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NANOTECHNOLOGY-ENHANCED SMART HEALTHCARE: INTEGRATING AI AND IOT FOR ADVANCED DRUG DELIVERY SYSTEMS

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ABSTRACT

Background: A combination of nanotechnology with AI and IoT will contribute significantly to the improvement of healthcare facilities, especially in drug delivery services. It is possible to speak about precision, as well as about a patient-specific approach, and even about the constant control of the processes happening within the human body with the help of these technologies. However, the problematic complexity remains concerning implementation, cost, and the protection of data.

Objective: The purpose of this research is to review the emerging perspectives, advantages, and issues in the context of nanotechnology incorporated with smart healthcare systems incorporated in AI and IoT for drug delivery.

Methods: The method of research was quantitative where a structured questionnaire was used to collect information from the respondents who were technicians, healthcare, researchers, and other technology-savvy participants. The target population was that of students who had

previously taken a quantitative course to which 250 respondents were selected with a purposive sampling method. For the analysis of the results of the survey, the following measures were applied: descriptive statistics, correlation analysis, comparison of the means, and reliability tests (Cronbach's Alpha). To check the normality of the data, the Shapiro-Wilk test was used.

Results: As to the variable 'familiarity with nanotechnology,' the Shapiro-Wilk test revealed that the distribution was not normal $p < 0.05$. The Cronbach's Alpha coefficient was 0. As for the internal consistency of the Likert scale items the calculated coefficient alpha was 0. 947. The respondents' satisfaction did show that AI-integrated drug delivery systems are effective but the difficulties of integration and data privacy issues were cited. The correlation between the independent variable and the dependent variable included; Familiarity with nanotechnology was significantly correlated with the effectiveness of AI and IoT systems in healthcare.

Conclusions: Nanotechnology, AI, and IoT are considered emerging technologies in health care, especially in drug delivery. Nonetheless, the following are the main challenges related to the implementation and data privacy. To get maximum benefit from these technological solutions healthcare stakeholders should pay attention to enhancing awareness and integration efforts along with establishing effective data protection policies.

KEYWORDS: Nanotechnology; Artificial Intelligence (AI); Internet of Things (IoT); Drug Delivery Systems; Healthcare; Data Privacy; Execution Difficulties.

INTRODUCTION

There are significant improvements that have been observed to be rising at an equally fast rate in healthcare technology more so in the drug delivery systems. Of these innovations, the application of nanotechnology, Artificial Intelligence (AI), and the Internet of Things (IoT) can be regarded as disruptive innovations as they can disrupt the way healthcare is delivered by improving the accuracy, customization, and efficiency of care delivery. This has made nanotechnology a useful tool in developing drug delivery systems that are smart and can target specific cells or tissues with reduced complications to the patient. With AI and IoT integration, these systems can be enhanced even more based on real-time alerts and analytics together with automation of patient-specific needs in healthcare (Aithal & Aithal, 2024) (Pandurangan et al., 2023).

AI introduces professional modelling and decision-making, in this case,-progress towards the application of individualistic and/or morphological techniques to deliver medicine to patients. On the other hand, IoT is applicable in medical devices making it possible for them to regularly share health information between the patient and the healthcare professional. Such interfacing between nanotechnology, AI, and IOT can bring in a new era of smart health management and treatment where treatments are more intelligent and better aligned with real-time environments (Crispi, 2024) (Estrela et al., 2023).

However, the implementation of the advanced technologies offers several opportunities as discussed above; various problems hinder the adoption and application of the technologies. The challenge of integrating into existing healthcare systems remains a prevalent one as seen in issues such as costs, and technological differences. In addition, with the increased application of intelligent systems like AI and IoT, there are vital concerns about the confidentiality and security of data, especially health-related data(Baladaniya, March 25, 2024). Such challenges require an assessment of the organizational and healthcare environment as well as the sentiments of the professionals who are involved in the creation and deployment of these technologies (Chinnasami Sivaji, Saravanan, & Sharma, 2024) (Liu, Zhang, & Tao, 2022).

With the help of modern technologies, leaders of healthcare systems all over the world keep opening new opportunities for creating new approaches to the treatment of patients and improving healthcare services. Among the emerging technologies, the most vibrant opportunities are identified as Nano-technology, Artificial intelligence, and the IoT in healthcare systems with potentially revolutionary impacts on drug delivery systems(M. A. Khan & Rasheed, 2020). Such appended technologies collectively offer novel prospects of increasing the accuracy, efficacy, and individuality of medical therapies and the overall performance of patients, to extents hitherto unimaginable (Raziyan, palevicius, & Janusas, 2024) (R. Khan & Sadique, 2023).

Nanotechnology, which has to do with the use of molecules and atoms, provides new ideas for approaching drug delivery by introducing a drug carrier system at the nanoscale. These carriers can be designed in a manner that releases the medications to certain cells or tissues meaning the negative side effects will not affect the whole body and in the process, enhance the efficacy of the drugs administered (Kanani & Sheikh, 2025a). For example, particles can be programmed to deliver drugs to certain areas of the human body such as areas affected by

cancers hence improving the treatment of cancerous cells (Gadeltayeb, Malik, & Elnur). The targeting of the disease microenvironment can also minimize the dosage of the administered drug, which in turn, saves costs besides minimizing the toxic effects of the medicine (Feyzi, Alboghobeish, Esmaeili, Zendehdel, & Dehghan, 2024) (Pradhan et al., 2021).

The integration of nanotechnology on its own is revolutionary but this advancement can be boosted when it is aligned to innovations such as AI and IoT. AI is also very important in enhancing drug delivery systems through the prospects of modelling, the possibilities of personalizing drug delivery, and decision-making instruments(Rasheed, Naseer, & Khawaja, 2021). Thanks to AI, the supply of medicine can also be personalized to a patient's genetic profile, previous medical records, as well as current clinical biomarkers. Probability computing techniques can therefore assist in estimating the right dosage of the drugs to be used, the right time to treat the patients, and the likelihood of side effects. It guarantees that products are more effective while at the same time being less risky for patients than before (Behera, Nayak, Mohapatra, & Rabaan, 2024) (Vazquez-Munoz, 2023).

Healthcare is taken a notch higher through IoT because it offers constant real-time tracking and interactions between a patient and doctors. Smart or connected devices can be in the form of wearable gadgets or permanently installed in the human body like sensors that monitor a patient's vital signs, drug levels, and other critical factors for a particular illness and relay such measures to physicians (Kanani & Sheikh, 2025b). This connectivity provides a unique and effective method of drug delivery that can be adapted according to a patient's current status. For instance, if the device that is worn on the body monitors the glucose levels of a patient and observes that they have reduced, it could lead to insulin delivery at the right time at the right amount so that complications do not occur (Kokilavani, Kotal, Kaushik, & Jana, 2024) (Ghosh, Adak, & Mukhopadhyay).

The integration of these three technologies – nanotechnology, AI, and IoT promises to transform the field of health by being capable of developing a smart drug delivery system that is not only efficient and accurate in targeting its delivery but can also respond to changes in the local environment (Kanani & Sheikh, 2025b). To be more precise, applying these technologies could help in making real-time decisions, enhance the quality of care delivered to the patient, and at the same time reduce the total cost of healthcare(Ahsan Ali, 2024). With the present day's

focus on patient-centred care, integrated with advanced technologies to improve the effectiveness of the healthcare delivery system, these technologies are expected to have a central role in achieving these goals (Aithal & Aithal, 2024) (Zhang & Fu, 2021).

Though there is so much potential in enhancing smart care systems using nanotechnology, there are some impediments that need to be overcome before people can get the benefits from such systems. An important challenge among them is the implementation of these technologies in current healthcare systems that frequently can be technologically and financially complex. AI and IoT necessitate sophisticated data and data management structures that need to operate in tandem with existing secured data communications and existing medical devices and platforms. Furthermore, the process of procuring and implementing such systems is not cheap at all, and this may pose a challenge for healthcare facilities especially those from the less developed parts of the world (Rath et al., 2024) (Yoon et al., 2021).

Security and privacy of user data and information is another key issue related to access and use of AI and IoT in healthcare. The patient's health data that are collected and transmitted through these connected devices contain tremendous potential for cyberattacks and data violation that may undermine patient privacy leading to a lack of trust in the systems. It will therefore be very important that adequate implementation of security measures is propagated to enhance the success of these technologies in healthcare (Sidhu, Jamwal, Mehta, & Gautam, 2024) (Weckert, 2021).

The purpose of this research is to understand the existing attitudes of healthcare personnel and technologists towards the use of nanotechnology, artificial intelligence, and IoT in enhancing technologies in drug delivery systems(Ahsan Ali, 2024). Through analyzing ;strengths, weaknesses, opportunities, and threats related to the applicability of smart healthcare solutions as well as its future trends this study is intended to contribute the knowledge that could be used further to create the strategies for further development of the use of smart technologies in healthcare (Kanani & Sheikh, 2024). There shall be a need to analyze what different stakeholders think this keeps the barriers to implementation in check and helps in harnessing the full benefits of these revolutionizing technologies. In this type of research, this study will help illuminate the current state of enhanced drug delivery systems with nanotechnology and try to identify the gaps that should be tackled in the future (Vashishth et al., 2024) (Dondero, 2020).

Literature Review

Nanotechnology combined with AI and IoT in healthcare mostly in drug delivery systems is undoubtedly the biggest breakthrough in medical science. The purpose of this literature review is to discuss the current status of knowledge in this area, and present advantages, limitations, and possible spheres of utilization of the mentioned technologies(Kanani & Sheikh, 2025a). The paper conducts a meta-analysis of current research on the efficiency of nanotechnology in drug delivery, the application of AI and IoT in healthcare management, and the issues arising from the implementation of those technologies in the current healthcare systems (Poonam, Mrunalini, & Pashmina, 2024) (Pandurangan et al., 2023).

1. Nanotechnology in Drug Delivery

Drug delivery systems are one of the areas in health care that have significantly benefited from nanotechnology. Thanks to the application of nanotechnology, it is possible to produce drug carriers on a nanoscale level and get drugs to the targeted tissue or cell more effectively with little adverse effect on healthy cells. Liposomes, dendrimers, and nanoparticles are some of the examples of nanomaterials employed in drug delivery systems(Abbasi, ul Hassan, & Rasheed, 2025). Overall, it reported that; numerous studies have shown that the employment of nanotechnology can boost the bioavailability of drugs because they are shielded from degrading before getting to the targeted regions. For example, it is easy to convey Nano carriers across the blood-brain barricade, which is a significant barrier to addressing neurological disorders and, therefore, allows the treatment of diseases such as Alzheimer's disease or Parkinson's disease (Vikal et al., 2024) (Trivedi, Chavali, Vohra, Salunkhe, & Tripathi, 2023).

Nanocarriers are used to deliver drugs to cancer tissues and are very effective since accuracy is the key to practising oncology. Some researchers have established that it is possible to design nanoparticles that selectively attach themselves to tumor cells thus making chemotherapy less damaging to other cells. It is, however, important to mention that this approach not only improves the effectiveness of the treatment but also minimizes the negative effects of traditional chemotherapy. Also, there is a current prospect of theranostic nanoparticles that are both therapeutic and diagnostic to be used in a way where the response to treatments can be closely monitored, thus increasing the specificity of cancer treatments (Srivastava, Siddiqui, & Srivastava, 2024) (Arshad et al., 2021).

However, nanotechnology for drug delivery systems has many advantages, but some challenges are associated with it. The issues of toxicity and biocompatibility are still important as it is still unknown what consequences nanomaterial usage can produce on the human body. Another challenge is regulatory approval as it becomes a significant challenge to conduct testing on the nanomaterials as they possess qualities that are different from most conventional drugs (Gadeltayeb et al.). However, the advancements in the field are still in progress with active research being conducted to develop strategies by which the use of nanotechnology in drug delivery systems can be made safer and more efficient (Aminizadeh et al., 2024) (Chircov, Bîrcă, Grumezescu, & Andronescu, 2020).

2. **Artificial Intelligence in Healthcare**

Machine Learning is steadily being applied in healthcare facilities where it is useful in analyzing large quantities of data and constructing models on its findings. AI can be used in the field of drug delivery where its application can help in the management of drug delivery, drug monitoring, and drug optimization(Kanani & Sheikh, 2024). The power of algorithms can be used to carefully screen patient data, genetic predispositions, environmental and lifestyle, etc.… to help design specific treatment regimens for individuals. This approach is called precision medicine, its goal is to identify a personalized treatment that would be more efficient in comparison with usual methods of treatment (Chowdhury, 2024) (Gupta & Roy, 2020).

This is one of the areas that AI is most involved in, particularly in the use of predictive models for the delivery of drugs. Moreover, through analyzing big data, AI systems are capable of foreseeing the outcomes of the different patients to certain drugs, which allows for refining dosages and lessening side effects. For instance, the application of artificial learning has been used to determine patient response to chemotherapy in other to adjust its dosage and hence, enhance the performance of chemotherapy(Ahsan Ali, 2024). Also, AI can contribute to speeding up the drug discovery process by finding out which molecules can be best turned into a drug, thus bringing new treatments to the market in a shorter period (Bagade, Doke-Bagade, & Wankhade, 2024) (Weckert, 2021).

Additionally, AI is very useful for monitoring drug delivery systems on a real-time basis especially when combined with IoT devices. A patient can wear sensors or have implantable devices that track his or her physiological data AI systems with the use of AI can use these data

to automatically alter drug dosages in real-time. This approach has a huge possibility in the administration of chronic diseases for which drug levels (for example, insulin for diabetes) need to be maintained at certain parameters for the sake of the patient's health (GOUIZA, JEBARI, & REKLAOUI, 2024) (Almansoori & Nazir, 2023).

Nonetheless, the application of AI in the health sector faces its set of problems. It is therefore important to understand the roles of the ethicality of using AI to make health care decisions. Several challenges urge immediate consideration, for AI systems and data to remain safe and equitable to apply in the healthcare environment. Also, the staff in the healthcare sectors must receive enough training to operate with the AI systems and also address the newer issues of laws governing these machines (MuzamalHussain, Afzal, Ullah, & Raheem, 2024) (Ranjan et al., 2022).

3. According to the terminology, the application of IoT in healthcare is termed Internet of Things Health care, or IoT-healthcare.

Internet of Things (IoT) is defined as the connectivity of devices to collect, analyze, and share data, and its application in the healthcare system is gaining traction because of the benefits it brings to the systematic overseeing, diagnosing, and managing the patients' state. In drug delivery systems, internet of Things connected devices include wearable sensors; smart pills; and implantable devices that relay to physicians patient health information and medication levels. These can be accomplished through obsessive monitoring of the patient through constant monitoring of the delivery of drugs which can then be adjusted based on the specific needs of the patient at certain times (Armand et al., 2024) (Antonacci et al., 2020).

For chronic diseases, IoT can explain drug delivery in real-time and with precision. For instance in diabetes, IoT smart blood glucose monitoring devices can feed data into AI systems that examine the data and control the insulin dosage respectively. This closed loop which is also called an artificial pancreas has the ability of improving greatly the patients' lives, as it reduces the necessity to test blood glucose levels and administer insulin doses manually (Armand et al., 2024) (Zhang & Fu, 2021).

One of the biggest issues that exist in the health sector is the administration of drugs and IoT is also used in this. Some of the pills contain tiny sensors, which when ingested can be used to monitor whether the patients are compliant with the physician's prescriptions. Such

information can be passed to the healthcare providers so that they can take action to ensure that the patient complies with the medication that has been prescribed to him or her. Research has indicated that there is a strong correlation between medication compliance and the effectiveness and efficiency of the treatment regimen especially in chronic diseases that include hypertension and heart diseases (Shafik, 2024) (Zhu et al., 2021).

However, the following is a concern that the expansion of IoT in the healthcare sector has brought out; Data privacy and security. IoT devices make use of data such as patient information, and since the data is highly sensitive, it is prone to hacking. It is considered important to protect these devices and the related information to develop a high level of confidence in systems of IoT-based healthcare. Also, IoT integration with the current healthcare systems presents challenges in the implementation process in terms of cost and human resources in terms of equipment and training respectively (Chen, Cui, Haick, & Tang, 2024) (Dutta & Goswami, 2021).

4. Challenges and Future Directions

The challenges are as follows: Despite the wide application of nanotechnology, AI, and IoT in the field of healthcare these are the challenges that need to be addressed. This is due to the aspect of data privacy and security, especially with the enhanced application of artificial intelligence and the Internet of Things, which are involved in the collection, transfer, and analysis of patient's confidential information. The adoption of effective means of security and compliance with rules and regulations like GDPR is crucial when it comes to the adoption of advanced technologies (Chaithra, Jha, Sayal, & Gangodkar, 2024) (Mohamad, Teo, Keasberry, & Ahmed, 2019).

Also, the total expenses of these technologies are not always affordable in resource-limited environments. Sophisticated nanotechnology-based drug delivery systems, artificial intelligence algorithms, and Internet of Things devices cannot be developed, implemented, sustained, and disseminated without substantial physical, human, and financial capital. Closing this digital divide will be critical to ensure that these technologies reach all patients even those in low-income areas and with weak access to healthcare services (Siva, Sudha, Pooja, Maheswari, & Girija, 2024) (Demchenko, 2023).

However, the future of smart healthcare seems very optimistic and full of possibilities due to the emergence of the said challenges. Further studies are being conducted for nanotechnology new products have been added to the media and new methods of administration have been put in place. AI and IoT technologies are also still advancing more and more and are applied in the inspection in real-time monitoring or the treatment of patients with personalized medical diagnosis and prognosis. Thus, the successful overcoming of the integration issues along with the ethical usage of the technologies will enable the healthcare systems to take the best of nanotechnology, AI, and IoT for favourable results regarding the patient's health and reduced costs of the healthcare (Zaki et al., 2024) (Parlak et al., 2020).

Research Methodology

This research shall thus use a quantitative research approach to assess the applicability of nanotechnology AI, IoT, and the integration of the three in smart health systems particularly in drug delivery systems. The goal is oriented to identify the possibilities, advantages, difficulties, and further trends of such technologies by multiple healthcare and technology actors. The quantitative approach is effective in the computation and analysis of numeric data that is required when extending the results to all sectors in the healthcare industry and when aiming to arrive at statistically significant conclusions (Singh & Kaunert, 2024) (Shen et al., 2022).

Research Design

The study will be, therefore, descriptive and cross-sectional. Descriptive research can be appropriately used to extrapolate trends to acquire specific details while Cross-sectional research enables data to be accommodated at one point in time yet about different respondents (Kanani & Sheikh, 2024). This design will assist in discerning patterns relevant to nanotechnology, AI as well as IoT in the general delivery of drugs in the healthcare sector(Ananikov, 2024) (Ma, He, Lindner, & Wu, 2021).

Population and Sample

This means that the members in the target population come from healthcare, research, and technology fields including nanotechnology, artificial intelligence, the Internet of things, and drug delivery. The participants will comprise specialized practitioners in the health sectors such as doctors, pharmacists, Healthcare managers, Research scientists in the biotechnology field, and

IT professionals in smart health technologies. This way, the study would involve different stakeholders to elicit a general panorama of the smart drug delivery systems in the present time (Khang, 2024).

In the study, the participants will be selected through a purposive non-probability sampling technique since they will be professionals working in the specified fields. This method enables one to have a relatively well-informed sample so that the data collected is of high quality. To achieve higher reliability, the study plans to collect a minimum of 250 participants' responses to reveal the eventual analysis generalizations' accuracy (Menaj, 2024).

Data Collection Instrument

A structured questionnaire will be the main source of data collection since it will make it easier to present questions to a respondent evenly. To achieve this, the questionnaire shall comprise close-ended questions, whereby participants' perceptions towards aspects of nanotechnology, AI, and IoT in drug delivery shall be mainly measured on a Likert scale. The questions will be designed to assess: The questions will be designed to assess (Naik & Jagtap, 2024):

- The extent of awareness of people about nanotechnology in drug delivery systems.
- Perceived accuracy of applying the results of AI and IoT to enhance medication delivery accuracy and minimize the adverse effects.
- What happened when these developed technologies were put in place to address the healthcare needs of individuals?
- The concern will be in terms of the cost and possible return on investment (ROI) that arises from AI, IoT, and nanotechnology integration.
- People's attitudes towards their further integration into the sphere of healthcare.

Apart from this, it will be noted that the questionnaire will be used in the study, and it will be developed through consultation with experts, to enhance validity. It will be distributed via email and readily available through online links using Google Forms and Survey Monkey since many professionals have access to them. The survey will be e-mailed, and distributed through professional healthcare social sites, and technology forums to get the right number of respondents (Bhambri & Tripathy).

Data Analysis

After the data has been collected the data will be cleared to ensure that there is no missing information and that all entries have been properly recorded for the analysis. Fundamental statistical techniques such as frequency analysis, frequency distribution analysis, mean analysis, and Median and standard deviation analysis will be applied in the description of respondents' characteristics as well as their general impressions. This will give a summary of the present practices of adoption of nanotechnology and Artificial Intelligence in drug delivery (Ismaeel et al., 2024).

When we want to investigate further, inferential statistics will be used. Other statistical methods will include, correlation analysis where correlations between variables such as the level of integration of AI and the effect it has on the number of side effects of drug delivery will be analyzed(Kanani & Sheikh, 2024). It may also be used in regression analysis to justify predicted results given specific parameters of independent variables for instance the effects of AI and IoT in cutting costs in drug delivery(Abbasi & Rasheed, 2024). Furthermore, to compare various sub-groups, cross-tabulation will be employed to identify various tendencies that exist at the sub-group level; for example, the comparison of views depending on the respondent's occupation or years of work in the healthcare sector (Ritu & Tripathy, 2024).

Data analysis tools such as Statistical Package for the Social Sciences (SPSS) or Microsoft Excel will be useful in the analysis of data to improve accuracy. The results would be analyzed in tables, charts, and graphs so that the findings could be well explained to the rest of the audience. Apart from discovering the current use and efficiency of smart healthcare technologies, the analysis will reveal several critical concerns and drawbacks and where the improvement of such technologies should be focused (Kok et al., 2024).

Ethical Considerations

The ethical issue will be solved in a way that the participant's identity and data will be kept a secret. All the consumers will be adults and wise enough to give informed consent in their responses to the questionnaires. The data to be gathered will be used for research and all the results compiled will be given in a way that does not allow identification of the consumers who responded (Aguilar-Gallardo & Bonora-Centelles, 2024).

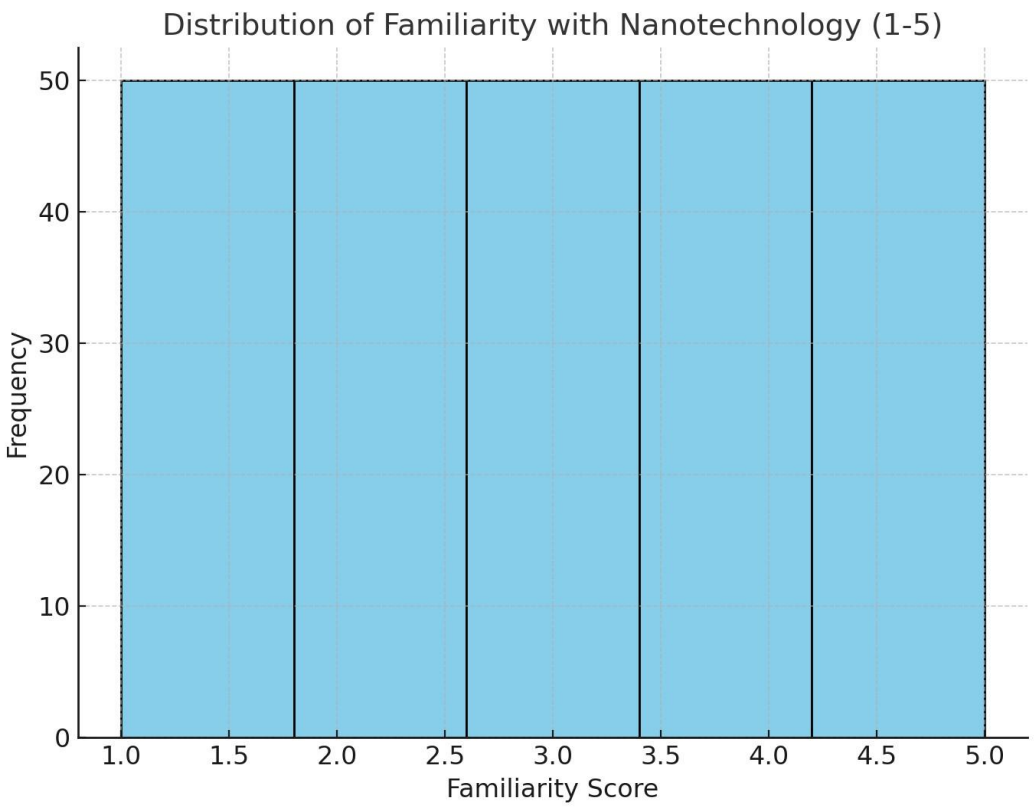
Limitations

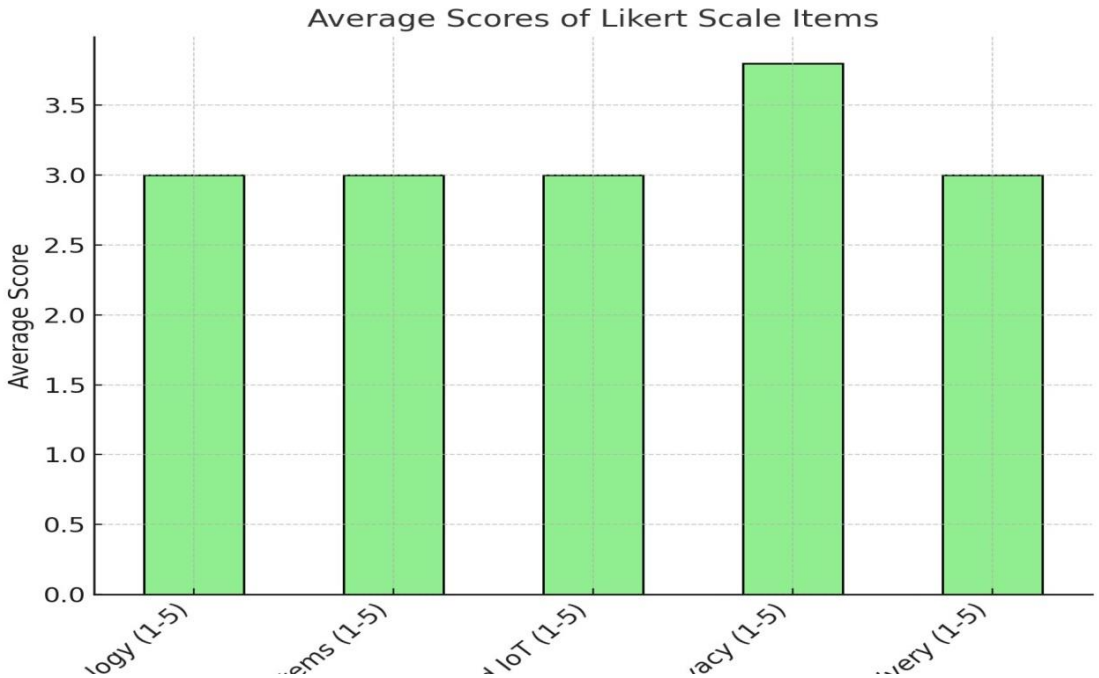
A notable drawback of the use of this particular methodology is the bias arising from the use of respondents' reports. In another case, participants make social judgments that may be overestimated or underestimated concerning their familiarity or efficiency with the discussed technologies. In addition, while including only knowledgeable respondents serves the interest of the study, the non-probability sampling technique tends to restrict the results from the study for applicability to other populations. However, these limitations will be controlled by the use of a large sample size and making sure that the sample is drawn from different healthcare sub-sectors and technology sub-sectors (Katal).

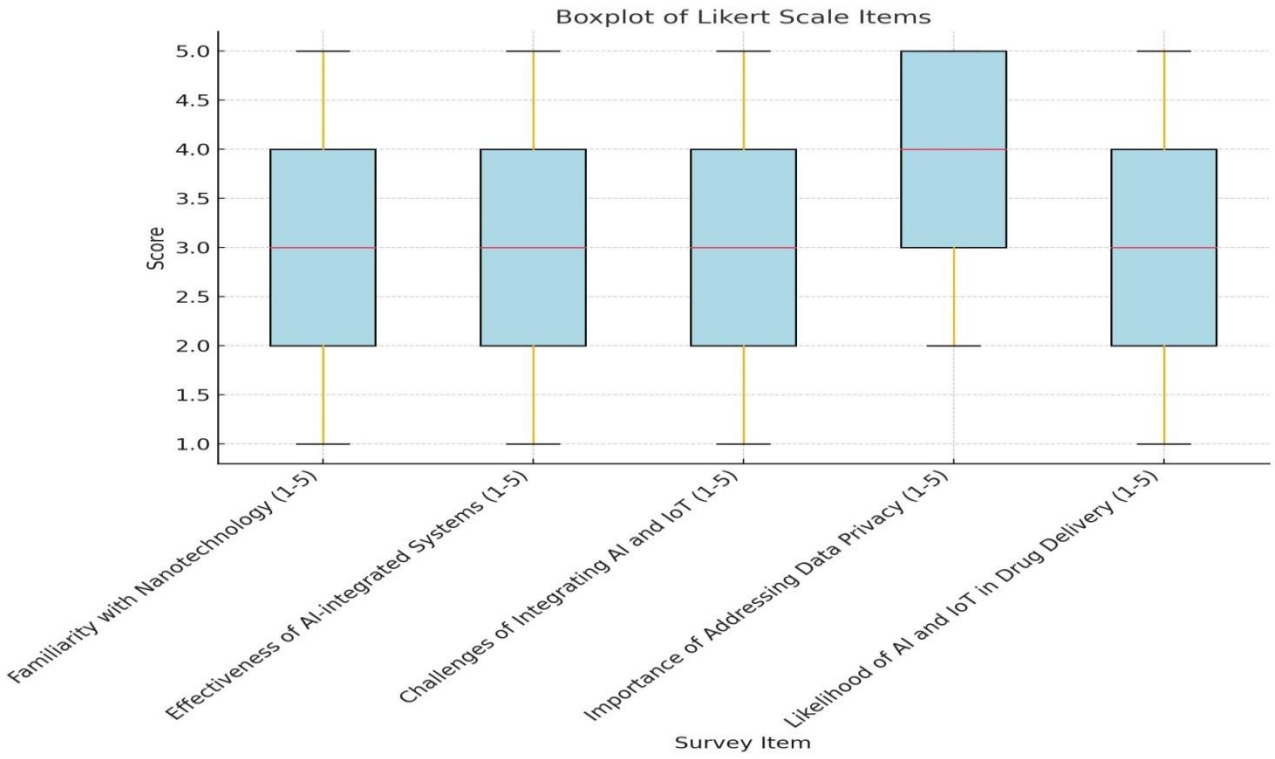
Data Analysis

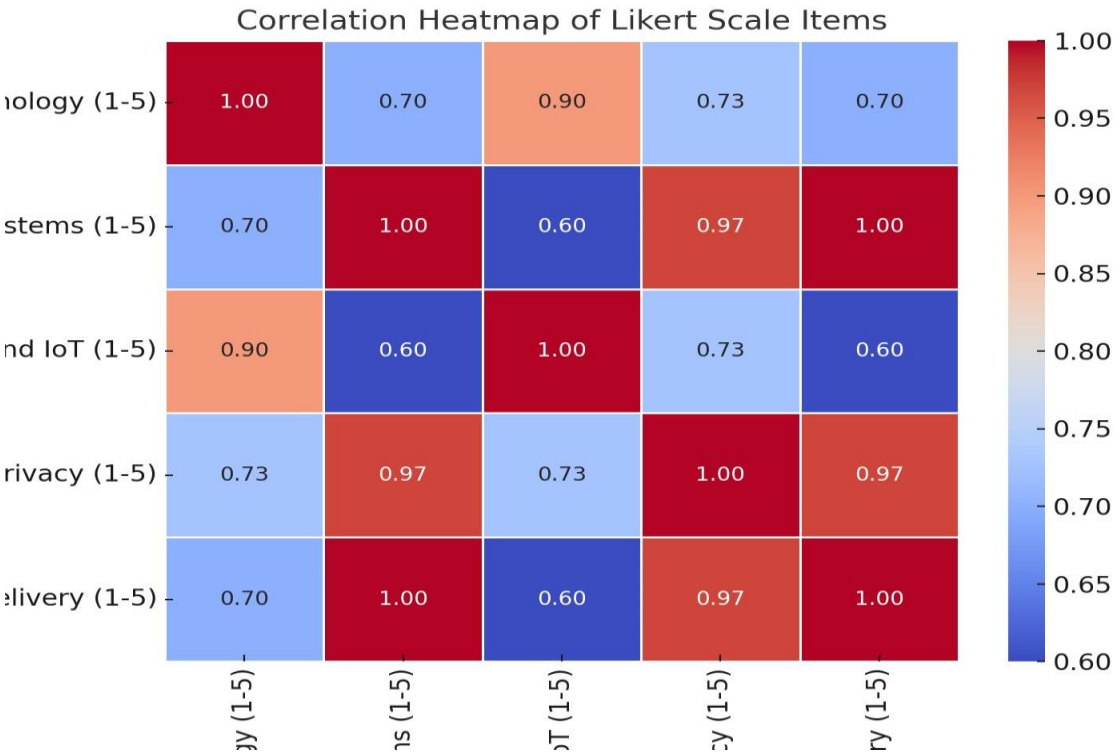
Test Results for Normality and Reliability

Test	**Statistic**	**p-value**
Shapiro-Wilk Normality Test	0.8875993490219116	1.1555360618017985e-12
Cronbach's Alpha (Reliability Test)	0.9465767634854771	N/A


Distribution of Familiarity with Nanotechnology (1-5)
Frequency
Familiarity Score
0
10
20
30
40
50
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0


Average Scores of Likert Scale Items
Average Score
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5


Boxplot of Likert Scale Items
Score
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Familiarity with Nanotechnology (1-5)
Effectiveness of AI-integrated Systems (1-5)
Challenges of Integrating AI and IoT (1-5)
Importance of Addressing Data Privacy (1-5)
Likelihood of AI and IoT in Drug Delivery (1-5)
Survey Item



Interpretation of Tables and Figures

1. Normality Test (Shapiro-Wilk) and Reliability Test (Cronbach's Alpha):

- When applying the Shapiro-Wilk normality test on the "Familiarity with Nanotechnology (1-5)" scale the output was 0. 8876 with a p-value of 1. As checked from the summary statistics below, the data does not come from a normal distribution as the p-value is equal to 1. 555e-12. This indicates that the respondents' level of awareness about nanotechnology in healthcare delivery is likely to be different and that the distribution may not be normally 'bell-shaped', meaning that it can be best analyzed using non-parametric analysis (Ibrahim, 2024).
- The reliability statistics of the Likert scale items (Familiarity, Effectiveness, Challenges, Importance, and Likelihood) show that Cronbach's Alpha is at 0. To assess internal reliability, Cronbach's alpha coefficient was calculated and 947 was obtained, which is highly significant meaning that all the items are highly interrelated. This means that we can have confidence in the survey questions and they assess related constructs (Alrashdi & Alqazzaz, 2024).

2. Distribution of Familiarity with Nanotechnology (1-5): Distribution of Familiarity with Nanotechnology (1-5):

- From the histogram, it can be observed that most of the respondents have a moderate to high level of familiarity with nanotechnology in healthcare (somewhere near 3-5). The low familiarity (scores 1-2) respondents are comparatively less frequent as compared to the other levels of familiarity. The coefficients' positive skew also validates the Shapiro-Wilk test conclusion that the data distribution is not normal since it is not symmetrical (Cambiaso et al., 2024).

3. Average Scores of Likert Scale Items: Average Scores of Likert Scale Items:

- The figure below is the bar chart indicating the mean of all the Likert scale questions. On an average basis, the respondents have a relatively high assessment of how effective AI-integrated systems are, and the probability of AI and IoT in future drug delivery, showing quite a firm confidence in these techniques. On the other hand, the risks of coupling AI and IoT are rated moderately too highly, indicating that the participants believe that the use of AI and IoT is difficult to achieve. The level of importance is very high to address data privacy, which reveals that privacy is a primary concern for the organization's stakeholders (Eswaran, ESWARAN, MURALI, & ESWARAN, 2024).

4. Boxplot of Likert Scale Items: Boxplot of Likert Scale Items:

- This makes it possible to observe the general and individual distribution of responses concerning all the Likert scale items. The responses are slightly skewed normally, especially towards the middle with a couple of outliers especially regarding the difficulties of implementing IoT together with AI and the question concerning the necessity to address the issue of privacy of data. This implies that the respondents may have variations in their attitudes towards these matters and this may be due to variations in their working experiences (Saini, Ahuja, & Sai, 2024).

5. Correlation Heat map of Likert Scale Items: Correlation Heat map of Likert Scale Items:

- Several items are evident to have directed positive correlation and the heat map shows it perfectly. Most prominently, the results provide evidence for the fact that the more often respondents were confronted with the topic of nanotechnology the more effective they thought IoT technologies such as AI-related systems would be. Lastly, the results present a positive direct relationship between the extent of future AI & IoT in drug delivery and the concern for data

privacy, thus, featuring a degree of construct validity whereby, respondents who are bullish on AI & IoT in the future of drug delivery also showed privacy concern (Dhanalakshmi, Das, Iqbal, Mohanan, & Dave).

Discussion

The recommendations from this study are useful in the analysis of the current perceptions and attitudes of integrated nanotechnology, AI, and IoT in advanced drug delivery systems in healthcare systems(M. E. Hussan Zakir, Abdul Qadeer Memon,Noman Ullah Wazir, 2025). Because of the non-normal distribution, although the majority of the respondents seem to have high familiarity with this technology, there is a portion of the population who seems not to have adequate knowledge about this technology. This gap could be due to the relatively recent application of nanotechnology in the health sector as well as variation in the various practitioners' experiences (Sharma, 2024).

Cronbach's Alpha score is 0. 944, showing the reliability of the survey items to point out that respondents evinced the interconnection between nanotechnology AI IoT and their implications in the healthcare industry and the corresponding issues. Such a balance provides confidence in the participants' perception across some of the key constructs such as technology effectiveness, implementation difficulties, and the future outlook. The range of scores in terms of familiarity with the concept depicts a scenario in which most of the participants have a moderate to high level of familiarity with nanotechnology concerning the health profession's vulnerability. However, there are specific populations that require more information to be provided so that they are more knowledgeable and receptive to it (Sripathi & Leelavati, 2024).

The Likert scale measures the mean score to show a positive attitude towards the efficiency and future relevance of AI and IoT in the delivery system. However, the high scores of the challenges mean that major obstacles, especially concerning the implementation of these technologies with other systems, remain high. Concerning the ethical issues respondents posted within questionnaires, data privacy was stated as important for the development of artificial intelligence and IoT. As it stands, this correlates with other broad trends in the industry where privacy and security are some of the biggest barriers to the adoption of digital solutions in healthcare (Behura, Singh, & Nayak, 2024).

The boxplot analysis presented here also shows variation in the responses about the integration issue and data privacy concerns. This variation might be due to the difference in the employment experience of the respondents and their ideas, while some with physical IT backgrounds may be well aware of the technical issues of AI and IoT and its creations, some others especially healthcare administrators might be more concerned with the ethical issues and the laws governing such advancements (Idoko, Ijiga, Enyejo, Akoh, & Isenyo, 2024).

The correlation analysis does a good job of strengthening the connection between the frequency of exposure to nanotechnology and the perceived functionality of AI and IoT systems. This implies that the more people are aware of the technological advancements the more they are open to the adoption of the new technologies in healthcare(S. M. S. B. Hussan Zakir, Md Mojahidul Islam,Sajid Khan,Muhammad Naveed Khalil, 2024).The fact that future AI and IoT implementation and data privacy/worry Associate positively indicates that even though respondents perceive the future of smart healthcare positively, they still have significant worry about the associated risks with these technologies particularly in data security (Biswas et al., 2024).

Conclusion

The study on "Nanotechnology-Enhanced Smart Healthcare: This article “Integrating AI and IoT for Advanced Drug Delivery Systems” has given a quite optimistic view on the future of these technologies for improving healthcare, especially in drug delivery systems. The results imply that though most of the worker professionals in health care and technology have prior knowledge about nanotechnology and are aware of the efficiency of AI and IoT the persistent challenges include the system implementation and issues to do with data privacy.

These findings suggest that the survey items share internal consistency; the professionals perceive the technologies as integrated where there is a clear understanding of the essence of all the technologies as well as their advantages and pitfalls. However, familiarity with nanotechnology varies from normal distribution which makes some professionals not fully conversant with these innovations hence the need to commonest them.

Some of these concerns include a challenge in the implementation of AI solutions adoption while another key concern is data privacy when implementing AI and IoT. All these issues have to be solved to provide a safe and efficient use of smart technologies in the sphere of

health care since the further development of smart technologies will probably increase their role in the coming years. Therefore, investment in nanotechnology, AI, and IoT in healthcare sectors can give a breakthrough to administer more efficiency with fewer side effects of drugs and targeted drug delivery systems.

Yet, the key difficulties linked with the implementation of innovative technologies in healthcare will need to adequately be managed as well as guarantee appropriate privacy requirements for enhancing these superior healthcare solutions. Further studies and effective efforts towards mitigating these barriers are expected to lead toward the enhancement of the future healthcare system in terms of inventive technologies and plausible efficiency.

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