م. 14، ع. 2، ص. 75–92، 2021.
[5] R. Puri, "The Impact of Interactive Learning Platforms on Student Engagement," *Journal of E-Learning Research*, vol. 19, no. 3, pp. 120–137, 2021.
[6]م. الجاد الله، "معايير تقييم المنصات التعليمية الإلكترونية"، *المؤتمر الدولي للتعليم الرقمي*، جامعة القاهرة، ص. 205–220، 2021.
[7]س. الباوي و ع. غازي، "أثر استخدام منصة Google Classroom على تحصيل طلبة قسم الحاسبات"، *مجلة تكنولوجيا التعليم*، م. 12، ع. 3، ص. 78–92، 2019.
[8]ح. الميلبي، "تأثير المنصات الإلكترونية على مستوى تحصيل الطلاب: دراسة تجريبية"، *مجلة التعليم الرقمي*، م. 14، ع. 1، ص. 35–50، 2022.
[9]أ. الذهلي، "أثر المنصات التعليمية على تحصيل طلاب مادة الرياضيات"، *مجلة أبحاث التربية*، م. 18، ع. 1، ص. 22–40، 2024.
[10] F. Amiri, "Student Satisfaction with E-Learning Platforms: A Case Study," *International Journal of Educational Technology*, vol. 21, no. 1, pp. 15–32, 2024.
[11]خ. الصيداوي، "اتجاهات الطلاب نحو التعلم الإلكتروني باستخدام المنصات التعليمية"، *مجلة العلوم التربوية*، م. 10، ع. 4، ص. 99–113، 2023.
[12]ف. الدوسري، "تقييم استخدام أعضاء هيئة التدريس للمنصات التعليمية في تدريس اللغة الإنجليزية"، *مجلة التعليم العالي*، م. 9، ع. 1، ص. 33–48، 2016.
[13]م. أبو شخيدم، "فاعلية التعليم الإلكتروني أثناء جائحة كورونا من وجهة نظر المدرسين في جامعة فلسطين التقنية خضوري"، *مجلة التعليم الإلكتروني*، م. 15، ع. 2، ص. 45–67، 2020.
[14]ت. تمارا، م. محمد، ي. يوسف، و م. مجدلاوي، "دور المنصات الإلكترونية في تعزيز التفاعل بين الطلبة في الجامعة الأردنية"، *دراسات التعليم العالي*، 2014.
[15]أ. شريف و ي. الدولات، "توصيات حول استخدام المنصات التعليمية في تدريس العلوم لزيادة التفاعل"، *مؤتمر التعليم الرقمي*، جامعة عمان، ص. 180–195، 2019.
[16]أ. جمانة، "مدى استخدام معلمي الرياضيات للمنصات التعليمية وتأثيرها على التحصيل الدراسي"، *مجلة التعليم والتكنولوجيا*، م. 16، ع. 2، ص. 67–80، 2023.
[17]خ. الصيداوي، "اتجاهات الطلاب نحو التعلم الإلكتروني باستخدام المنصات التعليمية"، *مجلة العلوم التربوية*، م. 10، ع. 4، ص. 99–113، 2023.

LARVICIDAL ACTIVITY OF AMARANTHUS HYBRIDUS EXTRACT AND BIO-SYNTHESIZED COPPER NANOPARTICLES AGAINST MOSQUITO VECTORS

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Larvicidal Activity of Amaranthus Hybridus Extract and Bio-synthesized Copper Nanoparticles against Mosquito Vectors

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Abstract— This research covers the synthesis and characterization of Cu nanoparticles using leaf extract of Amaranthus hybridus and the larvicidal evaluation of Amaranthus hybridus and Cu nanoparticles. Nanoparticles are an important area in biotechnology that has been attracting interest recently. The bottom-up method of synthesizing nanoparticles using plant extract (green synthesis) was adopted for this study. In this study, copper nanoparticles were successfully synthesized using the leaf extract of African spinach and characterized using various instruments. The FTIR analysis reveals the presence of various functional groups, such as the O-H (hydroxy) group, which was observed at 3363 cm^{-1}; the O=C (carbonyl) group, which appears at 1633 cm^{-1}; the sp^3 C-H peak, which appears at 2924 cm^{-1}; C-C at 1014 cm^{-1}; and the Cu-O peak, which was observed at 676 cm^{-1}. A similar peak was not observed on the FTIR of Amaranthus hybridus. The SEM analysis shows crystalline irregular morphology. While the XRD analysis shows a face-centered cubic crystalline (FCC) shape, the size of the Cu nanoparticles was calculated to be 18.61 nm. The larvicidal activity of Amaranthus hybridus shows lethal concentration (LC) against Culex larvae; for the first instar, LC50 was found to be 40.42 mg/L, and LC90 was 82.08 mg/L. Second instar LC50 was 43.75 mg/L, and LC90 was 85.42 mg/L. For third/fourth instar, LC50 was 42.40 mg/L, while LC90 was 82.40 mg/L. Lethal dose/lethal concentration against Anopheles (LC50) for all instars was 32.86, 47.20, and 43.20 mg/L, respectively. LC90 was found to be (70.35, 87.20, 83.20) mg/L. The larvicidal activity of Cu NPs was calculated, and LC50 against Culex was found to be 22.20, 26.05, and 30.97 mg/L, respectively, and LC90 was found to be 42.20, 49.30, and 63.23 mg/L. While the LC50 of Anopheles larvae was found to be (28.84, 36.07, 35.40) mg/L and the LC90 was (52.09, 71.79, 64.60) mg/L, the correlation for both Culex and Anopheles' larvae was significant for all instars.

Keywords— Amaranthus Hybridus, Nanoparticles, Anopheles Larvae.

I. INTRODUCTION

Amaranthus hybridus falls under the Amaranthaceae family, encompassing 60-70 species. The Amaranthus genus is widespread across temperate and tropical zones worldwide, boasting about 70 species and 4,000 varieties [1]. In tropical African regions, its leaves and tender shoots are harvested and prepared by cooking, frying, or steaming, serving as a key food source during droughts [2]. Known as "amaranth" or "pigweed," Amaranthus hybridus is an annual herbaceous plant reaching heights of 1-6 feet. It contains phytochemicals such as alkaloids, flavonoids, tannins, saponins, phenols, phytic acids, and hydrocyanic acid, alongside nutrients like β-carotene, thiamine, riboflavin, niacin, pyridoxine, ascorbic acid, tocopherols, and amino acids [3]. Also, according to [4], Amaranthus hybridus contains alkaloids, flavonoids, saponins, and tannins, while glycosides, anthraquinones, and phlobatannins were not detected. Medicinally, the plant addresses conditions like eye, ear, and stomach issues; dysentery; diarrhea; and serves as a diuretic, lactation aid, and treatment for hemorrhoids, menstrual issues, venereal diseases, paralysis, epilepsy, convulsions, and spasms [1].

The global nanoparticle market has expanded with growing interest in nanotechnology. "Nanoparticle" derives from the Greek "nano," meaning "dwarf," referring to particles with a size of one-billionth of a meter in diameter [5]. These particles, ranging from 1 to 100 nanometers, have drawn significant focus over the last decade for their diverse applications, especially in medicine [6].

Materials sized 1-100 nm are universally recognized as nanoparticles or nanomaterials [7]. Their small scale enhances versatility, aiding cellular uptake and supporting in vitro research and industrial applications [8, 9]. Metal nanoparticles, formed from metal salts or precursors, are valued for their localized surface plasmon resonance (LSPR) traits, with alkali and noble metals like copper, silver, and gold showing broad absorption in the visible solar spectrum [10].

Mosquitoes are categorized under phylum Arthropoda, class Insecta, and order Diptera [11], with three subfamilies, namely Toxorhynchitinae, Anophelinae, and Culicinae [12]. Over 3,530 mosquito species exist, organized into 43 genera within the Culicidae family [13]. Among them, Anopheles, Aedes, and Culex stand out for transmitting diseases to humans, birds, and mammals [14]. The Anopheles genus, named by Johann Wilhelm Meigen in 1818, includes "nail" or "marsh" mosquitoes [15], primarily known for carrying malaria via the Plasmodium parasite, a major health concern in tropical and subtropical areas [16]. Of over 450 Anopheles species, roughly 40 efficiently spread malaria [17]. In Africa, dominant vectors like Anopheles fenestus and Anopheles gambiae span central regions, joined by Anopheles arabiensis in sub-Saharan West Africa, while Anopheles darlingi leads in South America, and Asia features species like Anopheles minimus, Anopheles punctulatus, and Anopheles dirus, complicating vector studies [18].

The Culex genus thrives in tropical and temperate regions, with around 770 species, some acting as disease vectors for birds, humans, and animals [19, 20]. Notable species like Culex pipiens and Culex quinquefasciatus are critical for transmitting diseases, aided by their ability to feed on both humans and animals, spreading West Nile virus, Japanese encephalitis, St. Louis encephalitis, filariasis, and avian

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malaria [21]. Culex mosquitoes are vital in epidemiology, carrying pathogens like the filariasis parasite and arboviruses, driving morbidity and mortality in subtropical and tropical zones [22].

A. Mechanism of Action of Metal Nanoparticles on Larvae

- Oxidative stress: metal nanoparticles induce the production of reactive oxygen species (ROS) that lead to oxidative damage in mosquito larvae [23]. Metal nanoparticles trigger oxidative stress by producing ROS such as superoxide (O_2-), hydroxyl radicals (OH.), and hydrogen peroxide (H_2O_2). In mosquito larvae, excessive ROS disrupt cellular balance by damaging lipids, proteins, and DNA.
- Membrane disruption: studies on Cu NPs have shown that they cause rupture in the midgut epithelium of larvae, causing leakage of cellular contents and impaired osmoregulation physical damage due to interaction of metal nanoparticles and cellular membrane [24] [25]. Similarly, the metal nanoparticles destabilize cell membranes through electrostatic interactions or direct physical damage. The positive charge of the metal nanoparticles enables them to bind to the negatively charged membrane components, altering membrane permeability.
- Enzyme inhibition: metal nanoparticles can interfere with enzyme activities that are crucial for larval survival and development [26]. Cu^{2+} ions from Cu nanoparticles suppress acetylcholinesterase, a key enzyme for function, resulting in paralysis and death. Also, metal nanoparticles impair proteases and amylases in the larval gut, hindering nutrient digestion and absorption, which prevents molting or pupation [27].
- Physical contact and cuticle penetration: Due to their nano size, metal nanoparticles interact directly with the larval cuticle (the protective outer layer). Metal nanoparticles also breach the cuticle via spiracles and the digestive tract, inflicting mechanical harm to epithelial cells [26].

B. Materials

Beaker, weighing balance, spatula, cuvette, stirring rod, syringe, hot plate, Whatman No. 1 filter paper, measuring cylinder, hot air oven, mortar and pestle, plastic cups, FTIR machine (PerkinElmer), spectrum version 10 03 09, UV-vis spectrophotometry machine (Jenway 6705), SEM machine (Hitachi 4160), and XRD spectrophotometer (X-pert plus). CuSO4. 6H2O, distilled water, KBr.

II. METHODOLOGY

A. Preparation of 0.1 M Copper Sulfate Hexahydrate (CuSO4. 6H20)

We weighed 6.69 g (0.025 mol.) of $CuSO_4 \cdot 6H_2O$ and transferred it into a 250 cm^3 volumetric flask. We added a little quantity of distilled water and then shook it until it completely dissolved, and then we filled it to the mark using distilled water.

B. Synthesis of Copper Nanoparticles

We poured 250 cm^3 of 0.1 M copper sulfate solution into a 500 cm^3 beaker. Using a syringe, we slowly added 62 cm^3 of aqueous Amaranthus hybridus leaf extract dropwise to the copper sulfate solution with continuous stirring. We maintained the temperature at 60°C. We observed a color change and noticed the formation of copper nanoparticles as precipitate formed. We allowed the reaction mixture to stand for 24 hours to let the particles settle. Then, we decanted the mixture, washed the residue with deionized water, and dried it at 110°C in a hot air oven for 6 hours to obtain fine Cu NPs. We adopted the method of [28] with little modification.

C. Characterization

We carried out various analyses and employed them for the characterization of the synthesized Cu nanoparticles. We employed various characterization techniques, which include UV-visible spectrophotometry, Fourier transform infrared (FTIR) spectrophotometry, scanning electron microscopy (SEM) coupled with energy dispersive X-ray (EDX), and X-ray diffraction (XRD).

D. UV-Visible Spectrophotometry

We collected a small aliquot of Cu nanoparticles and poured it into a clean cuvette, then placed it into the UV-Vis spectrophotometer (Jenway 6705) and scanned from 200 nm to 800 nm to find the wavelength of maximum absorbance (λmax). Then we varied the wavelength and ran it to find the absorbance. We used distilled water as a blank. We employed the method of [29]. With little modification.

E. Fourier Transform Infrared (FTIR)

We took 50 mg of Cu nanoparticles and mixed them with 250 mg of KBr. Using a hydraulic press, we made the mixture into a pellet and then pressed it into a disc. We used this disc to acquire the spectra within the range 4000–200 cm^{-1}.. We carried out the analysis using an FTIR spectrophotometer (PerkinElmer).

F. Scanning Electron Microscopy (SEM)

We conducted SEM analysis using SEM (Hitachi 4160) in order to determine the morphology, size, and composition of the element present in the synthesized nanoparticles.

G. X-Ray Diffraction (XRD) Analysis

We conducted XRD analysis using X-pert plus in order to find the average crystalline size. The Debye-Scherrer equation was used to calculate the average crystalline size. The Debye-Scherrer equation is as follows:

$D = K\lambda/\beta COS\theta$

Where D = particle size

K = Constant Volume

λ = X-ray wavelength (0.154nm)

θ = Bragg's angles (in degrees).

P = Line broadening at half the maximum intensity

H. Larvicidal Bioassay

We collected Culex and Anopheles' larvae from stagnant water in Gombe metropolis and sorted them into three groups based on their growth stages. We combined the third and fourth instars into one group due to the difficulty in obtaining a uniform population. Meanwhile, we prepared a 100 mg/L Cu NPs stock solution and used it to produce other subsequent concentrations through serial dilution. In a plastic cup, we filled it with 100 ml of distilled water to serve as the control. Next, we prepared 100 ml of 10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L, and 50 mg/L Cu Np concentrations, and then we placed 25 larvae into each concentration and assessed them for

larvicidal activity. We recorded the larval mortality after 24 hours of exposure.

I. Statistical Analysis

We calculated the percentage mortality using Abbott's formula. Then, we carried out probit analysis to determine lethal concentration at 50% (LC50) and lethal concentration at 90% (LC90), correlation, and chi-square distribution using statistical software SPSS 2016.

III. Result And Discussion

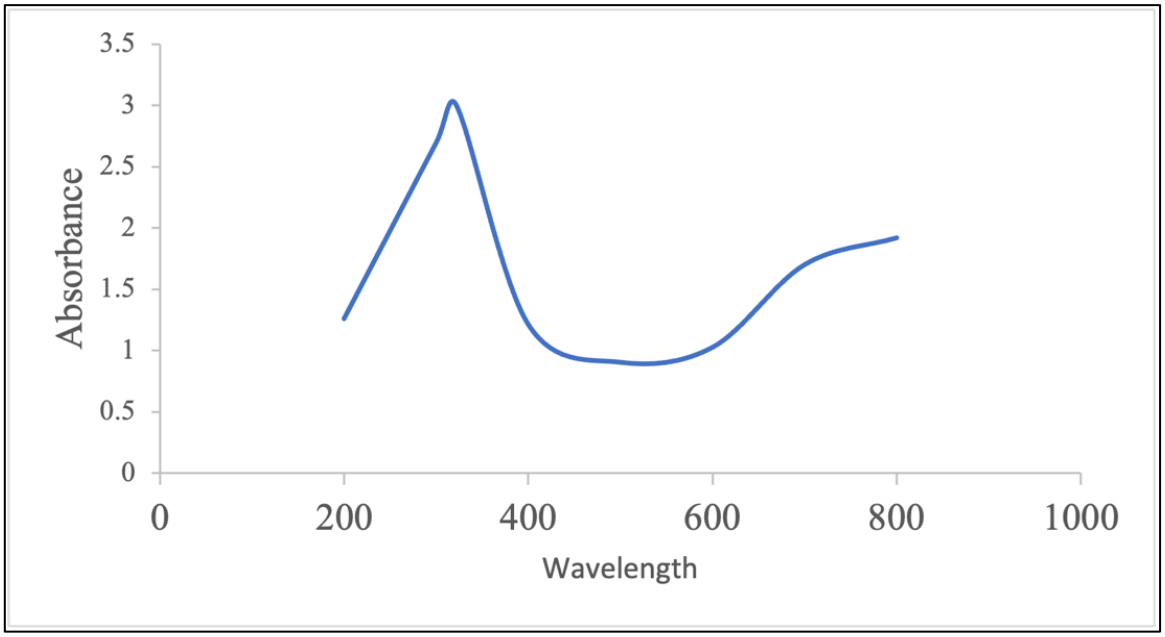

Fig. 1. Showing the result of UV-vis analysis of Cu NPs

The wavelength of maximum absorbance was found at 322 nm, which is near the region of absorbance of violet color, which corresponds to the change of color of the solution from light blue to dark blue. A similar λmax was found by [30], which shows the maximum absorbance at 340nm. The absorbance was ascribed to surface plasmon resonance. The wavelength of maximum absorbance λmax is affected by many factors; hence, the λmax of Cu NPs is not peculiar [31].

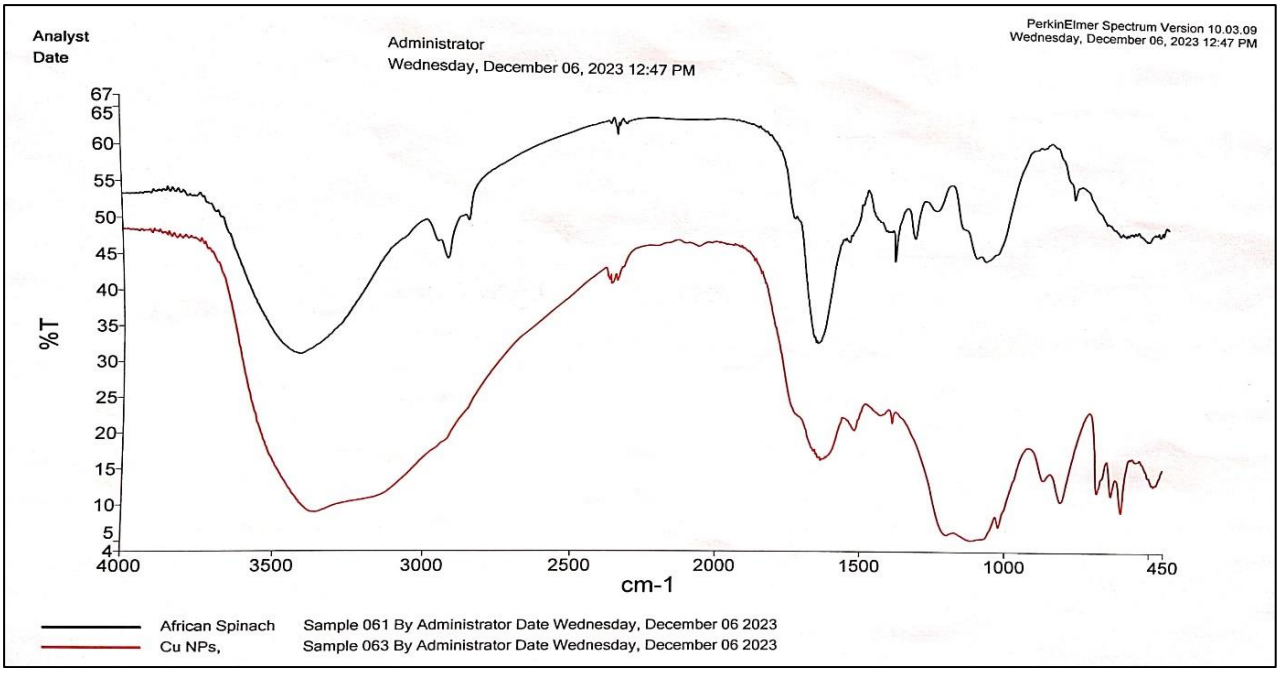

Fig. 2. Superimposed FTIR of African spinach and Cu NPs

Major peaks were observed at 3418 cm-1, 3363 cm-1, 2924 cm-1, 1644 cm-1, 1633 cm-1, 1384 cm-1, 1384 cm-1, 1072 cm-1 1014 cm-1, 676 cm-1 for the African spinach and Cu NPs which are due to vibration of bonds (stretching or bending) of molecules.

Table 1: Showing IR absorption (cm-1) frequencies of African spinach and Cu NPs

African spinach (Cm^{-1})	**Cu NPs (Cm^{-1})**	**Literature (Cm^{-1})**	**Assignment**	**Probable source**
3418 Br (S)	3363 Br (S)	3200-3500	OH	Alcohol, phenol, carboxylic acid, tannin, alkaloid, flavonoid
2924 Sh (M)	N. O	2800-3000	Sp^3 C-H	Alkane
1644 Sh (S)	1633 Sh (S)	1620-1680	C=O, C=C, C=N	Carbonyl, alkene, alkaloid, Aldehyde, ketone.
1314 Sh (M)	1384 Sh (S)	1360-1390	C-H, C-N	Amine, alkane, alkene, alkyl,
1072 Br (M)	1014 Br (S)	1150-1250	C-C, C-O	Carboxylic acid, alkane, ether, esther, alkoxy
N. O	676 Sh (S)	450-600	Cu-O	$CuSO_4$. $7H_2O$, Phytochemicals

Fig. 3. Showing the SEM result for Cu NPs

The SEM result of the Cu nanoparticles under ×500 magnification, as shown in figure 4, shows irregular surface morphology, mostly crystalline with triangular-like shapes of different sizes, which might be due to aggregation of the nanoparticles

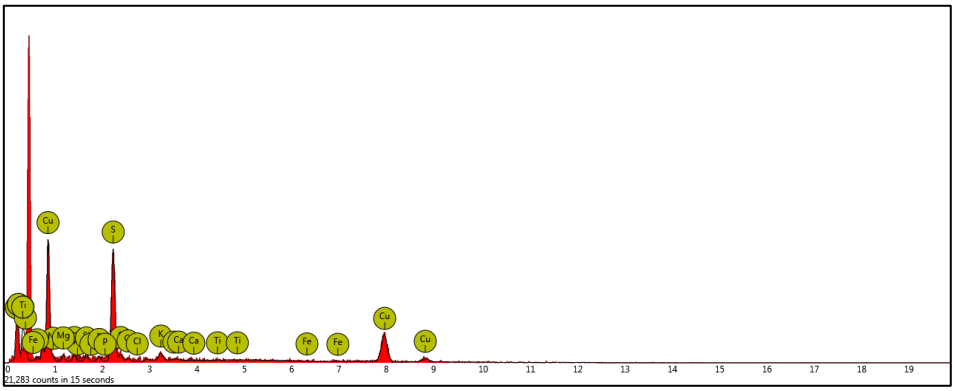

Fig. 4. The EDX of Cu NPs

In the copper NPs Cu and sulfur have the higher percentage of 60.54% and 23.85% while iron and titanium have the least percentage of 0.34% and 0.24% respectively. Other elements are in trace amounts.

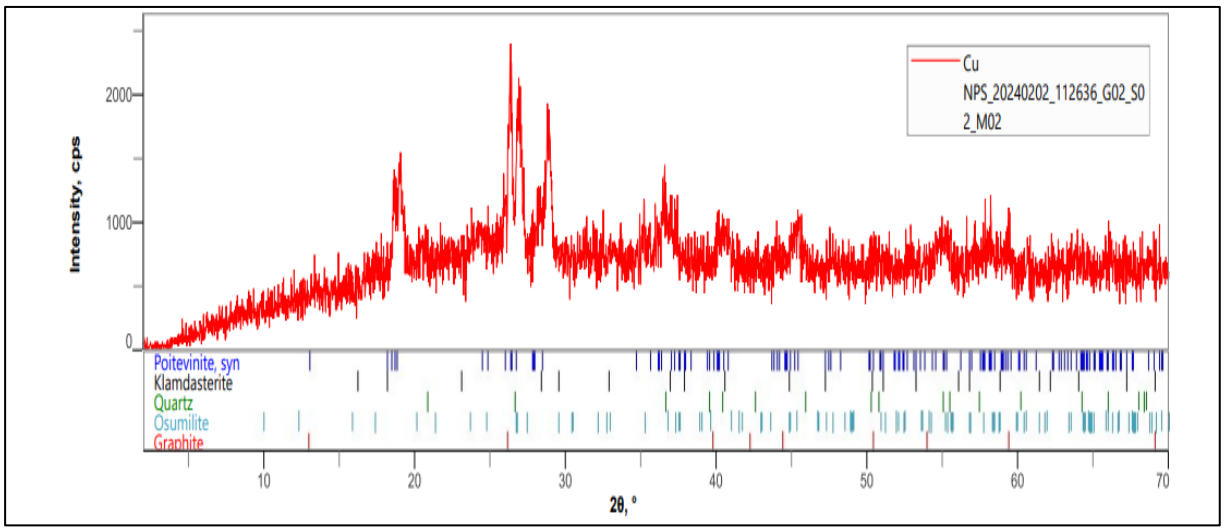

Fig. 5. Showing the XRD result of Cu NPs

The XRD analysis of the synthesized Cu nanoparticles shows eight (8) prominent peaks at 2θ = 19.02, 26.33, 26.87, 28.87, 36.51, 40.49, 45.27, and 55.20, which correspond to the planes of (200), (202), (220), (300), (321), (303), (323), and (404). Respectively, this shows a face-centered cubic (FCC) structure, which is in agreement with the crystalline structure of Cu. The sizes were calculated to be 12.5nm, 55.51nm, 16.92nm, 19.55nm, 8.62nm, 10.67nm, 13.61 nm, and 11.47 nm, respectively, and the average crystalline size was 18.61nm. This is similar to the report by [32] that found the average crystal size to be 11±1 nm.

Table 2: Showing the larvicidal activity of African spinach on culex larvae

CULEX	S/N	CONC (mg/L)	% MOTALITY	LC50 (mg/L)	LC90 (mg/L)	R	X^2
FIRST INSTAR	1	10	20	40.42	82.08	0.980	0.714
	2	20	28				
	3	30	44				
	4	40	52				
	5	50	56				
SECOND INSTAR	1	10	16	43.75	85.42	0.958	0.787
	2	20	24				
	3	30	44				
	4	40	48				
	5	50	52				
THIRD/ FORTH INSTAR	1	10	16	42.40	82.40	0.877	0.430
	2	20	20				
	3	30	52				
	4	40	48				
	5	50	52				

Table 2 above shows the result of larvicidal activity of plant extract on Culex larvae; the highest mortality was found to be 56%, 52%, and 52% at 50 mg/L for all instars, respectively. The lethal concentrations (LC) at 50% and 90% were calculated, and the results show good correlation.

Table 3: Showing the larvicidal activity of African spinach on anopheles' larvae

ANOPHELES	S/N	CONC (mg/L)	% MOTALITY	LC50 (mg/L)	LC90 (mg/L)	R	X^2
FIRST INSTAR	1	10	20	32.86	70.35	0.984	0.853
	2	20	28				
	3	30	48				
	4	40	56				
	5	50	64				
SECOND INSTAR	1	10	16	47.20	87.20	0.967	0.810
	2	20	20				
	3	30	28				
	4	40	48				
	5	50	52				
THIRD/ FORTH INSTAR	1	10	12	43.20	83.20	0.953	0.830
	2	20	28				
	3	30	44				
	4	40	48				
	5	50	52				

Table 3 above shows the result of larvicidal activity of African spinach on Anopheles' larvae; the highest mortality was found to be 62%, 52%, and 52% at 50 mg/L for all instars, respectively. The lethal concentrations (LC) at 50% and 90% were calculated, and the results show a good correlation above 0.9 for all instars. The mortality is attributed to the presence of phytochemicals in the leaves of the plant extract. This work can be compared to the work of [33], which found similar results.

Table 4: Showing the larvicidal activity of Cu nanoparticles on culex larvae

CULEX	S/N	CONC Mg/L	% MOTALITY	LC50 mg/L	LC90 mg/L	R	X^2
FIRST INSTAR	1	10	24	22.20	42.20	0.990	0.880
	2	20	44				
	3	30	68				
	4	40	92				
	5	50	100				
SECOND INSTAR	1	10	20	26.05	49.30	0.995	0.049
	2	20	44				
	3	30	56				
	4	40	72				
	5	50	92				
THIRD/ FORTH INSTAR	1	10	20	30.97	63.23	0.967	0.104
	2	20	36				
	3	30	56				
	4	40	64				
	5	50	68				

Table 4 above shows the result of larvicidal activity of Cu nanoparticles on Culex larvae; the highest mortality was found to be 100%, 92%, and 68% at 50 mg/L, while the lowest mortality (24%, 20%, and 20) % was recorded at 10 mg/L for all instars, respectively. The lethal concentrations (LC) at 50% and 90% were calculated, and the results show good correlation above 0.9 for all instars. Similar findings were reported by [34].

Table 5. Showing the larvicidal activity of Cu NPs on anopheles' larvae

ANOPHELES	S/N	CONC Mg/L	% MOTALITY	LC50 mg/L	LC90 mg/L	R	X^2
FIRST INSTAR	1	10	24	28.84	52.09	0.976	0.099
	2	20	32				
	3	30	44				
	4	40	68				
	5	50	92				
SECOND INSTAR	1	10	24	36.07	71.79	0.973	0.110
	2	20	28				
	3	30	40				
	4	40	60				
	5	50	64				
THIRD/ FORTH INSTAR	1	10	16	35.4	64.60	0.990	0.635
	2	20	32				
	3	30	40				
	4	40	60				
	5	50	68				

Table 5 above shows the larvicidal activity of Cu NPs on Anopheles' larvae. For the first instar, the LC50 was found to be 2.84 mg/L, 52.09 mg/L for LC90, and the correlation was 0.976. For the second instar, LC50 was 36.07 mg/L and LC90 was 71.79 mg/L, and the correlation was 0.973, while for the third/fourth instar, LC50 was 35.4 mg/L and LC90 was 64.60 mg/L with a correlation of 0.990. The highest mortality was recorded at 50 mg/L, while the lowest mortality was recorded at 10 mg/L. The correlation was significant; this work relates to the research done by [35].

IV. Conclusion

Cu NPs were synthesized using aqueous African spinach extract and the nanoparticles were obtained as a fine powder. The nanoparticles were subjected to series of characterization as follows, the UV analysis of the nanoparticles, the wavelength of maximum absorbance of was found at 322 nm for and Cu NPs. The FTIR analysis reveals the various functional groups that are present in the plant extract and Cu NPs the functional groups include hydroxy group (O-H), carbonyl (=O), Sp3 C-H, Sp2 C=H and metal-oxygen (M-O). The SEM analysis of Cu nanoparticles shows crystalline structure with irregular morphology. The XRD analysis of Cu nanoparticles shows FCC crystalline shape with size 18.61nm for Cu NPs.

The larvicidal activity of plant extract and Cu nanoparticles against culex and anopheles' larvae was carried out. The highest mortality was found at 50 Mg/L the lethal dose or lethal concentration (LC) was calculated for 50% and 90% mortality also the correlation shows higher significance with minimum of 0.861 and maximum of 0.995. Cu NPs was the most effective with lowest mortality of 20% and highest mortality of 100% for culex larvae and 16% lowest and 92% highest mortality for anopheles' larvae.

References

[1] Ogwu M. C., "Value of Amaranthus (L.) species in Nigeria," *IntechOpen*, 2020, doi: 10.5772/intechopen.86990.

[2] Mekonen T., Giday M., and Kelbessa K., "Ethnobotanical study of home garden plants in Sebeta-Awas District of the Oromia Region of Ethiopia to assess use, species diversity and management practices," *Journal of Ethnobiology and Ethnomedicine*, vol. 11, p. 64, 2015.

[3] Akubugwo I. E., Obasi N. A., Chinyere G. C., and Ugbogu A. E., "Nutritional and chemical value of Amaranthus hybridus L. leaves from Afikpo, Nigeria," *African Journal of Biotechnology*, vol. 6, no. 24, pp. 2833–2839, 2007.

[4] Usunobun U., Akoma O. C., and Ekpemupolo I. S., "In vitro antioxidant activity, minerals and phytochemical composition of Amaranthus hybridus leaves," *Journal of Basic and Applied Sciences*, vol. 2, no. 1, pp. 13–23, 2016.

[5] Plé J., Dabert M., Lecoq H., Hellé S., Ploux L., and Balan L., "Antimicrobial and mechanical properties of functionalized textile by nanoarchitectured photoinduced Ag polymer coating," *Beilstein Journal of Nanotechnology*, vol. 14, no. 1, pp. 95–109, 2023.

[6] Tahir I., Ali H., and Sonia G., "Synthesis of iron oxide, cobalt oxide and silver nanoparticles by different techniques," *International Journal of Science and Engineering Research*, vol. 7, no. 11, pp. 1178–1221, 2016, doi: 10.1142/S0219581X14300016.

[7] Nejabat M., Samie A., Ramezani M., Alibolandi M., Abnous K., and Taghdisi S. M., "An overview on gold nanorods as versatile nanoparticles in cancer therapy," *Journal of Controlled Release*, vol. 354, pp. 221–242, 2023.

[8] Ravishankar S., Nedumaran A. M., Gautam A., Ng K. W., Czarny B., and Lim S., "Protein nanoparticle cellular fate and responses in murine macrophages," *NPG Asia Materials*, vol. 15, no. 1, pp. 1–16, 2023.

[9] Nejabat M., Samie A., Ramezani M., Alibolandi M., Abnous K., and Taghdisi S. M., "An overview on

gold nanorods as versatile nanoparticles in cancer therapy," *Journal of Controlled Release*, vol. 354, pp. 221–242, 2023.
[10] Patil A. A., "Nanoparticles: properties, application and toxicities," *International Journal of Innovative Science, Engineering and Technology*, vol. 8, no. 5, 2020.
[11] Gaugler R., *Medical Entomology for Students*, Oxford University Press, Oxford, UK, 2016.
[12] Mullen G. R. and Durden L. A., *Medical and Veterinary Entomology*, Academic Press, Cambridge, MA, USA, 2009.
[13] Chandra G. C. G., Ghosh A. A. G., Bhattacharjee I. B. I., and Ghosh S. K., "Use of larvivorous fish in biological and environmental control of disease vectors," in *Biological and Environmental Control of Disease Vectors*, CABI, Boston, MA, USA, pp. 25–41, 2013.
[14] Gubler D. J., "The global threat of emergent/re-emergent vector-borne diseases," in *Vector Biology, Ecology, and Control*, Springer, New York, NY, USA, pp. 39–62, 2010.
[15] U.S. Fish & Wildlife Service, "Nail mosquito overview," accessed Dec. 16, 2023. [Online]. Available: https://www.fws.gov/species/nail-mosquito-anopheles
[16] World Health Organization, "World malaria report," 2021. [Online]. Available: https://www.who.int/teams/global-malaria-programmes/reports/world-malaria-report-2021. Accessed Dec. 15, 2024.
[17] Global Vector Hub, "Anopheles Mosquito," 2024. [Online]. Available: https://globalvectorhub.tghn.org/vector-species/anopheles-mosquitoes/. Accessed Dec. 19, 2024.
[18] Sinka M. E., "Global distribution of the dominant vector species of malaria," in *Anopheles Mosquitoes—New Insights into Malaria Vectors*, IntechOpen, 2013.
[19] Bhattacharya S., Basu P., and Sajal B. C., "The Southern House Mosquito, Culex Quinquefasciatus: Profile of a Smart Vector," *Journal of Entomology and Zoology Studies*, pp. 73–81, 2016.
[20] Gil P., Exbrayat A., Loire E., Rakotoarivony I., Charriat F., Morel C., et al., "Spatial scale influences the distribution of viral diversity in the eukaryotic virome of the mosquito Culex pipiens," *Virus Evolution*, 2023, doi: 10.1093/v3/vead054.
[21] Turell M. J., "Members of the Culex pipiens complex as vectors of viruses," *Journal of the American Mosquito Control Association*, vol. 28, no. 4s, p. 123, 2012.
[22] Madhav M., Blasdell K. R., Trewin B., Paradkar P. N., and Lopez-Denman A. J., "Culex-transmitted diseases: mechanisms, impact, and future control strategies using Wolbachia," *Viruses*, vol. 16, no. 7, p. 1132, 2024, doi: 10.3390/v16071134.
[23] Govindarajan M., Benelli G., and Rajeswary M., "Larvicidal activity of silver nanoparticles synthesized using Murraya koenigii extract against dengue and filariasis vectors," *Parasitology Research*, vol. 115, no. 7, pp. 2875–2885, 2026.
[24] Kalaiarasi R., Jayaprakash A., and Kumar P., "Larvicidal activity of copper nanoparticles against Aedes aegypti," *Journal of Cluster Science*, vol. 30, no. 5, pp. 1263–1271, 2019.
[25] Murugan K., Benelli G., Panneerselvan C., et al., "Cymbopogon citratus-synthesized gold nanoparticles boost the predation efficiency of copepod Mesocyclops aspericornis against malaria and dengue mosquitoes," *Experimental Parasitology*, vol. 153, pp. 128–138, 2015.
[26] Benelli G., "Mode of action of nanoparticles against insects," *Environmental Science and Pollution Research*, vol. 25, no. 13, pp. 12329–12341, 2018.
[27] Suresh U., Murugan K., Benelli G., et al., "Tackling the growing threat of dengue: *Phyllanthus niruri*-mediated synthesis of silver nanoparticles and their mosquitocidal properties against the dengue vector *Aedes aegypti* (Diptera: Culicidae)," *Parasitology Research*, vol. 114, no. 4, pp. 1553–1562, 2015.
[28] Andualem W. W., Sabir F. K., Mohammed E. T., Belay H. H., and Gonfa B. A., "Synthesis of copper oxide nanoparticles using plant leaf extract of *Catha edulis* and its antibacterial activity," *Journal of Nanotechnology*, 2020, Article ID 2932434, doi: 10.1155/2020/2932434.
[29] Danbature W. L., Shehu Z., Joshua J., and Adam M. M., "Moringa oleifera root-mediated synthesis of nano silver particles and the antibacterial application," *Journal of Chemical Society of Nigeria*, vol. 40, no. 3, pp. 504–516, doi: 10.46602/jcsn.v46i3.626.
[30] Wu S., Rajeshkumar S., Malini M., and Vanaja M., "Green synthesis of copper nanoparticles using *Cissus vitiginea* and its antioxidant and antibacterial activity against urinary tract infection pathogens," *Artificial Cells, Nanomedicine, and Biotechnology*, vol. 48, no. 1, pp. 1153–1158, 2020.
[31] Murthy A., Tegene H. C., Kassa M., Ruzuayehu A., and Temesgen A., "Synthesis of green copper nanoparticles using medicinal plant *Hagenia abyssinica* (Brace) J.F.Gmel. leaf extract," *Journal of Nanomaterials*, pp. 1–12, 2020.
[32] Ghosh M. K., Sahu S., Gupta I., and Ghoral T. K., "Green synthesis of copper nanoparticles from an extract of *Jatropha curcas* leaves: characterization, optical properties, CT-DNA binding and photocatalytic activity," *RSC Advances*, vol. 10, pp. 22027–22035, 2020.
[33] Abubakar N., Mukhtar M. M., and Fujita R., "Telfairia occidentalis as a potential larvicide against human malarial vector, *Anopheles coluzzi* [Diptera: Culicidae]: A first report," *International Journal of Tropical Diseases*, vol. 5, no. 1, 2022.
[34] Narayanan L., Senthil R. S., and Kamaraj C., "An investigation into the larvicidal activity of biologically synthesized silver and copper oxide

nanoparticles against mosquito larvae," *Chemistry & Biodiversity*, vol. 21, no. 4, e202301774, 2024.

[35] Shehu Z., Abba E., Wilson D. L., Poloma K. Y., Adamu Z. A., Namau Z. K., et al., "Bio-fabrication of ZnO-CuO nanoporous composite and its application as nanolarvicidal agent for malaria vectors," *Journal of Pharmaceutical Research International*, vol. 32, no. 34, pp. 31–39, 2020, doi: 10.9734/JPRI/2020/v32i3430962.

استطلاع لقياس فاعلية توظيف الذكاء الاصطناعي وتحليل البيانات على تحسين إدارة المعرفة في مؤسسات المعلومات والمكتبات العمانية

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الملخص:

تهدف هذه الدراسة إلى استكشاف فاعلية تكامل الذكاء الاصطناعي وتحليل البيانات في تحسين إدارة المعرفة في مؤسسات المعلومات والمكتبات العمانية. تواجه هذه المؤسسات تحديات في تبني أحدث التقنيات بسبب نقص الكفاءات والموارد. تسلط الدراسة الضوء على دور الذكاء الاصطناعي في تحسين عمليات التصنيف والبحث واسترجاع المعلومات، ودور تحليل البيانات في تعزيز اتخاذ القرارات. باستخدام منهجية كمية تعتمد على استبيانات موجهة للعاملين والمستفيدين، تسعى الدراسة إلى تقديم توصيات لتطوير استراتيجيات فعّالة تعزز من كفاءة إدارة المعرفة وجودة الخدمات المقدمة. من خلال اعتماد منهج التحليل الكمي، تم جمع بيانات عبر استبيانات موجهة إلى موظفي المكتبات والمستفيدين لتقييم تجربتهم مع الذكاء الاصطناعي وتحليل البيانات. أظهرت النتائج أن تطبيقات الذكاء الاصطناعي حسّنت بشكل كبير من كفاءة التصنيف واسترجاع المعلومات، بينما كان لتحليل البيانات دور بارز في تعزيز اتخاذ القرارات المستنيرة. ومع ذلك، أظهرت الدراسة وجود بعض التحديات مثل البنية التحتية المحدودة وحاجة الموظفين إلى مزيد من التدريب. تشير النتائج إلى أن دمج الذكاء الاصطناعي وتحليل البيانات في عمليات المكتبات والمعلومات يمكن أن يسهم في تحسين الكفاءة التشغيلية وجودة الخدمات، ويساعد في دعم اتخاذ القرارات المبنية على البيانات. كما تقدم الدراسة توصيات لتجاوز التحديات الحالية، بما في ذلك تحسين تدريب الموظفين، والاستثمار في البنية التحتية الرقمية، وتطوير استراتيجيات دمج فعّالة. في الختام، تكمن فوائد دمج الذكاء الاصطناعي وتحليل البيانات في تطوير خدمات المكتبات العمانية وتعزيز دورها في العصر الرقمي، ولكن يتطلب الأمر جهدًا منسقًا للتغلب على العوائق التقنية والموارد المحدودة.

***الكلمات المفتاحية: الذكاء الاصطناعي**، تحليل البيانات، إدارة المعرفة، المكتبات العمانية.*

Survey to Measure the Effectiveness of Utilizing Artificial Intelligence and Data Analysis in Improving Knowledge Management in Omani Information Institutions and Libraries

***Abstract*— This study aims to explore the effectiveness of integrating artificial intelligence (AI) and data analytics in improving knowledge management in Omani information institutions and libraries. These institutions face challenges in adopting the latest technologies due to a lack of competencies and resources. The study highlights the role of AI in improving classification, searching, and information retrieval processes, and the role of data analytics in enhancing decision-making. Using a quantitative methodology based on surveys directed at employees and users, the study seeks to provide recommendations for developing effective strategies that enhance the efficiency of knowledge management and the quality of services provided. Through the adoption of a quantitative analysis approach, data was collected via surveys targeted at library staff and users to evaluate their experiences with AI and data analytics. The results showed that AI applications significantly improved the efficiency of classification and information retrieval, while data analytics played a prominent role in enhancing informed decision-making. However, the study also identified some challenges, such as limited technological infrastructure and the need for additional training for staff. The results suggest that integrating AI and data analytics in library and information processes can contribute to improving operational efficiency, service quality, and data-driven decision-making. The study also provides recommendations for overcoming current challenges, including improving staff training, investing in digital infrastructure, and developing effective integration strategies. In conclusion, the integration of AI and data analytics offers significant benefits for the development of Omani library services and enhances their role in the digital age. However, it requires a coordinated effort to overcome technical barriers and limited resources.**

Keywords— *Artificial Intelligence, Data Analysis, Knowledge Management, Omani Libraries.*

I. المقدمة وخلفية البحث

تعتبر إدارة المعرفة أحد الركائز الأساسية لتطوير أداء مؤسسات المعلومات والمكتبات، حيث تسهم في تحسين العمليات التشغيلية وتقديم خدمات ذات جودة عالية. ومع التطور السريع للتقنيات الرقمية، أصبح الذكاء الاصطناعي وتحليل البيانات من الأدوات المحورية في تعزيز هذه الإدارة .

في السياق العماني، تسعى المكتبات والمؤسسات المعلوماتية لمواكبة التحولات الرقمية، إلا أنها تواجه تحديات تتعلق بنقص الكفاءات والموارد التقنية. لذا، تركز هذه الدراسة على تحليل دور التكامل بين الذكاء الاصطناعي وتحليل البيانات في تحسين إدارة

شكل 1: العناصر المرتبطة بالدراسة

المعرفة وتقديم حلول للمشكلات الحالية. شملت الدراسة التركيز على العناصر التي يقوم عليها توظيف التكنولوجيا في علم المكتبات والمعلومات الموضحة في المخطط أدناه:

II. عناصر الدراسة

وهنا يتم توضيح التكامل بين إدارة المعرفة في مؤسسات المعلومات ومراكز مصادر التعلم وطريقة تحليل البيانات المتوفرة فيها وأهمية توظيف أدوات وتطبيقات الذكاء الاصطناعي في تطوير وتحسين مؤسسات المعلومات وهو ما يوضحه الجدول أدناه:

جدول 1: يوضح مقارنات عناصر الدراسة وارتباطها بالذكاء الاصطناعي

المجال	الدور في إدارة المعرفة	أدوات تحليل البيانات المستخدمة	تطبيقات الذكاء الاصطناعي
إدارة المعرفة	تنظيم وتخزين واسترجاع المعرفة لتحسين العمليات والخدمات	-	-
تحليل البيانات	اكتشاف الأنماط والاتجاهات في البيانات لتعزيز القرارات المعرفية	أدوات إحصائية (SPSS، Excel) وبرمجيات تحليل البيانات (مثل R)	-
الذكاء الاصطناعي	أتمتة عمليات إدارة المعرفة مثل التصنيف والبحث واسترجاع المعلومات	-	أنظمة التعلم الآلي، معالجة اللغة الطبيعية، والتطبيقات التنبؤية
التكامل بين الثلاثة	تحسين كفاءة وفعالية إدارة المعرفة باستخدام التحليل الذكي للبيانات	دمج أدوات التحليل مع أنظمة إدارة المعرفة	تطوير نماذج استباقية باستخدام الذكاء الاصطناعي لتحسين تجربة المستخدم وتعزيز الأداء

التكامل بين إدارة المعرفة، تحليل البيانات، والذكاء الاصطناعي:

إدارة المعرفة: تركز على العمليات اليدوية أو شبه الآلية لتخزين واسترجاع البيانات.

تحليل البيانات: يوفر رؤى دقيقة لاستخدام البيانات من خلال الكشف عن الأنماط والتوجهات.

الذكاء الاصطناعي: يعزز الأتمتة والقدرة على التعامل مع البيانات غير المهيكلة، مما يسهم في تسريع وتحسين عملية اتخاذ القرارات.

التكامل: يربط العمليات الثلاث لتعزيز الكفاءة والإنتاجية، مع تحسين دقة وجودة المعلومات المقدمة.

III. مشكلة البحث

تعاني المكتبات ومؤسسات المعلومات العمانية من تحديات كبيرة في الاستفادة المثلى من تقنيات الذكاء الاصطناعي وتحليل البيانات، مما يؤثر سلباً على كفاءة إدارة المعرفة وجودة الخدمات المقدمة. من هنا جاءت هذه الدراسة من أجل استقصاء ومعرفة مدى أهمية توظيف أدوات وتطبيقات الذكاء الاصطناعي في المكتبات ومؤسسات المعلومات ومراكز مصادر التعلم في سلطنة عمان. وتسليط الضوء على أهمية التكامل بين الذكاء الاصطناعي وتحليل البيانات كنهج حديث لتحسين العمليات التشغيلية ودعم اتخاذ القرار في هذه المؤسسات، مع تحليل العوائق الحالية وتقديم حلول استراتيجية لتجاوزها. وحسب المراجع والبحث الذي قام به الباحثان فقد دعمت تلك الإجراءات مواصلة هذه الدراسة وإيجاد النتائج والتفاسير والتوصيات المرتبطة بها. من هنا جاءت هذه الدراسة للاعتقاد بأن هنالك فوائد ومنافع لمؤسسات المعلومات ومصادر التعلم من خلال توظيف أدوات وتطبيقات الذكاء الاصطناعي في تحليل بيانات المكتبات والمعلومات.

IV. أسئلة البحث

1. ما هي التحديات التي تواجه المكتبات العمانية في تطبيق تقنيات الذكاء الاصطناعي وتحليل البيانات؟
2. كيف يمكن لهذه التقنيات أن تسهم في تحسين عمليات إدارة المعرفة؟
3. ما هي الاستراتيجيات الفعالة لتطبيق هذه التقنيات في المؤسسات العمانية؟

V. أهداف البحث

1. استكشاف تأثير الذكاء الاصطناعي وتحليل البيانات في تحسين إدارة المعرفة.
2. تقييم فعالية التكامل بين التقنيات الحديثة في المكتبات العمانية
3. تقديم توصيات لتحسين استراتيجيات إدارة المعرفة باستخدام التكنولوجيا الحديثة.

VI. الأدبيات والدراسات السابقة المرتبطة بالدراسة

تشير الدراسات إلى أن إدارة المعرفة تعتمد على تخزين المعرفة وتبادلها واسترجاعها بشكل يضمن تحسين العمليات والخدمات داخل المكتبات. وأوضحت الأدبيات دور الذكاء الاصطناعي في تحسين كفاءة العمليات، مثل التصنيف الذاتي للمعلومات واسترجاعها باستخدام الخوارزميات الذكية. ويعتمد تحليل البيانات على استخراج الأنماط والمعلومات المهمة من البيانات الضخمة، مما يساهم في اتخاذ قرارات مبنية على البيانات لتحسين العمليات والخدمات .

أثبتت دراسات حديثة أن الجمع بين الذكاء الاصطناعي وتحليل البيانات يعزز من القدرة على إدارة المعرفة بفعالية في المكتبات ومؤسسات المعلومات، خاصة في بيئات المعلومات الحديثة ومن هذه الدراسات دراسة [6] تتعلق بتحديد دور تطبيقات الذكاء الاصطناعي في تحسين ودعم عمليات إدارة المعرفة، مع التركيز على كيفية تحسين الأداء واتخاذ القرارات في المؤسسات، وأثر التحديات والمخاطر المرتبطة باستخدام هذه التطبيقات .

استخدمت منهجية بحثية تتضمن:
-استعراض الأدبيات المتعلقة بتطبيقات الذكاء الاصطناعي في إدارة المعرفة.
-تحليل استراتيجيات تطبيق الذكاء الاصطناعي وتأثيرها على عمليات إدارة المعرفة.
-استكشاف الجوانب الأخلاقية والقانونية المرتبطة بتطبيقات الذكاء الاصطناعي.
-جدول الآثار المحتملة لأنظمة الذكاء الاصطناعي لإدارة المعرفة، يوضح مختلف
التطبيقات مثل:
-خلق المعرفة: اكتشاف أوجه القصور وتعزيز التحليلات التنبؤية.
-تخزين المعرفة واسترجاعها: حصاد المعرفة وتصنيفها.
-مشاركة المعرفة: ربط الأشخاص وتعزيز الذكاء التعاوني.
-تطبيق المعرفة: تعزيز تطبيق المعرفة الموجودة.

وجاءت النتائج العامة لها كما يلي:
1 .تحسين الإنتاجية والكفاءة: التطبيقات الفعالة للذكاء الاصطناعي تعزز من عمليات إدارة
المعرفة.
2 .تحديات ومخاطر: تواجه المؤسسات تحديات تتعلق بتطبيق الذكاء الاصطناعي في
سياقات مختلفة.
3 .شراكة بين العنصر البشري والذكاء الاصطناعي: ضرورة بناء شراكة متكاملة بين العاملين والأنظمة الذكية لتحقيق أفضل النتائج.

وهذه الدراسة تتماشى مع هدف دراستنا الحالية في استخدام الذكاء الاصطناعي لتحسين تحليل البيانات في المكتبات ومؤسسات المعلومات. كما يركز كلاهما على عمليات إدارة المعرفة المماثلة، مثل إنشاء المعرفة وتخزينها واسترجاعها ومشاركتها وتطبيقها. تسلط الورقة الضوء على هذه العمليات باعتبارها مجالات مهمة حيث يمكن للذكاء الاصطناعي أن يحدث تأثيرًا كبيرًا، وهو أمر ذو صلة أيضًا بدمج الذكاء الاصطناعي وتحليل البيانات في المكتبات العمانية. وتختلف الدراستان من حيث السياق الجغرافي حيث لا تتناول الورقة على وجه التحديد سياق مؤسسات المعلومات العمانية، بينما يركز استكشاف تكامل الذكاء الاصطناعي على التحديات والفرص الفريدة الموجودة في عمان. قد تؤدي هذه الخصوصية الجغرافية إلى استراتيجيات ونتائج تنفيذ مختلفة. إلا أنهما يختلفان في تركيزهما الجغرافي، وتركيزهما على تحليل البيانات، ومراعاة العوامل الثقافية المحلية .

وجاءت دراسة [8] لبحث كيفية إيجاد طرق وآليات لتحديد مدى استفادة المكتبات الأكاديمية من تقنيات الذكاء الاصطناعي في تحسين خدمات المعلومات المقدمة للمستخدمين. حيث تسعى الدراسة إلى فهم التحديات التي تواجه المكتبات في تطبيق هذه التقنيات وتأثيرها على جودة الخدمات، تم استخدام منهج تحليل وصفي لجمع البيانات من المكتبات الأكاديمية، بما في ذلك مكتبات جامعة السلطان قابوس ومكتبة جامعة كوالالمبور. اعتمدت الدراسة على تحليل بيانات من خلال استبيانات ومقابلات مع العاملين في المكتبات. كما تم استخدام نماذج تحليلية لتقييم فعالية تقنيات الذكاء الاصطناعي في تحسين الخدمات. وأظهرت النتائج أن المكتبات الأكاديمية تستخدم تقنيات الذكاء الاصطناعي بشكل متزايد في مجالات مثل إدارة المعلومات، وخدمات الإعارة، ودعم البحث .

استخدمت هذه الدراسة جدول مقارنة بين استخدام تقنيات الذكاء الاصطناعي في المكتبات الأكاديمية المختلفة. كما أنه تم انشاء رسم بياني يوضح توزيع استخدام تقنيات الذكاء الاصطناعي حسب نوع الخدمة المقدمة. بالإضافة لمخطط يبين مراحل تطبيق تقنيات الذكاء الاصطناعي في المكتبات الأكاديمية.

وتوصلت الدراسة إلى تحديد عدة تحديات، مثل نقص التدريب للعاملين وصعوبة دمج التقنيات الجديدة في الأنظمة القائمة. كما أكدت الدراسة على أهمية تحسين البنية التحتية لتكنولوجيا المعلومات لدعم تطبيقات الذكاء الاصطناعي.

وهكذا نرى أن هذه الدراسة تهدف إلى تقييم مدى استفادة المكتبات الأكاديمية من تقنيات الذكاء الاصطناعي وتأثيرها على جودة الخدمات، وتسلط الضوء على تحسينات في خدمات معينة وتوصيات خاصة بتدريب العاملين على استخدام تقنيات الذكاء الاصطناعي.

بينما دراستنا تهدف إلى استكشاف كيفية تحسين إدارة المعرفة من خلال تكامل الذكاء الاصطناعي وتحليل البيانات، مما قد يتضمن جوانب أوسع من تقديم الخدمات. كما تركز على تحسين استراتيجيات إدارة المعرفة بشكل عام، مما قد يتطلب تغييرات في الثقافة التنظيمية للمكتبات ومؤسسات المعلومات ومراكز مصادر التعلم.

كما أن الباحثة [5] أوضحت أن دراستها تتمثل في مشكلة عدم استغلال وتوظيف أدوات وتقنيات الذكاء الاصطناعي، وخاصة تقنية الواقع المعزز(AR) ، بشكل كافٍ في المكتبات الأكاديمية. على الرغم من الفوائد الكبيرة التي يمكن أن توفرها هذه التقنيات في تحسين تجربة المستخدمين وتسهيل الوصول إلى المعلومات، إلا أن الكثير من المكتبات لا تزال تعتمد على الطرق التقليدية في تقديم خدماتها. تم استخدام المنهج الوصفي التحليلي، الذي يعتمد على مراجعة الأدبيات والدراسات السابقة، لجمع البيانات وتحليلها وإجراء دراسات تجريبية لتطبيق تقنيات الواقع المعزز في بعض المكتبات الأكاديمية، مع التركيز على التحديات والفرص التي تواجه تنفيذ هذه التقنيات. استخدمت الدراسة مخطط يوضح العلاقة بين استخدام تقنيات الذكاء الاصطناعي وتحسين تجربة المستخدم في المكتبات الأكاديمية. وجدول يحتوي على مقارنة بين المكتبات التي تستخدم الواقع المعزز وتلك التي لا تستخدمه من حيث رضا المستخدمين. كما استخدمت رسم بياني يعرض نسبة استخدام الواقع المعزز في المكتبات الأكاديمية عبر السنوات. وأظهرت نتائج التجارب أن استخدام الواقع المعزز في المكتبات الأكاديمية يعزز من فعالية البحث والوصول إلى المعلومات. وتم تحديد عدد من التحديات، مثل الحاجة إلى تدريب العاملين في المكتبات وتوفير المعدات اللازمة .

وهكذا نرى أن هذه الدراسة تختلف عن دراستنا في نطاق التركيز. حيث تركز الدراسة الأولى على تطبيقات محددة مثل تقنية الواقع المعزز (AR) في المكتبات الأكاديمية، وتهدف إلى تعزيز تجربة

المستخدم وتحسين الوصول إلى المعلومات. بينما تركز دراستنا على تحسين إدارة المعرفة ككل في المؤسسات العمانية، مستعرضةً كيفية استخدام الذكاء الاصطناعي وتحليل البيانات في تنظيم المعلومات وتسهيل تدفق المعرفة بين العاملين.

بالإضافة إلى ذلك، تختلف المنهجيات المستخدمة في كلتا الدراستين. تعتمد الدراسة الأولى على المنهج الوصفي التحليلي لتقييم تطبيقات الواقع المعزز، بينما تستخدم دراستنا منهجيات تحليلية مختلفة تشمل تجارب ميدانية ودراسة حالة لتقييم تأثير الذكاء الاصطناعي على إدارة المعرفة في المؤسسات. هذا التنوع في الأهداف والمنهجيات يعكس اختلافات أساسية في كيفية تناول كل مبحث ودراسة في كيفية تحسين وتطوير المكتبات ومؤسسات المعلومات وتوظيف أدوات وتقنيات الذكاء الاصطناعي بها .

الذكاء الاصطناعي وتحليل البيانات

يشهد العالم تحولًا رقميًا سريعًا بفضل الثورة الصناعية الرابعة، مما يفرض على مؤسسات المعلومات تبني تقنيات الذكاء الاصطناعي لتحسين خدماتها، حيث "أصبح الذكاء الاصطناعي جزءًا لا يتجزأ من حياة المجتمعات، بما في ذلك المكتبات ومراكز المعلومات". يحتاج المتخصصون إلى اكتساب مهارات رقمية وتقنية مثل تحليل البيانات وإدارة المحتوى الرقمي وحل المشكلات التقنية، لذلك فإن الاستثمار في تطوير المهارات وتطبيق الذكاء الاصطناعي يعزز قدرة المؤسسات على المنافسة وتحقيق النجاح في العصر الرقمي.

تهدف الدراسة [9] إلى تحليل كيفية استخدام هذه التقنيات لتحسين خدمات المكتبات وتسهيل البحث الأكاديمي، مع تحديد التحديات التي تواجه تطبيقها. أظهرت النتائج أن "70% من المشاركين لديهم معرفة بالذكاء الاصطناعي. تواجه تطبيقات الذكاء الاصطناعي في المكتبات تحديات تقنية واجتماعية وقانونية، مثل الخصوصية وجودة البيانات والتكلفة العالية .[10]

أشار المشاركون إلى إمكانية تحسين خدمات الفهرسة وتصنيف المواد باستخدام الذكاء الاصطناعي، بالإضافة إلى تحسين توفير المواد العلمية للطلاب والأساتذة حسب [9] والتي توصي بضرورة توفير البنية التحتية اللازمة وتبني برامج تدريبية للموظفين لتمكينهم من استخدام الذكاء الاصطناعي بشكل فعال. كما يمكن للذكاء الاصطناعي أن يساعد المكتبات في تحسين عمليات البحث والاسترجاع، وتقديم خدمات مرجعية افتراضية، واستخدام الواقع الافتراضي لزيادة محو الأمية المعلوماتية بحسب.[10]

تشير الدراسة [9] إلى أن تطبيق الذكاء الاصطناعي في المكتبات الجامعية الجزائرية يمكن أن يحسن بشكل كبير من جودة الخدمات المقدمة، خاصة في مجالات الفهرسة وتصنيف المواد وتوفير المعلومات. كما تؤكد الدراسة على أهمية مواكبة المكتبات الجامعية للتطورات التكنولوجية الحديثة لضمان استمراريتها وفعاليتها في دعم البحث العلمي والتعليم العالي. فقد باتت المكتبات بحاجة إلى تبني تقنيات الذكاء الاصطناعي لتحسين خدمات البحث والاسترجاع والتحليل الوثائقي.

VII. منهجية الدراسة

تعتمد الدراسة على المنهج الكمي الذي يتضمن تصميم استبيان موجه إلى:

1. العاملين في المكتبات العمانية ومراكز مصادر التعلم في المدارس العمانية
2. المستفيدين من خدماتها.

VIII. خطوات تصميم ونشر الاستبانة

- تصميم الاستبيان لقياس تأثير الذكاء الاصطناعي وتحليل البيانات .
- توزيع الاستبيان وتحليل البيانات باستخدام برامج إحصائية .
- استخلاص نتائج تسلط الضوء على التحديات والفرص.

تم تصميم الاستبانة لتحقيق أهداف الدراسة من خلال ثلاثة محاور رئيسية. المحور الأول ركز على البيانات الديموغرافية، حيث تم جمع معلومات عن الجنس والذي كان بنسبة تقارب 50% لفئة الذكور ونسبة 35% للإناث، أما العمر فقد تراوحت أعمار المستجيبين بين أقل من 30 سنة الى أعلى من 40 سنة وجاءت أعلى نسبة للأعمار بين 31 الى 40 عاماً بنسبة 42% من اجمالي عدد الاستجابات البالغة 85 استجابة والذي تتضح نسبه في المخططات أدناه.

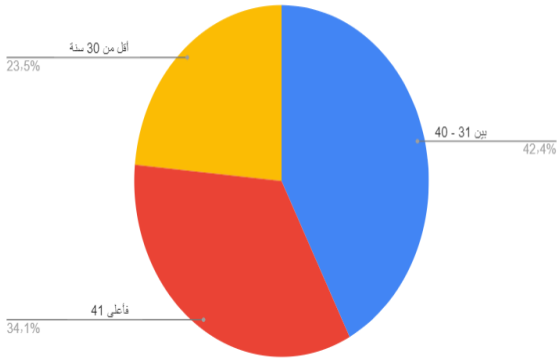
جدول 2: جدول يلخص المقارنات بين الدراسات والأدبيات السابقة التي لها صلة بالدراسة

الدراسة	الموضوع	المنهجية	النتائج	التحديات	التوصيات
[2]	تطوير العلوم الاجتماعية والإنسانية في عصر الذكاء الاصطناعي	مراجعة أدبية تحليلية	تطور ملحوظ في تطبيقات الذكاء الاصطناعي لتحليل البيانات والبحث المعرفي	نقص التطبيقات المخصصة للقطاعات الثقافية	تطوير تطبيقات ذكاء اصطناعي مخصصة للمكتبات والقطاعات الثقافية
[4]	أخلاقيات وتطبيقات الذكاء الاصطناعي في المكتبات	مراجعة أدبية تحليلية	تطبيقات الذكاء الاصطناعي تُحسن تجربة المستخدم من خلال أتمتة العمليات مثل التصنيف والاسترجاع	قلة وعي العاملين بتحديات الخصوصية المرتبطة باستخدام الذكاء الاصطناعي	تقديم برامج توعية موجهة حول الأخلاقيات والخصوصية في تطبيقات الذكاء الاصطناعي
[6]	دور تطبيقات الذكاء الاصطناعي في تحسين ودعم عمليات إدارة المعرفة	دراسة تحليلية مقارنة لتطبيقات الذكاء الاصطناعي في المكتبات الجامعية في دول المغرب العربي	تحليل البيانات يُسهم في تحسين اتخاذ القرار، واكتشاف الأنماط في استخدام الموارد	غياب سياسات مؤسسية واضحة لدعم التكامل بين التقنيات	إعداد سياسات مؤسسية طويلة المدى لدعم التكامل بين الذكاء الاصطناعي وتحليل البيانات
[1]	تقنيات الذكاء الاصطناعي في إدارة المعرفة بين النظرية والتطبيق	دراسة حالة تحليلية لتطبيق الذكاء الاصطناعي في المؤسسات الأكاديمية الجزائرية	تحسين تنظيم واسترجاع المعرفة، توفير الوقت والجهد	نقص الكوادر المتخصصة والتدريب	توفير برامج تدريبية مكثفة للعاملين، وزيادة الاستثمار في البنية التحتية
[3]	إدارة المعرفة والبيانات الضخمة	دراسة أدبية عن دور البيانات الضخمة في إدارة المعرفة	البيانات الضخمة تُساعد على تحليل أنماط الاستخدام وتحديد الاحتياجات المستقبلية	تحديات مرتبطة بتحليل البيانات بدقة بسبب نقص أدوات التحليل	الاستثمار في تقنيات تحليل البيانات الضخمة وربطها بإدارة المعرفة
[7]	الذكاء الاصطناعي لاسترجاع المعلومات: دراسة استكشافية لتطبيق Talk to Books	دراسة استكشافية لتحليل فعالية تطبيق ذكاء اصطناعي لاسترجاع المعلومات	تحسين دقة استرجاع المعلومات ورضا المستخدمين	قصور في تعدد اللغات وتحسين واجهة الاستخدام	تطوير تطبيقات متعددة اللغات وتقديم واجهات استخدام مبسطة

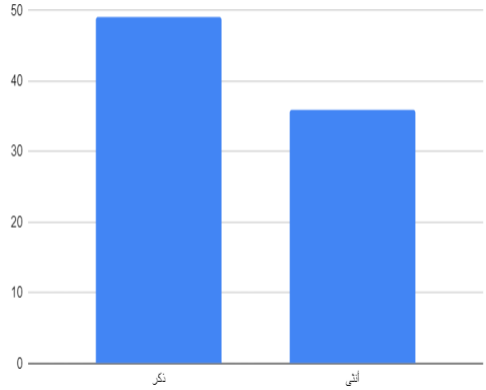
https://doi.org/10.20428/jst.v30i5.2822

جدول 3: وهنا جدول يوضح المقارنات الإحصائية والقراءات العددية بين الدراسات السابقة

الدراسة	نوع البيانات	حجم العينة	أدوات التحليل الإحصائي	النتائج الإحصائية الرئيسية	المخرجات الإحصائية
[2]	دور الذكاء الاصطناعي في تطوير العلوم الإنسانية	مراجعة أدبية	تحليل محتوى النصوص	لا توجد نتائج كمية مباشرة، ولكن النصوص تُشير إلى تطور إيجابي بنسبة 65% عند استخدام تقنيات الذكاء الاصطناعي	-
[4]	أخلاقيات الذكاء الاصطناعي في المكتبات	مراجعة 20 تطبيق مكتبي	تحليل نوعي للممارسات الأخلاقية	45%من التطبيقات تفتقر إلى إجراءات واضحة لحماية الخصوصية	تقديم توصيات لدمج الخصوصية في تصميم تطبيقات المكتبات
[6]	تحسين إدارة المعرفة عبر الذكاء الاصطناعي	200 موظف في المكتبات الجامعية	تحليل مخرجات استبيان باستخدامR	85%من المشاركين لاحظوا تحسناً في اتخاذ القرار بسبب تقنيات تحليل البيانات	30%ذكروا نقص السياسات المؤسسية لدعم التقنيات الحديثة
[1]	مدى تأثير الذكاء الاصطناعي على استرجاع المعرفة	120 موظف في مؤسسات أكاديمية	تحليل إحصائي باستخدام SPSS	80%من المشاركين أكدوا تحسن كفاءة استرجاع المعلومات بفضل الذكاء الاصطناعي	40%اعتبروا أن التدريب غير كافٍ لتطبيق التقنيات
[3]	تحليل البيانات الضخمة لتحسين إدارة المعرفة	دراسة ميدانية شملت 150 مكتبة	تحليل استبيانات باستخدام Excel وSPSS	70%من المكتبات أظهرت تحسناً في اكتشاف الأنماط واتخاذ القرارات	تحديات في استخدام أدوات التحليل بسبب نقص الخبرة
[7]	تجربة استخدام تطبيق Talk to Books	50 مستخدم	تقييم تجربة المستخدم بناءً على استبيانات	90%من المستخدمين أعجبوا بدقة استرجاع المعلومات، ولكن 20% واجهوا مشاكل في التفاعل مع واجهة الاستخدام	تطوير التطبيقات لتلبية احتياجات المستخدمين من حيث التفاعلية واللغات

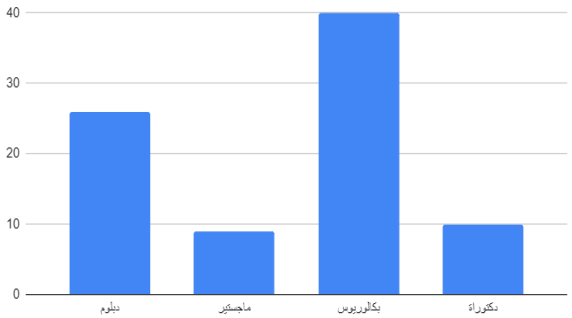


شكل 2: نسب أعمار المستجيبين



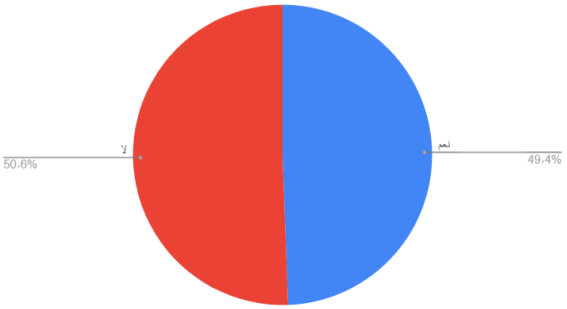
شكل 3: توزيع نسبة استجابة الجنس

أما بالنسبة للمستوى العلمي فقد كانت أعلى استجابات لحاملي درجة البكالوريوس بنسبة 40% تلتها درجة الدبلوم بنسبة 25% وبعدها الدكتوراة ثم الماجستير وهو ما يوضحه المخطط، وبالنسبة للوظيفة التي تم وضعها لتصنيف المستجيبين وتحليل الإجابات بناءً على خصائصهم المختلفة من مختصين ومهتمين ومستخدمين للمكتبات والمعلومات ومراكز مصادر التعلم.



شكل 4: توزيع نسب مؤهلات المستجيبين

كما تضمن المحور سؤالًا افتتاحيًا حول مدى استخدام المستجيبين لأدوات وتطبيقات الذكاء الاصطناعي في حياتهم اليومية، مما يساعد في قياس مستوى الوعي والتفاعل مع هذه التقنيات جاءت نسب المستجيبين متكافئة في حدود 50% للإجابات بنعم ولا كما يوضحه المخطط، وهو ما شجع الباحثان على ضرورة مواصلة اجراء هذه الدراسة والتي تستدعي توظيف أدوات وتقنيات الذكاء الاصطناعي فيها.

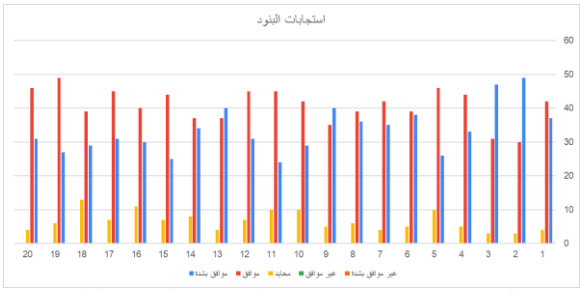


شكل 5: توزيع نسبة سؤال مستوى الخبرة في الذكاء الاصطناعي

أما المحور الثاني فقد تضمن بنودًا متعلقة بالهدف الأول والثاني للدراسة، وهو استكشاف تأثير الذكاء الاصطناعي على تحسين إدارة المعرفة. ركزت الأسئلة والتي كان عددها 10 أسئلة على تقييم مدى قدرة الذكاء الاصطناعي على تحسين تصنيف البيانات، وتقليل الأخطاء التشغيلية، وتوفير الوقت أثناء البحث عن المعلومات. وقد أظهرت النتائج استجابات إيجابية بشكل عام حيث كانت الاستجابات بدرجة موافق وموافق بشدة هي الأعلى وتراوحت بين 30 الى 50 % من الاستجابات، مما يعكس إدراكًا واسعًا بين المستجيبين لدور الذكاء الاصطناعي في تعزيز كفاءة إدارة المعرفة وضرورة توظيفه في إدارة بيانات هذه المؤسسات.

أما في المحور الثالث، تم التركيز على تحقيق الهدف الثالث للدراسة وهو تقييم فعالية التكامل بين الذكاء الاصطناعي وتحليل البيانات في المؤسسات العمانية. شملت الأسئلة العشرة التي تم تحديدها لهذا المحور على تقييم دور هذا التكامل في تحسين عمليات اتخاذ القرار، وتعزيز كفاءة العمليات الإدارية والخدمية، ودعم التحول الرقمي والذي كانت نتائجه الأعلى لاستجابات (موافق بشدة) بنسب تصل الى 50% وتلتها استجابات (موافق) بنسب بين 25 و 40% وهو ما عزز هذه الدراسة.

النتائج أظهرت أن غالبية المستجيبين يرون هذا التكامل كعنصر أساسي لدفع عجلة التطور الرقمي، مما يعكس توجهًا إيجابيًا نحو الاستفادة من التقنيات الحديثة وهو ما يوضحه المخطط التالي:



شكل 6: توزيع نسبة استجابات المحورين الثاني والثالث

تحليل البيانات أظهر أن المستجيبين لديهم وعي كبير بأهمية الذكاء الاصطناعي وتحليل البيانات في تعزيز كفاءة المكتبات والمؤسسات. وبناءً على هذه النتائج، يمكن التوصية بضرورة تعزيز استخدام الذكاء الاصطناعي في المكتبات العمانية، وتنظيم دورات تدريبية لزيادة الوعي والاستفادة العملية من تقنيات تحليل البيانات. كما يُقترح تطوير منصات رقمية متكاملة لتسهيل عمليات إدارة المعرفة ودعم التحول الرقمي. كما تعكس الدراسة فرصًا كبيرة لتطبيق الذكاء الاصطناعي وتحليل البيانات في المؤسسات العمانية، مع تأكيد ضرورة تهيئة البيئة المناسبة لتعظيم الفائدة من هذه التقنيات المستقبلية.

IX. النتائج

1. تحسين العمليات التشغيلية:
أظهرت نتائج الدراسة أن تطبيقات الذكاء الاصطناعي، مثل أنظمة التصنيف الذاتي ومعالجة اللغة الطبيعية، ساهمت بشكل كبير في تحسين كفاءة استرجاع المعلومات وتنظيم البيانات، مما أدى إلى تقليل الأخطاء التشغيلية وتسريع الأداء.

2. تعزيز اتخاذ القرارات:
بيّنت الدراسة أن أدوات تحليل البيانات مكّنت المكتبات من استخراج أنماط واتجاهات دقيقة، ما أدى إلى اتخاذ قرارات مبنية على بيانات حقيقية وساهم في تحسين تخصيص الموارد.

3. تحديات رئيسية:
كشفت الدراسة عن تحديات ملحوظة، منها نقص التدريب الموجّه للعاملين، وضعف البنية التحتية التكنولوجية، وغياب استراتيجيات واضحة لتطبيق التكامل بين الذكاء الاصطناعي وتحليل البيانات.

4. إيجابية التكامل التقني:
أثبت التكامل بين الذكاء الاصطناعي وتحليل البيانات أنه عنصر فعّال في تحسين تجربة المستخدم ودعم التحول الرقمي في المكتبات العمانية، مع تعزيز جودة الخدمات المقدمة.

X. المناقشة

1.مقارنة النتائج مع الدراسات السابقة:
تتفق نتائج الدراسة مع الأدبيات التي تؤكد دور الذكاء الاصطناعي في تحسين إدارة المعرفة من خلال إتمام العمليات وتوفير الوقت والجهد. على سبيل المثال، أثبتت دراسات مثل دراسة [1] أن الذكاء الاصطناعي يساهم في رفع كفاءة استرجاع المعلومات بنسبة تصل إلى 80%.

2. التحديات والحلول المقترحة:

أشارت النتائج إلى عوائق تقنية وبشرية مشابهة لما ورد في دراسات أخرى، مثل نقص الخبرات والبنية التحتية. لحل هذه المشكلات، تُوصى المكتبات العمانية بتبني خطط تدريبية مستدامة، والاستثمار في تحديث البنية التحتية الرقمية، وإنشاء شراكات مع المؤسسات الأكاديمية والتقنية.

3. القيمة المضافة:
تتميز هذه الدراسة بتسليط الضوء على أهمية التكامل بين الذكاء الاصطناعي وتحليل البيانات، حيث لم تقتصر النتائج على تحسين كفاءة العمليات، بل شملت دعم استراتيجيات التحول الرقمي للمكتبات العمانية، مما يعزز قدرتها على المنافسة في العصر الرقمي.

4. نظرة استشرافية:
أكدت الدراسة أن التكامل بين الذكاء الاصطناعي وتحليل البيانات يمثل فرصة واعدة للمكتبات العمانية لتحقيق تقدم مستدام في إدارة المعرفة. ومع ذلك، يستدعي ذلك تطوير سياسات واضحة وتشجيع البحث العلمي لاستكشاف المزيد من التطبيقات المبتكرة لهذه التقنيات.

XI. الخاتمة

توصلت الدراسة من خلال الاستطلاع وقياس الأراء حول تكامل الذكاء الاصطناعي وتحليل البيانات كأداة فعّالة لتحسين إدارة المعرفة في المكتبات العمانية، من خلال تعزيز الكفاءة وجودة الخدمات. وأثبتت نتائج هذه الدراسة أن التكامل بين الذكاء الاصطناعي وتحليل البيانات يمثل حلاً محوريًا لتحديات إدارة المعرفة التي تواجه المكتبات العمانية .

تقنيات الذكاء الاصطناعي تساعد في اتخاذ القرارات المدعومة بالبيانات من خلال ما أظهرته الدراسة للحاجة إلى معالجة التحديات المتمثلة في نقص التدريب، وضعف البنية التحتية، وتطوير استراتيجيات تكامل فعّالة. إن الاستثمار في هذه التقنيات لن يعمل فقط على تحسين كفاءة المكتبات ومؤسسات المعلومات، بل سيعزز من دورها المحوري في دعم التحول الرقمي في السلطنة.

XII. التوصيات

1. تعزيز تدريب العاملين في المكتبات على استخدام تقنيات الذكاء الاصطناعي وتحليل البيانات من خلال توفير دورات تدريبية مخصصة للعاملين في المكتبات لتعزيز مهاراتهم في استخدام الذكاء الاصطناعي وأدوات تحليل البيانات، وإطلاق برامج تطوير مهني مستدامة بالتعاون مع المؤسسات الأكاديمية والبحثية .
2. توفير البنية التحتية المناسبة لدعم التكامل بين هذه التقنيات وذلك بالاستثمار في تحديث البنية التحتية التقنية للمكتبات بما يدعم تكامل الذكاء الاصطناعي وتحليل البيانات. وتبني تقنيات السحابة لتسهيل الوصول إلى أدوات تحليل البيانات وخدمات الذكاء الاصطناعي.
3. تطوير أدوات ذكاء اصطناعي مخصصة للمكتبات العمانية لتلبية احتياجاتها الخاصة، ثم العمل على تعزيز استخدام تطبيقات تحليل البيانات لاستكشاف الأنماط وتحسين تجربة المستخدم .
4. دعم الأبحاث المستقبلية لدراسة التأثيرات طويلة المدى لتبني هذه التقنيات وتشجيع إجراء دراسات معمقة حول التأثيرات طويلة المدى لتطبيق تقنيات الذكاء الاصطناعي وتحليل البيانات مع توجيه الأبحاث نحو استكشاف حلول مبتكرة لتحديات الدمج بين هذه التقنيات في إدارة المعرفة.

XIII. المراجع

[1]و. ورقلي و م. بو خالفي، "تقنيات الذكاء الاصطناعي في إدارة المعرفة بين النظرية والتطبيق"، الجزائر، 2023.
[2]ن. ب. ح. الخروصي و س. ب. م. السيابي، "تطوير العلوم الاجتماعية والإنسانية في عصر الذكاء الاصطناعي"، مسقط، 2024.
[3]م. صالح و م. السريحي، "مراجعة أدبيات موضوع: إدارة المعرفة والبيانات الضخمة"، *المجلة العربية للنشر العلمي*، 2023.
[4]أ. ح. عبدالقادر، "أخلاقيات وتطبيقات الذكاء الاصطناعي في المكتبات"، *مجلة كلية الآداب، جامعة بني سويف*، 2024.
[5]ر. س. علي، "استخدام تقنيات الذكاء الاصطناعي في الكشف عن الجرائم"، *مجلة الدراسات القانونية والاقتصادية*، 2023.
[6]ن. مدوري و م. و. سعيد، "دور تطبيقات الذكاء الاصطناعي في تحسين ودعم عمليات إدارة المعرفة"، *مجلة الاستراتيجية والتنمية*، 2024.
[7]أ. م. الخليفة، "الذكاء الاصطناعي لاسترجاع المعلومات: دراسة استكشافية لتطبيق"Talk to Books ، *مجلة بحوث كلية الآداب، جامعة المنوفية*، 2021.
[8]أ. الهنائي و س. الجابري، "تطبيقات تقنيات الذكاء الاصطناعي في خدمات المعلومات في المكتبات الأكاديمية"، *المجلة العربية الدولية لتكنولوجيا المعلومات والبيانات*، تموز - أيلول 2023.
H. Mammeri [9]، "واقع استخدام تكنولوجيات المعلومات والذكاء الاصطناعي في المكتبات الجامعية الجزائرية"، جامعة الجزائر، 2023.
[10]أ. ف. أ. سيد، "المنصات الشاملة للذكاء الاصطناعي وتطبيقاته في المكتبات: دراسة وصفية تحليلية مقارنة"، *مجلة علمية محكمة*، تشرين الثاني 2020.