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A cost-effective approach using generative AI and gamification to enhance biomedical treatment and real-time biosensor monitoring

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Biosensors are crucial to the diagnosis process since they are designed to detect a specific biological analyte by changing from a biological entity into electrical signals that can be processed for further inspection and analysis. The method provides stability while evaluating cancer cell imaging and real-time angiogenesis monitoring, together with a robust, accurate, and successful identification. Nevertheless, there are several advantages to using nanomaterials in biological therapies like cancer therapy. In support of this strategy, gamification creates a new framework for therapeutic training that provides patients and first aid responders with immunological, photothermal, photodynamic, and chemo-like therapy. Multimedia systems, gamification, and generative artificial intelligence enable us to set up virtual training sessions. In these sessions, game-based training is being developed to help with skin cancer early detection and treatment. The study offers a new, cost-effective solution called GAI, which combines gamification and general awareness training in a virtual environment, to give employees and patients a hierarchy of first aid instruction. The goal of GAI is to evaluate a patient's performance at each stage. Nonetheless, the following is how the scaling conditions are defined: learners can be divided into three categories: passive, moderate, and active. Through the use of simulations, we argue that the proposed work's outcome is unique in that it provides learners with therapeutic training that is reliable, effective, efficient, and deliverable. The examination shows good changes in training feasibility, up to 22%, with chemo-like therapy being offered as learning opportunities.

Keywords Generative artificial intelligence (GenAI), Machine learning (ML), Biomedical treatment, Biosensors, Cancer diagnosis, Gamification

Since ischaemic heart disease is the leading cause of death worldwide, cancer is regarded as the second most lethal disease^{1,2}. Furthermore, a quarter of the world's remaining population is expected to die from this disease, according to research conducted by the World Health Organization (WHO)^{1,2}. In 2020–2022, this equates to almost 19.3 million people^{1–4}. In contrast, there were almost 35 million new cases reported in 2024–2025^{2–5}. It is noteworthy that one of the three will be diagnosed with cancer at some point in the coming year. There are about 200 variations, nevertheless, and the top cancer category is shown as follows²: these are the first five types of cancer: hematologic system, skin, breast, prostate, lung, and blood. On the other hand, the most common cancers that affect both men and women are breast and prostate cancers^{2–4}. Numerous new cases have been recorded; in South Asia alone, 347,184 cases are probably reported per year^{2–4}. Several types of skin cancer severity are linked to viral infections and bacterial assaults. In contrast, the age range of cases that have been reported falls between 14 and 55 years old^{3,4}. Up till now, one of the major issues that has a direct impact on the

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diagnosis process is early diagnosis. In actuality, cancer is regarded as one of the costliest illnesses in addition to being a fatal one. In terms of expenditures incurred over the past year, the total is estimated to be \$250 billion^{4,5}.

Over 18.1 million non-melanoma skin cancer cases are omitted from 19.3 million cases, or 1/6 of the total number of cancer cases, according to a WHO report^{6,7}. Experts assess environmental factors and conclude that they are among them; second, genetics—specifically, autoimmune dysfunction, hereditary mutations, and crossover—may increase a person's risk of developing cancer. According to the council, the average rate of cancer survival over the past ten years has improved more than it did the year following the pandemic in terms of accurate diagnosis and treatment because of the revolutionary qualities of technical engagement that create the possibility of early diagnosis. As a result, the rate of influence on early diagnosis and cancer survival is lowered to 16%, which is regarded as a noteworthy value when compared to the traditional characteristics^{7–9}. To do this, cutting-edge digital technology combines with recently developed biosensor technology, which is a crucial component in the early identification of cancer, particularly skin cancer, which is usually diagnosed in its intermediate stage, as shown in Fig. 1. Furthermore, the reactions to treatment are noticeably inadequate¹⁰, meaning that despite no improvement in quality of life, patients continue to live.

The comprehensive investigation of skin cancer elucidates the function of some unchecked aberrant cells that proliferate within the human body, as highlighted in Fig. 1. These cells are sites of countable genetic accumulation, allowing for the examination of epigenetic abnormalities from both hereditary and environmental backgrounds^{8,10}. Undoubtedly, melanoma, squamous cell carcinoma, and basal cell carcinoma are problems caused by the proliferation of unchecked cells. One type of cancer that metastasized to other parts of the body is melanoma. UV light—which is essentially the sun—and sunbeds are the primary causes of this kind of skin cancer^{9,11}. As cancer progresses, it spreads beyond the areas of the skin and metastasizes to other parts; at this point, we must say that the cancer is essentially incurable.

By analyzing all such prospects, the utilization of cell-based biosensors makes the process more effective and reliable in terms of live cells as receptors and organization, offering benefits like rapid responses and non-invasive monitoring^{10,11}. It also values the ongoing dynamic monitoring regarding the progression of skin cancers. On the other side, the system's effectiveness is yet to mature, which means there are still limitations raised in terms of affecting cell viability, like sterilization and cell lifespan-related stuff^{9–11}. To robust the technological capabilities, the innovative AI assists biosensors in order to properly monitor due to the ability of bodily electro-physiological and electro-chemical signal communications for efficient biomedical disease diagnosis and treatment, especially for skin cancer, as shown in Fig. 2. However, these improvements can exemplify the trend to cost-efficient processes, effective delivery, medicine personalization, and precision towards point-of-care treatment.

The revolution of Generative Artificial Intelligence (GenAI) with the practical implementation of gamification makes the healthcare lifecycle more attractive, where the role of biosensing devices is critical^{12,13}. It is not only worn on patients' skin surfaces but also interacts with the wearable to acquire data from stakeholders in a day-to-day manner, along with responding actively to the patients in terms of helpful insight regarding their health status. On the other hand, conventional biosensing devices majorly focus on ubiquitous monitoring via managing physical signals, including evaluating body impulsions^{12–14}. Recently, the research focus has been diverted towards early cancer diagnosis and related biomedical treatments, where the staff, along with the patients/survival training need to be pushed near future regarding early diagnosis and first aid to reduce the emerging rate. To educate them in a proper manner, the multimedia-enabled GenAI and gamification play a

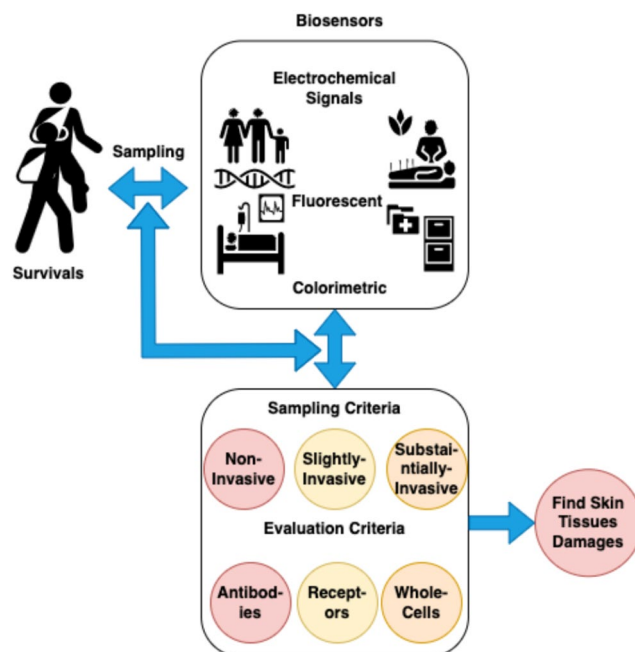


Fig. 1. Working sequence of biosensors for early cancer diagnosis.

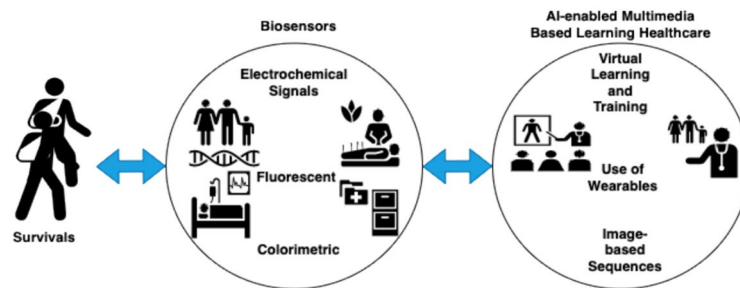


Fig. 2. The current AI assisted biosensors architecture for healthcare learning and training.

significant role in elaborating the process of diagnosis, detection, and level of impacts for early identification. However, the applicational activity of gamification is to provide a multimedia-enabled sequential design, where the levels create interest between stakeholders, just like gaming, and demonstrates how much they need to understand to classify symptoms of skin cancer^{12,14}.

Aims and objectives

This paper discusses the revolution of GenAI in the biomedical environment, which changed the dynamics in terms of elaborating the process hierarchy of cancer diagnosis and treatment. However, the existing artifacts generate realistic, novel, and new artifices at scale level in a higher order that reflects the characteristics of the training data but cannot be looped in. The content can be derivatives into six different folds, such as text, speech, image, music, video, and software codes to produce designs. There are a number of GenAI mechanisms proposed that foremost the foundation of AI techniques, especially models, which train the population of unlabeled data used for fine-tuning skin cancer symptoms and their impact. And so, the responses are back to the user in a formation of natural language—it that does not require any kind of knowledge to enter code. On the other hand, the adaptation criteria for innovation in the health environment need to fulfill the fundamental requirement of industrial healthcare, which is cost-effectiveness; in order to maintain this, a quality design that supports current material science development is the primary objective.

The mentioned enhancement integrates with the biosensing environment, where it helps the proposed work to make an effective, fast, efficient, and reliable infrastructure to capture remote sensing data accurately from multi-sources of registered stakeholders. The cycle to capturing data is defined as follows: (1) sensing data preprocessing, (2) filtering, (3) aggregation, (4) examination, (5) feature extraction, (6) pattern recognition, (7) presentation, and (8) decision-making. Now, these filtered data are used for training purposes to the participating stakeholders of the system, which enhances the capability to evaluate the severity impact of skin cancer in real-time. The major purpose of this proposed work is to reduce the rate of skin cancer survival while increasing the rate of effective biomedical diagnosis and treatments in a real-time manner. However, the main highlight of this proposed work is discussed as follows:

- Using biosensor technology with GenAI and gamification, this paper proposes a unique paradigm for biological diagnosis and therapy that incorporates multimedia elements like generating visual sequences.
- In order to provide an effective and reliable biomedical treatment that lowers the rate of the process, such as diagnosis, detection, and level of impacts for early identification accordingly, particularly for early skin cancer diagnosis, the proposed work primarily targets the cost-effective proposals of industrial healthcare.
- A proposed lifecycle is presented for gathering biosensing-enabled data from several participating stakeholder nodes. The following is a list of the proposed lifecycle's sequence:
 - Sensing data preprocessing.
 - Filtering.
 - Aggregation.
 - Examination.
 - Feature extraction.
 - Pattern recognition.
 - Presentation.
 - Decision-making.
- The gamification applicational activity is intended for trainees and offers a sequential generative approach with multimedia capabilities that explains the steps to comprehend how severity affects the classification of skin cancer symptoms and what precautions need to be taken.
- Additionally, this paper presents a list of difficult issues based on the proposed critical design, implementation, and deployment-related issues, some of which are described, and an argument that mentions potential strategies to do it.

Section distribution and alignment

The alignment of the complete manuscript is organized and structured as follows: section “[Related work](#)” discusses the detailed argument regarding the revolution of GenAI with gamification to train people for early diagnosis,

along with the robust processes of biomedical treatments, especially skin cancer. The problem description and formulation, and proposed solution in terms of architectural design in order to tackle the rising prospects in section “**Methods and materials**”. However, the simulations, results, and related discussions of the proposed work are presented in section “**Simulations, results, and discussion**”. In section “**Open research problem**”, a list of implementation issues is highlighted, and a few of them are discussed, along with the possible solutions. Finally, this paper concludes with the argument of a brief conclusion in section “**Conclusion**”.

Related work

The role of Artificial Intelligence (AI) in cancer detection is remarkable, especially in the finding of sequences of predictions that derivate cancer anomalies in an automated manner^{15,16}. The author^{14–16} indicated the emergence of AI in healthcare makes medical things more effective in terms of providing a promising option for enhancing accuracy and outcomes from registered patients. However, various applicational examples are listed in the domain of oncological assessment and dynamic monitoring that use the capability of AI, as shown in Fig. 3. It includes risk mitigation and their assessment, estimation of patient prognosis, early detection, and help in the selection of effective treatment out of others using deep knowledge. Apart from this, here we draw attention to the current healthcare environments for adaptation benefits of GenAI in real-time with gamification facilities. Some of the critical discussion on the mentioned topic is highlighted as follows.

On the other side, we evaluate the current sequence of AI-based cancer diagnosis and their process of investigation in order to achieve early diagnosis setup in a cost-efficient manner. After evaluation, we conduct the investigation in the following hierarchy: (1) role of biomarker detector, (2) computer-aided screening, and sensor-based revolution for proposing auto-diagnosis application for learning stakeholders, as shown in Fig. 3.

Generative artificial intelligence (GenAI) with gamification for cancer diagnosis and real-time monitoring

Recently, the revolution of GenAI has emerged as one of the game-changer angles that replaces most of the traditional hierarchies applying in the healthcare industry^{15–17}. The current architecture of GenAI in healthcare immersivity provide an automation in terms of generating new data, work arts, images, use cases, drug discovery, medical research, and patient care, along that supports health diagnosis^{15,16}. Most of previously published related studies upholds the discussion of immense promise, which is related to improving the capabilities of clinical trials and provide real-time biomedical facilities. In order to adopt this manner effectively, there is a requirement to tune the current application with GenAI, where intelligence in healthcare emphasize the transformative impact in terms to discover new paradigms. While integrating gamification with GenAI, some of the learning objectives are fulfilled, which also discussed in the mentioned research are expressed as follows^{16,17}:

- Generative AI enhances medical imaging and diagnosis, especially cancer.
- GenAI with gamification can draw a drug discovery development.
- Presenting personalized medicine and biomedical treatment sequences.
- Help medical research and knowledge generation.

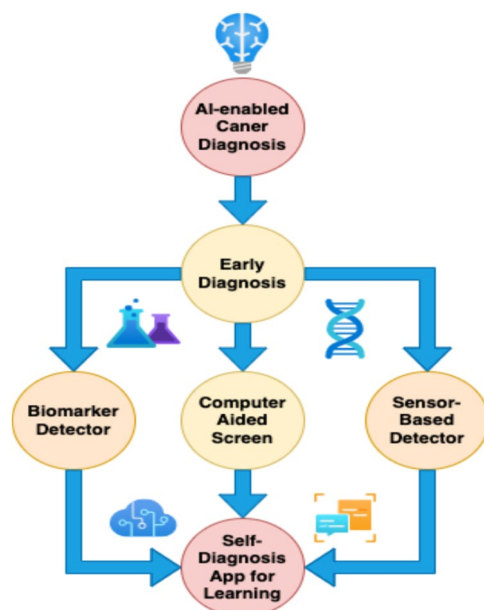


Fig. 3. Early diagnosis prospects.

Table 1 present the report of comparative analysis, where the topic of discussion is defined as follows: (1) highlight the major research problem, (2) research contributions, (3) research findings/gap analysis, and (4) references of the study.

How biosensors enhances biomedical treatment processes

The integration of biological sensors and generative AI has enabled the healthcare industry to deeply consider patient genetic profiles^{24,25}. In addition, it facilitates the management and monitoring of real-time data collection, sharing with interoperable features, and the preservation of medical histories^{25,26}. Thanks to this advancement, professionals can now create more accurate, efficient, and patient-focused processes for delivering healthcare that improves results while drastically lowering the likelihood of negative effects. Furthermore, cancer patient data is streamlined, and their evaluation procedures are optimized through the use of Generative AI in conjunction with biosensing-enabled services. In order to speed up processes within the bounds of efficiency and reliability, the technology does the following: it organizes molecular structures, predicts what factors need to be controlled that can interact, and speeds up identification sequences that are directly proportional to the evaluation of potential risk emerged in the bodies of cancer patients^{27–29}. The majority of researchers, however, presented their applications, which are considered to be the fruitful works based on the cooperative strategy of biological sensors and GenAI^{24–28}. The following highlights the proposed work’s targeted area^{26–29}: (1) image synthesis, (2) automation segmentation, (3) pathology prediction, (4) predicting drug-to-drug interactions, (5) clinical trial design, (6) biomarker discovery, (7) tailored treatment plans, (8) ethical and legal compliance assistance, (9) resource optimization in genetics testing, (10) tread identification and analysis, (11) optimization in resource utilization, and (12) automation in regulatory and compliance check.

Methods and materials

This section discusses a critical statement that addresses the actual prospect of highlighting the research problem, along with the operational activity of the proposed work, and mentions the argument regarding why the technological revolution needs to be integrated. The working objective of the proposed framework is discussed as follows:

Proposed framework

In this first phase, as illustrated in Fig. 4, we purpose a novel framework for biosensing-enabled E-healthcare platforms. This framework is intended for staff members or other relevant units to receive immersive learning and training in order to strengthen the process of early cancer diagnosis, particularly skin cancer and severity analysis. We establish a fresh prospect to offer immersive multimedia-enabled learning and training to participating stakeholders through the application of GenAI and the concept of gamification.

As seen in Figs. 4 and 5, the proposed framework’s working cycle is split into three parts: (1) biosensing-enabled data collection and prediction; (2) GenAI and gamification-based learning and training; and (3) measuring the learners’ learning scale for rewarding gaming-based learning. The registration of participants (referred to as participating stakeholders or survivors facing this kind of illness) is necessary in the first stage. To do this, the protocols are derived in Table 2, which defines the stages for logging in with uLog() and signing in with uSig(). After the application registration process is successful, the biosensor is turned on to gather data from the participant and send it to the learning environment, where a multimedia-enabled learning screen is shared in terms of mDU() and sS(). The data collection methods include (1) capturing, (2) sensing data preprocessing, (3) filtering, (4) aggregation, (5) examination, (6) feature extraction, (7) pattern recognition, (8) presentation, and (9) decision-making. With the association of gamification in the second stage, this sharing screen is able to display game-like sequences to raise the interest of the participants. Throughout this stage, the screen is continuously monitored by the organization under the supervision of experts/consultants.

Research problem	Research contributions	Findings/research gaps	References
The integration of biomedical sensors for infection management of cancer symptoms and diagnosis using MXenes	The major contribution of this paper is to bring an attention on authorities employ bio-nanotech to deploy an accurate, robust, and cheap biosensors to diagnose biomedical symptoms that involved in cancer diseases	MXene synthesis and sensing characteristics MXene biosensor limitations in terms of other diseases diagnosis	18
In this proposal, we investigate the integrational approach that is based on of AI-enabled machine learning and deep learning algorithms used for training models regarding biomedical diagnosis, especially cancer diagnosis and treatment	A list of approaches presented, even though self-learning enabled architecture Highlighting positive and negative results after evaluation	Standardized data hierarchy is missing No data organization and optimization strategy utilized simultaneously	19
A real-time monitoring approach is presented in the proposed work, where the association of AI is critical in process of collection, management, organization, optimization, and presentation throughout	The proposed work targets the industrial healthcare 4.0 Presenting improved self-management of chronic disease	Costly approach for real-time monitoring due to the requirement of wearable integration Scope of data privacy is another challenging prospect	20
The role of nanorobotics, like nanospheres, nanorods, and nanoparticles for biomedical diagnosis, including cancer diagnosis is proposed in this paper	Used crafting techniques for miniature machines Transformative real-time development for cancer diagnosis	Challenging on fabrication technique Privacy and security concerns	21,22
The problem that addressed in this paper is the designing hierarchy of interpretable machine learning system for enhancing trustworthiness in healthcare environment using collaborative approach	This paper highlights the associative challenges involved in the interpretable machine learning The proposal is designed for cancer diagnosis and their clinical trails	Lack in AI clinical decision that leads mistrust between decision makers System’s interoperability issues	21,23

Table 1. Comparative study (1).

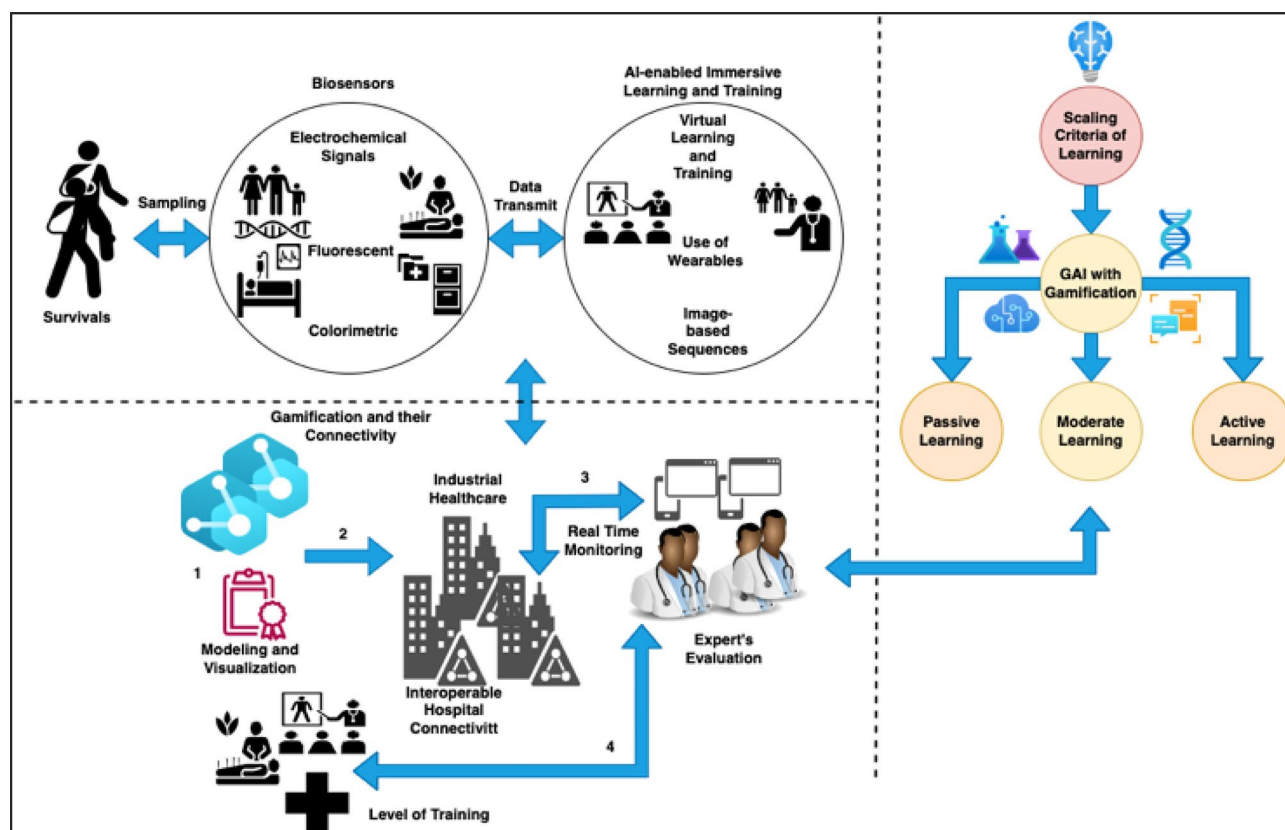


Fig. 4. Proposed framework.

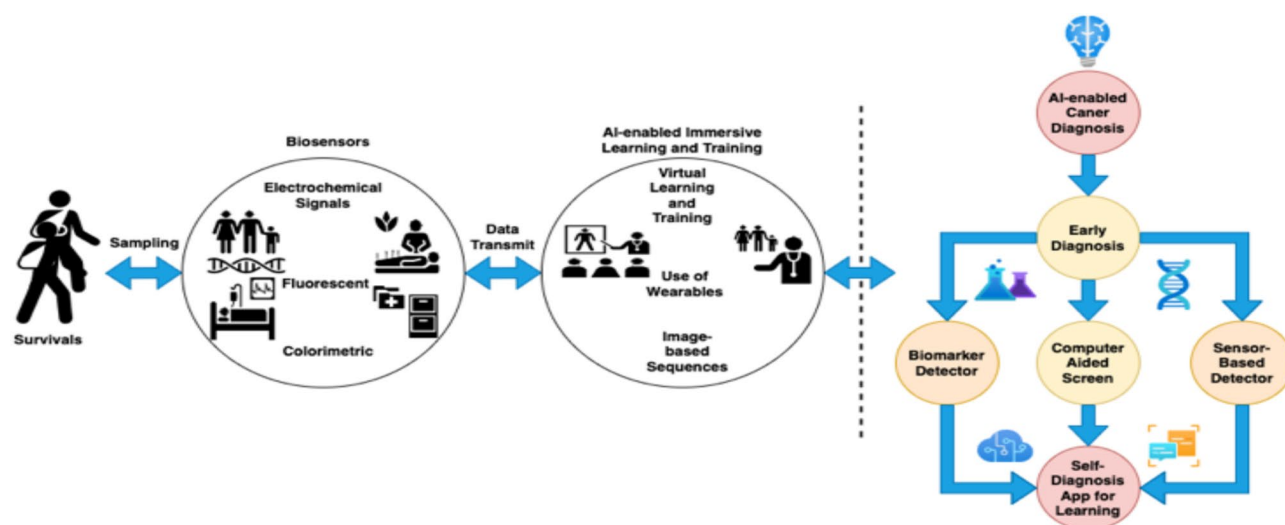


Fig. 5. Working hierarchy of the proposed framework.

In the third stage, the performance of the stakeholder is evaluated with the following scaling criteria and a learning threshold value: (1) active learner, (2) passive learning, and (iii) moderate learning. Because of this, the system can assign game-based learning rewards on such a basis.

Nevertheless, the main feature of the proposed framework—the working hierarchy for early cancer diagnosis—is divided into three sections to enable automation in the programmes, as shown in Fig. 5. The following is a mention of the metrics list: Biomarker identification, computer-assisted screening, and sensor-based detection are the three methods.

Fundamental Requirement: Learning staff, patients, and other related stakeholders are needed to registered Administrator manages the verification and validation scenarios

For testing process, the recruitment period for this study starts from 2/April/2024 (Tuesday) to 12/April/2024 (Friday)

Sampling criteria (i) capturing, (ii) sensing data preprocessing, (iii) filtering, (iv) aggregation, (iv) examination, (v) feature extraction, (vi) pattern recognition, (vii) presentation, and (viii) decision-making

Scaling sequences is derivate as (i) passive learning, (ii) moderate learning, and (iii) active learning

Primary Constraints: user login,
uLog();
user sign up,
uSig();
intercommunication network pathway,
iNP();
implicit biosensing data transmission,
iBDT();
explicit biosensing data transmission,
eBDT();
cloud storage connectivity,
cSC();
multimedia display units,
mDU();
share screen,
sS();
evaluate learning feedback;
eLF();
awarding criteria,
aC(passive learner/moderate learner/active learner);
timestamp [execution];

Process: if uLog == true:
 then, iNP() initiated;
 if iNP() == true:
 then, allow iBDT() / eBDT();
 and, mDU(): display sS();
 also, manage sDC() for each logs preservation;
 in addition, other activites are stored in accordance with uLog(), uSig(), iNP(), iBDT(), eBDT(), cSC(), mDU(), sS(), eLF(), aC(passive learner/moderate learner/active learner);
 after, eLF(get feedback);
 dispatch reward aC(passive learner/moderate learner/active learner);
 else uSig() == verify and validate;
 register successfully == true;
 then, change stage, update, share, and store;
 [execute];
 terminate;
else
 change stage, update, share, and store;
 [execute];
 terminate;

Outcome: iBDT(), eBDT(), mDU(sS()), aC(passive learner/moderate learner/active learner);

Table 2. Implementation sequences.

Table 2 presents the working executions of the proposed framework in the form of pseudocode, which majorly highlight the sequence of operations that elaborates the how these steps achieve a cost effective improved biomedical treatment and biosensors processes in cancer diagnosis and dynamic monitoring as follows:

Notation, problem description and formulation

In this proposed framework, the generative AI model allows applications to generate content, such as a sequence of images, just like human-created content. To generate such data, we integrate a large dataset of Skin Cancer

MNIST: HAM10000 (MNIST: HAM10000) by creating some of our own avatars to learn the underlying structure and characteristics of learning content, which enables us to proceed with originally and contextually related outcomes. However, the proposed GAI with gamification conducts learning and training in different ways, including text and sequence of images to create interest among stakeholders, where the data generation cycle in the multimedia environment is defined as follows:

$$P(y = 1|x) = 11 + e - (\beta_0 + \beta_1x_1 + \dots + \beta_nx_n) \quad (1)$$

where x represents participating stakeholders/survivals features and y is the binary outcome.

However, as a response, GAI identify the generated patterns and structures in order to predict the next cycle/upcoming content selections from the learners.

$$f(x) = 1N \sum i = 1Nk_i(x) \quad (2)$$

where $k_i(x)$ is the prediction.

The selections of the participants/learners are evaluated in the follows criteria (as illustrated in Fig. 6):

- 0.02 means passive learner
- 0.00 means active learner
- 0.02 means active learner

On the other side, the change in sequence of gamification data, we represent evaluation of each cycle with this manner:

$$f(x) = \text{sign}(w \cdot x + b) \quad (3)$$

where the proposed application examines in accordance with the weight vector of ' w ', x is the input feature, and b is the bias.

The sequence of medical condition-based content generation is one the critical criteria, which we achieve by designing through this formula:

$$P(A|B) = P(B|A)P(A)P(B) \quad (4)$$

where A and B represent medical conditions.

Whereas x_t represents the input features at time step ' t ' and ' h_t ' is the hidden state is defined as follows:

$$h_t = \text{proposed framework}(x_t, h_{t-1}) \quad (5)$$

In addition, the descriptors are implemented to manage sequence of multimedia display to the learner in accordance with the rule of

$$\text{Activity} = f(\text{Descriptors}) \quad (6)$$

where represent $f(\text{Descriptors})$ is the features extraction/display and ' f ' are ' a ' predictive function.

Table 3 mentioned a list of symbolic notations, along with their description, where the metrics of the table is divided two parts, such as notations and explanation.

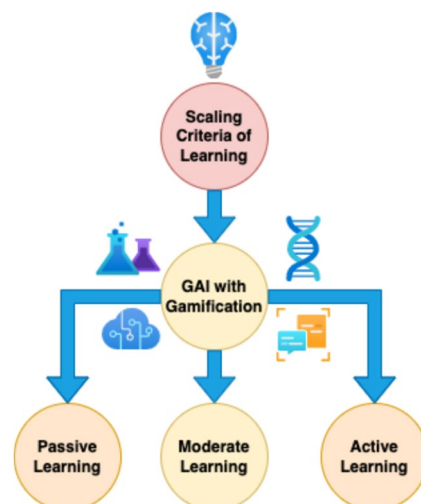


Fig. 6. Learning scale criteria.

Notation	Explanation
x	Participating stakeholders/survivals features
y	binary outcome
t	time step
f	Predictive function
ht	Hidden state
ki(x)	Prediction
f(Descriptors)	Features extraction/display
A and B	Medical conditions
w	Weight vector
x	INPUT/generated feature
b	Bias

Table 3. List of notations.

GAI with Gamification for Biosensors-enabled Real-Time Cancer Monitoring Data Handling

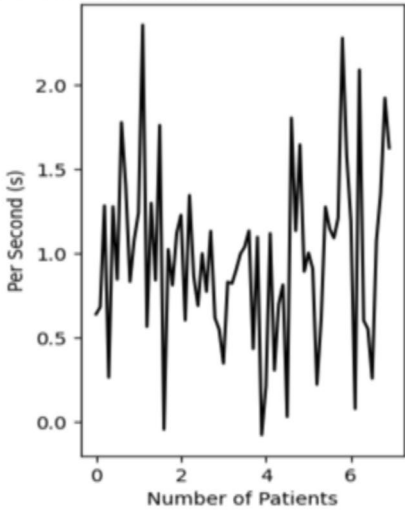


Fig. 7. Simulation result of the proposed framework of GAI with gamification for biosensors-enabled real-time data handling.

Simulations, results, and discussion

When start conducting the simulation of the proposed framework, a certain requirement that need to fulfill is mentioned as follows:

- Dataset association: Skin Cancer MNIST: HAM10000 (MNIST: HAM10000) and customized content in accordance with the created avatars
- Systems requirement: core i7 12th gen processor with 3.4 GHz clock speed
 - 16 GB RAM
 - 512 SSD
 - Integrated/shared graphic unit
- Network requirement: 6 Mbps to 10 Mbps network bandwidth is required

The simulation is conducted over the cycle that we have discussed in the section and subsection of method and material, where the initial test is based on GAI with gamification for biosensors-enabled data handling prospect, whose major priority is to provide real-time monitoring. Figure 7 present the uniqueness of the conducted simulation, where the registered stakeholders = 6 and the collection rate is 2.0 per second(s), which is approximate 22% better than other state-of-the-art methods^{30–34}.

On the other side, Fig. 8 illustrates the simulation result of the proposed GAI with gamification for biosensor-enabled data optimization in order to provide real-time cancer monitoring facilities. The test result is remarkable, where the removal of duplication data rate is = 5 with respect to 2 s (s).

GAI with Gamification for Biosensors-enabled Real-Time Cancer Monitoring Data Optimization

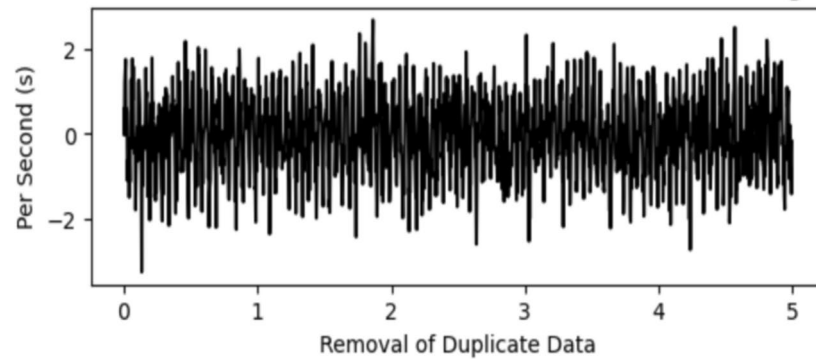


Fig. 8. Simulation result of the proposed GAI with gamification for biosensor-enabled real-time cancer data optimization.

GAI with Gamification for Learning-Level of Skin Cancer Severity

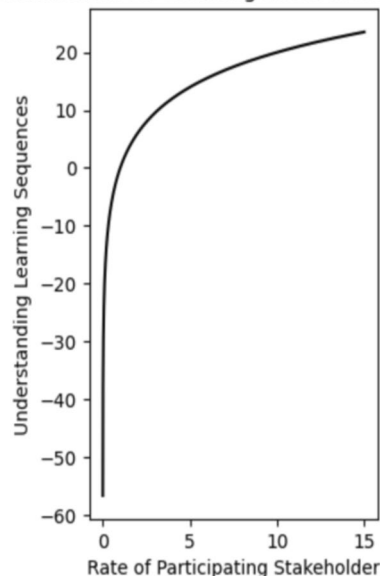


Fig. 9. Result of learning-level of skin cancer and their severity for early diagnosis.

However, Fig. 9 shows the result of the learning level of skin cancer and their severity for early diagnosis, where we receive the real-time rate of participating stakeholders is 15 and the sequence of learning understandings dispatch over the multimedia environment is 20 cycles.

In addition, we test the learning-level sequences of the proposed work, where the evaluation criteria of passive learners are represented as -0.02 , active learners as 0.00 , and moderate learners as 0.02 , as shown in Fig. 10. In order to do this, the system is made able to assign proper feedback regarding the focus on learning/training.

Whereas Fig. 11 illustrates the simulation result (1) of the proposed framework of GAI with gamification for evaluating processes, effectiveness, and robustness of biosensor use for early skin cancer diagnosis, where the metrics of the evaluation is the rate of data transmission, which is 253 gamification cycles over more than 500,000(s).

On the other end, Fig. 12 illustrates the simulation result (2) of the proposed framework of GAI with gamification for evaluating processes, effectiveness, and robustness of biosensor use for early skin cancer diagnosis, where the metrics of the evaluation is the rate of data transmitted, which is 257 gamification cycles over more than 800,000(s).

Here, Tables 4 and 5 represent the detailed report of comparative analysis of the proposed work with other state-of-the-art publications, where two different tests are conducted on certain points of discussion, which are highlighted as follows: (1) scaling of skin severity and analysis, (2) rate of cancer diagnosis, (3) overall clinical and medical accuracy, and (4) overall clinical and medical efficiency.

The overall performance of the proposed framework is presented in Fig. 13, where the metrics of evaluation are dependent on the generated number of trained stakeholders (G, A) with respect to training cost (c). The total

Learning-Level Sequences Analysis, Where -0.02 Indicates Passive, 0.00 Indicates Active, and 0.02 Indicates Moderate Learning

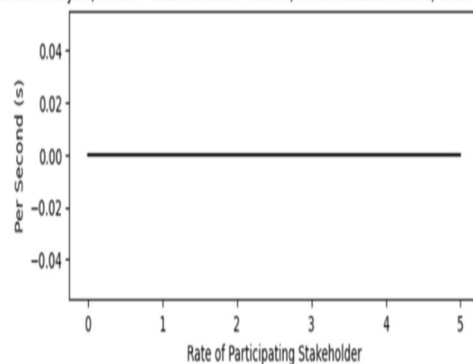


Fig. 10. Testing the learning-level sequences of the proposed work.

GAI with Gamification for Testing Processes of Biosensors Effectiveness in Skin Cancer Diagnosis

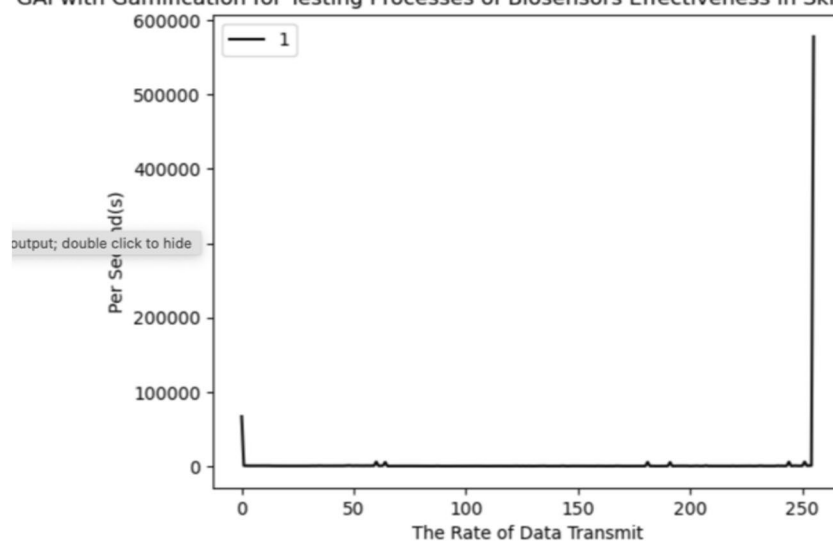


Fig. 11. Simulation result (1)-the proposed framework of GAI with gamification for evaluating processes, effectiveness, and robustness of biosensor for early skin cancer diagnosis.

GAI with Gamification for Testing Processes of Biosensors Effectiveness in Skin Cancer Diagnosis

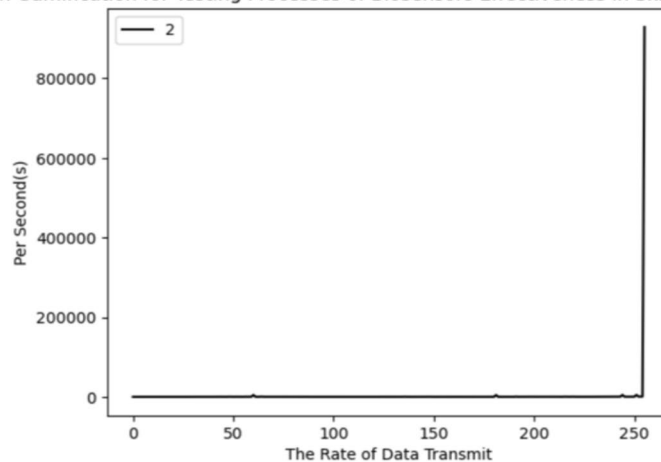


Fig. 12. Simulation result (2) of the proposed framework of GAI with gamification for evaluating processes, effectiveness, and robustness of biosensor for early skin cancer diagnosis.

Point of discussion	AI-enabled machine learning-based collaborative filtering with reinforcement (%)	Deep learning-based complex neural network architecture (%)	The proposed framework (%)
Scaling of Skin Severity and Analysis	88	93	95.1
Rate of Cancer Diagnosis	89	91	95.3
Overall Clinical and Medical Accuracy	87	92	95
Overall Clinical and Medical Accuracy Efficiency	88	93	95

Table 4. Report of comparative study (test 1).

Point of discussion	AI-enabled machine learning-based collaborative filtering with reinforcement (%)	Deep learning-based complex neural network architecture (%)	The proposed framework (%)
Scaling of Skin Severity and Analysis	86	89.8	95.1
Rate of Cancer Diagnosis	85	89.3	95.3
Overall Clinical and Medical Accuracy	91	89	95
Overall Clinical and Medical Accuracy Efficiency	88	93	95

Table 5. Report of comparative study (test 2).

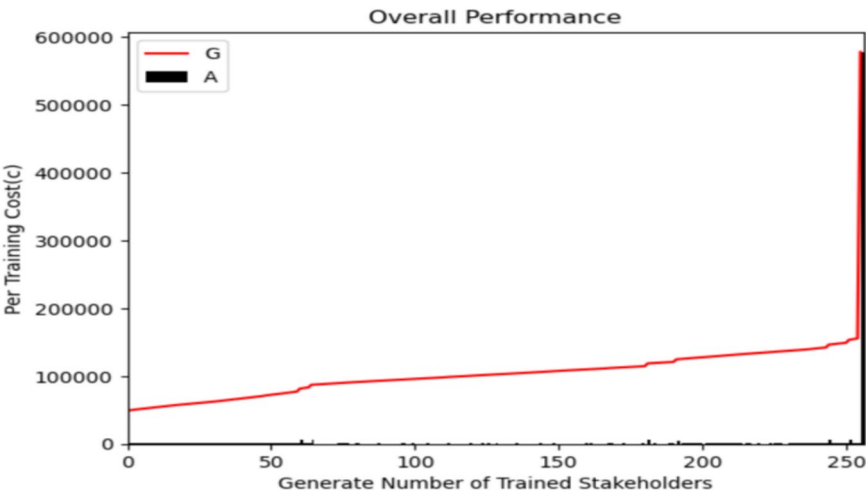


Fig. 13. The overall performance of the proposed framework (1).

cost that we receive via the simulation is the 279 trained stakeholders consumed in between 500,000–600,000 rs (where rs stands for rupees).

The overall performance of the proposed framework in terms of the yearly training ratio is presented in Fig. 14, where the metrics of evaluation are dependent on the generated number of trained stakeholders (G, A) with respect to year (y). The total cost that we receive via the simulation is the 266 trained stakeholders consumed between 1 and 1.2 y.

However, the list of state-of-the-art publications that are used in this comparison is listed as follows^{30–34}:

- J.G. Rani et al. [Artificial intelligence and surface electromyography for the identification of human activity]
- P. Dey et al. [Healthcare Applications of Machine Learning and Internet of Things Technologies]
- T.M. Ho et al. [Recognizing the Japanese healthcare system’s adoption of emotional artificial intelligence]
- J.S. Sidhu et al. [IoT and AI Integration for Natural Material Bioengineering]
- C. Delrue et al. [Raman Spectroscopy’s Effect on Skin Cancer Diagnostics: From Vibrations to Visions]

Open research problem

In this section, we present a list of implementations, designs, and deployments-related issues that those are needed to be addressed earlier before initiating the proposal based on biosensing-enabled GAI with gamification. This section highlights the mandatory requirements and standardization that need to be fulfilled in the near future for better developments, which are directly proportional to robust productivity.

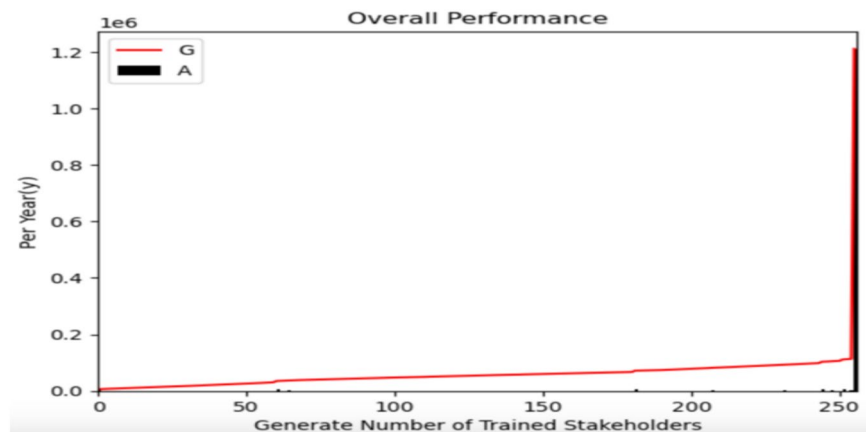


Fig. 14. The overall performance of the proposed framework (2).

Current developments of biosensors and their associations

Recently, the application of biosensors has mostly popped up in the domain of healthcare, where the contradiction is submitted to the health laboratory, especially for the distributed healthcare environment^{35,36}. As compared to the traditional method, the scientific diagnosis may take a sample of the patient and send it to the off-site laboratory for analytical results and evaluation. For instance, the tested patient experts their findings within hours/day due to taking care analysis. This method pushes the technology to move on early diagnosis manner, where the role of biosensing chipset is critical. Rapid identification of cancer takes time in order to react and then monitor the disease, like skin cancer severity analysis. However, the concept is to transform a biological reaction through biological material in a readable signal for the sake of proper, effective, and robust examination. In this whole scenario, the typical optical and electrochemical transducers are used to convert reactions into signals, which are readable in nature.

Cost-efficient hierarchy for biomedical data delivery

In this subsection, we highlight the usage of biosensing devices as an efficient data transmission, delivery, and preservation via the proposed network^{36–38}. Although, it enhances the processes in terms of efficiency, diagnosis, and treatment within a robust manner due to the association of biosensing technology. Currently, this technology serves with a grate manner in healthcare industry, especially in laboratory, sharing health learning experiences, awareness, and other related purposes, where it requires natural setting in order to allow accurate multimodal sequences for further evaluation. In this manner, the proposed framework plays a vital role in the management of large biomedical data, which is cost-efficient in nature. But still, it is one of the ways to design this particular solution; yet there are many are paradigms that may be useful. However, the list of steps that derivate a cost-efficient approach of data management is discussed as follows:

- sensing data preparation,
- filtering,
- aggregation,
- inspection,
- feature extraction,
- pattern recognition,
- presentation, and
- record.

Steps to deploy gamification in healthcare

In the healthcare environment, the process is to apply typical gaming and patches in a single point, such as performing healthcare niche operations called gamification, including finishing marathons, levels, awards, and badges for learning health activities, or achieving healthy habits^{38,39}. Improve biomedical treatment adherence may offer better results, like early diagnosis while examining symptoms in the real time. However, the distribution of health gamification is categorized in the following formats: (1) mobile application, (2) digitalized platforms, and (3) wearable devices-enabled applications. Thereby, all such applicational deployments requires some critical steps to be followed due to engaging stakeholders' participations in order to improve clinical results, especially early skin cancer detection and diagnosis as follows:

- capture reactions of the community as bio-signals and transformation
- create learning competitions
- create interest in learning
- give rewards
- track results
- immersive presentation and communication

Conclusion

This paper covers the present hierarchy of biosensing devices, especially those utilized for skin cancer diagnosis and treatment. These tools are used for real-time monitoring, biological diagnosis, and treatment. The GAI revolution has recently had positive effects on education, entertainment, and multimedia systems, among other sectors. Similar to this, it has an impact on the healthcare environment by displaying medical supplies and providing medical information for training, education, and awareness-raising objectives. Using this scenario requires increasing the level of engagement throughout the entire session in order to encourage participation, learning, and benefit. In order to assess this, the article put out a unique framework that combines gamification and generative artificial intelligence to convert medical training discoveries within the intended scope. Biosensing devices play a crucial part in this process by gathering data from the system and providing it to stakeholders, or the other way around. Sensing data preparation, filtering, aggregation, inspection, feature extraction, pattern recognition, presentation, and decision-making are all cited as steps in the data collection process. However, because of the cooperative processes of biosensors association for cancer detection, this advancement is becoming directly proportionate to the improvement of biomedical treatments, which can also influence the advancements in real-time monitoring. As a result, we have to conclude that the proposed activity is among the most affordable methods for raising public awareness. It is comparable to training healthcare personnel and the general public virtually on how to recognize the signs of skin cancer and how to administer first aid. On the other hand, the proposed work assesses training session learning capacity using the following criteria: passive, moderate, and active. Through the use of simulations, we argue that the proposed research outcome is unique in that it provides learners with therapeutic training that is reliable, effective, efficient, and deliverable. Training feasibility has improved up to 22% according to the evaluation, with opportunities for learning being provided by immunological, photothermal, photodynamic, and chemo-like therapies.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request. However, dataset association—Skin Cancer MNIST: HAM10000 (MNIST: HAM10000) and customized content in accordance with the created avatars.

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Author contributions

Author contributions: Conceptualization, A.A.K., A.A.L., S.A.I., R.A., S.A., A.M.B., M.A.; methodology, A.A.K., A.A.L.; software, A.A.K., S.A.I., R.A., S.A.; validation, A.A.K., A.M.B., M.A.; for-mal analysis, A.A.K., A.A.L., S.A.I.; investigation, A.A.K., A.A.L.; resources, A.A.K., A.A.L., S.A.I.; data curation, A.A.K., A.M.B., M.A.; writing—original draft preparation, A.A.K.; writing—review and editing, A.A.L., S.A.I., R.A., S.A., A.M.B., M.A.; visualization, A.A.K., S.A.I., R.A., S.A.; supervision, A.A.K., A.A.L.; project administration, A.A.K., A.A.L., S.A.I., R.A., S.A.; funding acquisition, R.A., S.A., A.M.B., M.A. All authors have read and agreed to the published version of the manuscript.

Declarations

Ethics approval and consent to participate

The committee of the Shenyang Normal University, China confirmed that all experimental protocols were approved by the organization. It is confirmed that the experiments follow the criteria of ethics approval and consent to participates.

Clinical trial number

Not applicable.

Consent to participate

No human subjects are harmed in this research.

Research involving humans and/or animals

Not applicable.

Consent for publication

No human subjects are harmed in this research, and we confirmed that all data shared with the participants.

There is no objection from the participants. All the participants/consents are agreed on the published version of this research.

Competing interests

The authors declare no competing interests.

Informed consent

The authors are attesting that the participants were aware of the study purpose, risks and benefits.

Additional information

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