A Query-Based Approach to Mitigate the Shortcomings of Widely Used Learning Methods through E-Learning

Khandoker Ashik Uz Zaman[1*], Yusuf Mahbubul Islam[2] and Md Abu Sayed[3]

[1,2,3*]Computer Science & Engineering, Independent University, Bangladesh, Plot 16 Aftab Uddin Ahmed Rd, Dhaka, 1229, Bangladesh.

*Corresponding author(s). E-mail(s): 2021065@iub.edu.bd; Contributing authors: ymislam@iub.edu.bd; asayed@iub.edu.bd;

Abstract

This paper begins with a review of existing learning methods, highlighting the limitations that hinder motivation, development of confidence, and memory retention. To address these gaps, we propose an e-learning strategy that uses technology to create a peer collaborative question development marketplace. The mobile application developed for this purpose is part of a progressive web application that functions as the peer collaborative questioning questions platform. The students' exchanges of questions are ranked using Bloom's Taxonomy, encouraging anonymous student questioning that should gradually lead to a deeper topic exploration. Our analysis, comparing an experimental group with a control, reveals that the proposed strategy creates a positive impact on students, enhancing their confidence, motivation, and querying skills. Furthermore, we found that enhanced questioning correlates with improved academic performance. Finally, we also discuss the potential challenges and how the dataset obtained from this study can be utilized for machine learning and artificial intelligence applications in e-learning.

Keywords: Educational Technology, Learning Methods, Querying, Active Learning, E-Learning, Virtual Learning Platform

1 Introduction

In today's dynamic job market and competitive academic landscape, the demand for critical thinking and problem-solving skills has sky-rocketed, making these essential qualities for any student striving to achieve success in their chosen field [1]. The limitations of traditional learning methods gave rise to active learning methods [2]. However, upon analysing various sources, it becomes evident that despite the advancements in active learning methods, challenges persist in areas such as fostering confidence, enhancing motivation, and improving memory retention [3–7]. To address these gaps in existing learning methods and enhance the learning experience, a collaborative question developing methodology is designed and pilot tested. This paper aims to build on the Query Based Access to Neurons (QuBAN) method, a method, proposed by Islam & Nashikh [8] showing how the methodology can be further augmented using technological tools embedding e-learning. The QuBAN method centers around accessing the learner's existing knowledge in the brain through questions, establishing connections between their current knowledge giving birth to further questions [8]. Research has shown that asking questions is an effective way to engage students to gain their attention [9]. As existing knowledge on a subject is accessed, it encourages participation for further questions thereby stimulating discussion, creative thinking, and critical thinking. In QuBAN questions are used as a learning tool as opposed to a method to simply diagnose student's understanding of the material, for the purposes of reviewing, restating, emphasizing, or summarizing classroom lectures [10]. Questions are not just a tool for assessment, but an essential tool for learning. To learn, we instinctively ask questions since childhood [11], driven by curiosity to learn about our selves and our environment. However, as we grow up, this curiosity often fades away [8]. QuBAN targets to revive this curiosity, getting peers to ask questions against questions posed on the current topic in the application. Here we use the benefits of technology to create a collaborative environment for the purpose of rekindling the students' innate instinct for questioning out of curiosity.

Several studies have shown that technology has a positive impact on education and learning. [3, 12]. This paper proposes the development of a progressive web application that integrates the QuBAN approach with technology. The application helps to make students more motivated, confident, and better at remembering information by using questions that make them think and connect new ideas to what they already know, following the ideas of constructivism. involves forging connections with existing knowledge, and cultivate a deeper understanding of the subject matter [13, 14]. The use of questions in the application aims to encourage students to ask more curiosity-driven questions, reviving their natural curiosity for learning through peer collaboration. Through a combination of active learning and technology, QuBAN proposes to empower students with the questioning skills that they need to succeed in their academic pursuits and future careers.

In our efforts to identify gaps in existing learning methods, we thoroughly reviewed multiple papers highlighting their shortcomings. The presence of these gaps emphasizes the need for improved learning methods. To address these gaps, we conducted a comprehensive review of papers on learning methodologies. This led us to propose using e-learning and querying techniques to mitigating these gaps.

2 Literature Review

Decades of research have demonstrated the limitations of passive traditional learning where students tend to be reluctant, fearful, or hesitant to express their opinions and often rely on rote memorization, hindering their creativity and overall learning experience [15]. While traditional learning methods remain prevalent, studies reveal that students retain much less material after completion of class compared to those taught in active learning environments [2]. Although active learning methods are effective, they are not without their limitations and shortcomings which most existing active learning methods fail to address [3–7]. However, it is crucial to acknowledge that there is no single teaching method that is universally suitable for all situations and students. The choice of the appropriate method depends on the desired learning outcomes, the discipline's requirements, and the teacher's level of comfort and experience [16].

2.1 Shortcomings of Existing Methods

Inquiry-Based Learning (IBL) and the Socratic Learning Method (SLM), Project-Based Learning (PBL), the Flipped Classroom Method (FCM), and Brain-Based Learning (BBL) are notable educational approaches, each contributing uniquely to the development of critical thinking, problem-solving skills, and practical experience in students. Despite their distinct advantages, these methods also face common and specific challenges that affect their implementation and efficacy.

IBL and SLM emphasize a question-driven learning process, fostering an environment that encourages students to think critically and solve problems autonomously. However, their effectiveness is often constrained by physical limitations such as insufficient time and inadequate classroom space. Discrepancies in students background knowledge can further complicate the learning process, necessitating additional resources for extended activities. Furthermore, potential peer pressure, along with a lack of support and clear objectives, can undermine student motivation and confidence [3, 4]. These methods overlook the fact that students may have given up on their innate curious nature, especially where academic studies are concerned.

PBL, on the other hand, immerses students in hands-on projects, providing a clear goal and incentive for learning. Yet, this method is not immune to challenges, with time constraints and resource allocation issues presenting significant hurdles. The influence of peers and a potential lack of guidance can also lead to reduced motivation and self-esteem among students [5].

The FCM seeks to increase student engagement by assigning readings as homework and dedicating class time to active problem-solving. While this approach aims to enhance participation, it may inadvertently demotivate low-achieving students, potentially widening the achievement gap [6].

BBL adopts a student-centred approach, incorporating brain-stimulating techniques to boost motivation and confidence. Its success, however, is heavily dependent on the teacher's understanding of neuroscience and the availability of necessary resources [7].

In conclusion, while each of these learning methods offers unique benefits in fostering student development, their effectiveness is contingent upon addressing their respective limitations. The specific learning objectives and classroom context play crucial roles in determining which method or combination of methods will yield the most beneficial outcomes for students.

2.2 E-Learning and the Evolution of Technology

The progression of e-learning has been significantly influenced by technological advancements, with tools like smart phones and laptops becoming integral to modern education. These devices have ushered in new possibilities for e-learning, enhancing both teaching and learning through increased learner motivation and confidence [12, 17, 18]. Research has underscored the multifaceted ways in which technology bolsters learning, from boosting motivation and providing easy access to information, to facilitating interactive experiences and offering personalized guidance [3, 12].

E-learning has evolved substantially, showcasing a variety of digital tools that serve as educational aids for both students and educators. Technology has also emerged as a pivotal enabler of collaboration in education, providing innovative tools and platforms that facilitate interactive learning and group work. These technological solutions enhance communication, foster a sense of community, and allow for real-time collaboration, thereby breaking down geographical barriers and creating a more inclusive and engaged e-learning environment [19] This technological progress has led to greater flexibility, mobility, collaborative potential, and increased motivation in the educational sphere. The integration of e-learning within higher education has notably reduced student drop-out rates and provided invaluable support to educators [20, 21]. Furthermore, e-learning addresses the limitations of traditional classroom education, promoting a learner-centered approach, facilitating knowledge sharing, and catering to the needs of lifelong learning in today's knowledge-based economy [22].

Looking forward, Artificial Intelligence (AI), particularly Machine Learning and Data Mining, is expected to play a pivotal role in the evolution of e-learning systems, aligning with the anticipated advancements in Web 3.0. This shift towards integrating AI technologies in education is poised to significantly shape the future of educational technologies, marking a new era in the synergy between effective learning methods and technological integration [23]. By embracing these advancements, educators can create a dynamic and enriching learning environment, empowering students to excel in their academic pursuits.

2.3 The Art of Questioning in Learning

Questioning holds a crucial place in the educational journey, serving as a key tool for learning and critical thinking. It emerges from students' knowledge gaps or their genuine desire to expand their understanding, playing a central role in activating prior knowledge, directing learning efforts, and enriching existing knowledge [24].

The art of questioning not only guides students through their learning journey but also ignites classroom discussions, boosting their motivation and interest in the subject matter. Additionally, it provides educators with a valuable means to assess students' comprehension, as well as their critical and analytical thinking capabilities. However, the impact of questioning extends far beyond its immediate utility in guiding, instructing, or assessing. Questions also communicate implicit messages about classroom expectations, the desired responses, and the key focal points of a lesson. When framed appropriately, questions have the power to encourage students to think critically, share diverse perspectives, and engage in meaningful discussions. On the contrary, restrictive questions can limit students to narrow responses that simply reflect the teacher's expectations, underscoring the importance of mastering the art of crafting effective questions for both educators and students [24].

Delving deeper, the practice of questioning questions emerges as a vital tool for enhancing understanding. By critically analyzing the nature and intent of questions, educators and students alike can unveil deeper layers of meaning and insight, encouraging a thorough exploration of the subject matter. This reflective practice challenges surface-level knowledge, fostering a richer understanding and prompting individuals to seek profound comprehension. Beyond being a reflective exercise, questioning questions also sheds light on the power dynamics within the classroom, prompting contemplation about which voices are predominantly heard and how students' views are valued. Through a critical examination of the questions posed, educators can transform classroom dynamics, ensuring a more equitable and empowering learning environment. This shift promotes a culture of inquiry, transforming students from passive recipients of information to active participants in the co-construction of knowledge alongside their peers and teachers. Such an environment nurtures curiosity, viewing questions as gateways to exploration rather than mere tools for assessment. In turn, this establishes a classroom atmosphere that champions continuous learning and values diverse perspectives, empowering students to take charge of their academic journeys [25].

As students advance in their academic journeys, there is a noticeable decrease in the quality and quantity of questions they ask. This trend is concerning because questions play an important role in demonstrating one's curiosity and desire to gain a deeper understanding of the world. As students advance in their academic journeys, there is a noticeable decrease in the quality and quantity of questions they ask. This trend is concerning because questions play an important role in demonstrating one's curiosity and desire to gain a deeper understanding of the world [24]. Factors contributing to this decline include social norms among peers, pressure from classmates, expectations for teachers to provide direct answers, traditional teaching methods, large class sizes, the lack of anonymous questioning options, and various personal reasons [26]. Addressing this issue necessitates the adoption of learning methodologies that champion the practice of asking questions and deeply contemplating them, fostering a learning environment where curiosity thrives and students are encouraged to delve deeper into their understanding.

Furthermore, implementing a taxonomy of questions is crucial for both educators and students, aiding in the comprehension and guiding of learners' reasoning processes during problem-solving activities, thereby contributing to the construction of knowledge [27]. By equipping students with the ability to pose meaningful questions, educators empower them to navigate the complexities of life beyond the classroom, fostering a critical and inquisitive mindset ready to challenge the status quo. Ultimately, while questions are foundational to learning, the practice of "questioning questions" enhances the educational experience, promoting a holistic approach to learning that values curiosity, diverse perspectives, and student empowerment.

2.4 Questions as a Learning Tool

Existing educational methodologies exhibit varied applications of questions, yet there's a noticeable trend where the assessment utility of questions tends to overshadow their role as learning tools. Inquiry Based Learning (IBL) stands out, predominantly leveraging questions within the learning journey itself as students are encouraged to formulate their own queries and seek answers through exploration [3]. Despite this, there's a high emphasis on using questions as learning tools, but the structure may sometimes fall short in providing sufficient guidance on effective question formulation. In contrast, the Socratic Learning Method (SLM) creates a continuous dialogue filled with critical questioning, fostering a reflective atmosphere that serves both learning and assessment simultaneously, yet potentially creating an environment that feels like constant evaluation [4].

Project-Based Learning (PBL) integrates questions into the learning process as students define project goals and navigate tasks, but there is a notable shift towards using questions for evaluative purposes as the project progresses, with a primary focus on outcomes over the inquiry process [5]. The Flipped Classroom Method (FCM) employs questions during interactive in-class sessions, aiming to engage students and deepen understanding, but it predominantly utilizes questions for assessment in both pre-class and post-class activities, potentially leading to an assessment-centric learning experience. Brain-Based Learning (BBL), while recognizing the cognitive stimulation that questions can provide, also predominantly applies questions as assessment tools, aiming to gauge understanding and application of knowledge [6].

Method	As Learning Tool	As Assessment Tool	Predominant Use
IBL	High	Low	Learning
SLM	High	High	Equal
PBL	Low	High	Assessment
FCM	Low	High	Assessment
BBL	Low	High	Assessment

Table 1 Comparison of varying focuses on questions across learning methods

These trends, as outlined in Table 1, highlights a significant gap in the current educational landscape, underscoring the need for methodologies that deliberately position questions as primary instruments for stimulating curiosity and facilitating deep learning. This ensures that the art of questioning transcends its evaluative function, becoming a central pillar in fostering a genuinely inquiry-driven learning experience.

2.5 Query-Based Access to Neurons

According to the theory of constructivism, individuals construct knowledge and derive meaning from their experiences [28]. This suggests that to foster effective learning, it's essential to relate new data to the pre-existing knowledge in one's mind. This linkage is neurologically represented by connections between neurons, and the strengthening of these connections is the basis of learning and memory retention [29].The Query-Based Access to Neurons (QuBAN) approach builds upon the theory of constructivism by formulating initial questions to tap into specific brain areas that holds a learner's pre-existing knowledge about a topic. By doing so, educators can reveal accurate or misguided knowledge, providing valuable insights into the learner's grasp of the topic. [8]. While most existing methods utilize questions to assess a student's understanding, QuBAN distinguishes itself by employing questions as a learning tool, propelling students to delve deeper into the subject matter. Research supports that posing questions captivates the entire brain, solidifying the idea that questions are an effective tool to retrieve existing knowledge [30]. For an optimal learning environment, a blend of the student's prior knowledge, intended course outcomes, and the educator's familiarity with diverse teaching methods is essential. This involves gauging the student's current knowledge base and implementing suitable learning techniques and interactive classroom tasks based on the assessment. Questioning is paramount in this model to encourage student engagement and participation. Expanding on initial questions with subsequent ones can deepen comprehension, while also honing critical thinking and inquiry capabilities. The QuBAN framework centers on questioning and integrates diverse learning strategies, enabling it to overcome limitations in existing methods and adapt to various educational contexts [8].

As part of our literature review, we have discovered that existing learning methods often face limitations such as physical constraints, lack of motivation, and insufficient confidence in course topics. Additionally, some methods fail to enhance long-term memory retention due to the absence of active learning techniques that encourage students to participate in their learning process. The QuBAN approach aims to address these gaps in traditional learning methods, but to further enhance its effectiveness, integrating technology is a crucial step, which is the objective of this research.

3 Methodology

The main goal of this study is to enhance QuBAN by using querying as the foundation of a progressive web application that functions as an interactive and competitive e-learning platform for students. The methodology employed in this research involves a systematic process of reviewing existing learning methods to identify their limitations and gaps. The review was conducted by searching through a variety of reputable sources, including Google Scholar, Eric, Frontier in Education, Springer and ScienceDirect to gather relevant academic papers on education and technology. Building on the knowledge from the literature review, we explored the potential of technology in addressing the identified gaps.

Based on the analysis of technological possibilities, we designed a progressive web application with a questioning platform at its core. The web application's functionality and user interface have been designed to ensure optimal user experience and the development of essential critical thinking skills using questions. The application has been experimented within 4 different classrooms on 2 different courses (CSC203-Data

Structure and CIS101-Fundamentals of Computers and Research) at Independent University, Bangladesh (IUB). One of the courses is a highly technical coding course (CSC203) and the other course is a less technical course (CIS101). There was an uneven number of classes for each courses due to university restrictions due to which only one of the class was taking Data Structure (CSC203) course and the other three of the classes were taking the Fundamentals (CIS101) course. The experiment was conducted on 126 students. The control group included 5 different classrooms of the same 2 courses consisting of 120 students. The experimental group was taught using the QuBAN method and the proposed web application while the control group was taught using conventional learning methods. Before and following the course, a survey questionnaire was administered to both the experimental and control groups to obtain a comparative analysis of how QuBAN performs in terms of student's motivation, confidence, and memory retention compared to existing learning methods.

3.1 E-Learning Using QuBAN Method

Technology can be a great supportive tool that can make learning more productive and meaningful. Online tools such as Coogle.it can help in mind mapping efficiently and other tools such as Mentimeter (clicker) are an effective tool for interactive presentations. Mentimeter.com or its sister website menti.com can be a great tool for initiating the class and querying the existing knowledge of students through questions, interactive presentations, responses, and feedback. To further integrate QuBAN with e-learning, we focus on the questioning part of the learning method. The concept of the proposed progressive web application derives from the fundamentals of questions and the development of knowledge from questioning questions.

The proposed questioning application makes use of Bloom's taxonomy keywords to analyse the type of questions asked by students and a specific score or points are assigned to each category of questions. The six categories of questions include: i) Knowledge-Based Questions (5 points) ii) Comprehensive Questions (10 points) iii) Application-Based Questions (15 points) iv) Analytical Questions (20 points) v) Evaluative Questions (20 points) vi) Synthetic Questions (30 points). This adds a gamification element to the application inducing better motivation and promoting competition. Using this scoring system, the highest score a student can score from a single question is 100 points which includes all the keywords belonging to each category considering it a high-level question as per Bloom's Taxonomy. A leaderboard system can be set up along with ranks such as Novice Questioner and Master Questioner and such to ensure higher levels of motivation and competition among students. Since students are too shy or afraid to ask questions, it is necessary to bring them into the habit of questioning, so the application features an anonymous system that will allow the students to ask questions anonymously without peer pressure but still receive points allowing them to evaluate themselves instantly and also participate in the competition. Apart from anonymous questioning and gamification elements, the application also includes asking pre-questions, questioning questions, and post-class feedback as its other core features. The core features of the application are highlighted in Figure 1.

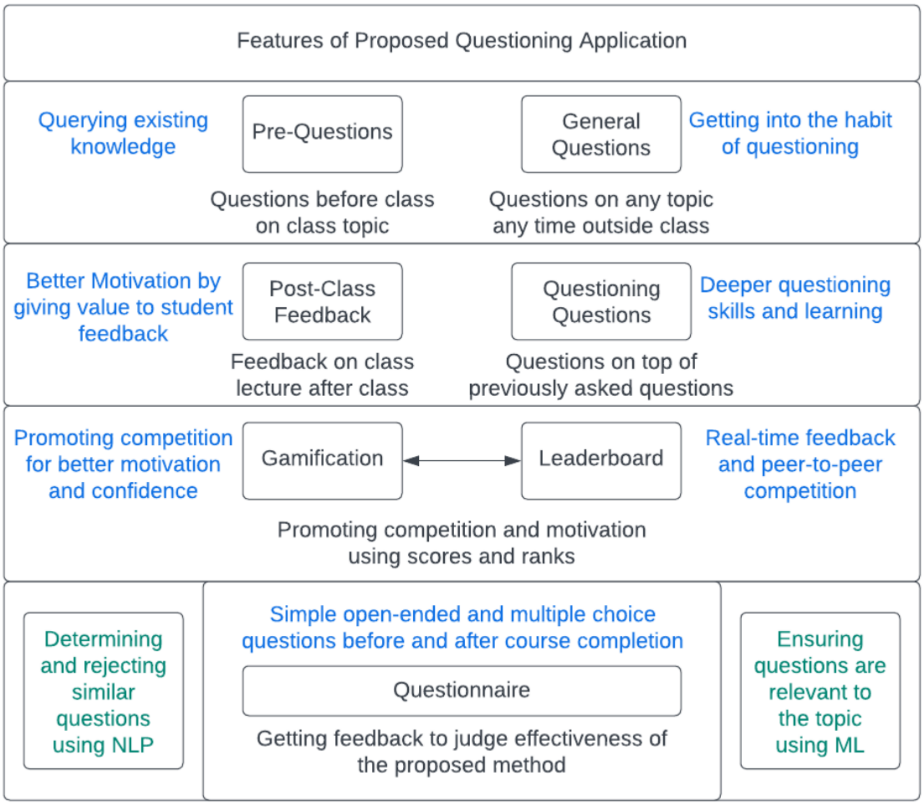

Fig. 1 Core features of the proposed web application.

3.1.1 Pre-Questions

The course outline is given at the beginning of every course in universities outlining the topics to be taught along with the course outcome but students rarely read it or try to understand it. But to learn, it is essential to be able to relate the existing knowledge to the newly learned information and the course outline clears out the objective of the course along with the topics of the course which is supposed to help them obtain pre-knowledge before starting the course. The use of the pre-questions functionality in the proposed application aims to make students ask questions using their existing knowledge or pre-knowledge on the topic whether it is right or wrong. By asking the pre-questions, students will have accessed the knowledge in their brain and when they participate in the classroom and when they listen to the teacher's lectures and participate in the classroom, they will be able to relate it to the new information taught in class.

The next step is to participate in the classroom attend the lectures and then reflect on the pre-questions asked before the class. The teachers can discuss the questions asked before the lecture and verify whether the student's queries have been answered and if not, the teacher can provide further guidance for the students to be able to reach the answer themselves. However, in a big classroom going through all the questions is not feasible which is why the scoring system can help the teacher choose the best and worst questions and discuss them. This will help give a comparison and guidance on how to improve and the others will also be able to relate to their lacking. This questioning loop is simplified in Figure 2.

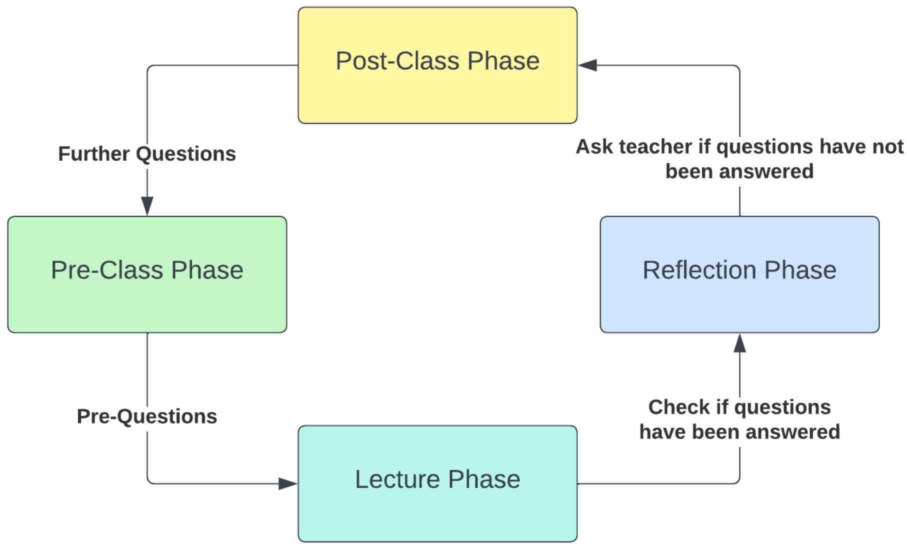

Fig. 2 The questioning loop of pre-questions

3.1.2 Questioning Questions

The core functionality that allows students to reflect on their questions is the use of the "Questioning Questions" feature which gives the student the ability to ask further and deeper questions on top of the previously asked questions and also improve the level of those questions using the score as a metric. This allows for deeper reflection on the topic and these questions can again be further discussed with the teacher (either out of the classroom or in the classroom depending on the time constraint) to get a better understanding of the topic. Figure 3 shows a simplified version of how questions questions work with the initial question being asked and rebuttal questions following it up leading to collaboration and discussion and as a result leads to self-reflection and deeper learning. The more questions an individual asks on a given topic, the more potential solutions he/she will uncover and the closer that individual will reach to the desired optimal solution. A potential system could be created which allows the teacher to answer a student's high-level query only when a certain threshold of questions has been asked on top of the initial question. Even a large-language model (LLM) or a Machine learning algorithm could potentially be integrated into the system in the future which allows it to answer the student's query when the threshold has been reached. When the student gets the answer as a reward for asking questions this will motivate the student to further ask more questions and this will also help to guide themselves by digging deeper into topics.

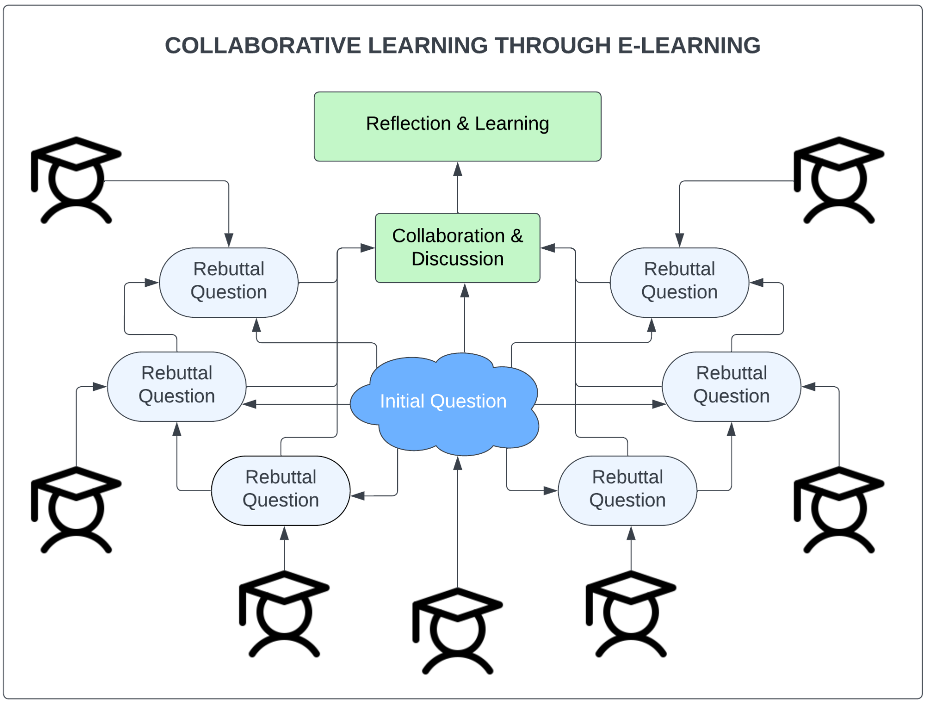

Fig. 3 The simplified workflow of questioning questions

3.1.3 Post-Class Feedback

The QuBAN method relies on the teacher having to select the learning/teaching method themselves based on some criteria, and this selection of method might not lead to the best outcome and motivation for students. This is precisely why feedback from the students is a vital part of determining the method. The post-class feedback functionality allows students to voice their opinions and also provides valuable feedback about their learning progress and what they want. This functionality will comprise mainly two questions: i) "What did you learn in this class?" and ii) "What do you want to learn next class". The first question will help the teacher understand if the method effectively worked on the students and the second question will help the teacher understand how and what the students want to learn. This information will help the teacher decide on the learning method and prepare themselves better and personalize the classroom lessons according to the student's needs and wants leading to better motivation and confidence.

3.1.4 General Questions

Allowing the students to ask general questions on any topic will allow them to enhance their questioning skills and not be restricted to the classroom topics. This feature will allow the students to hone their questioning skills without being restricted to specific classroom topics which can enhance their motivation and confidence when asking questions in the classroom either through the application or in person.

3.1.5 Further Motivation

It should be noted that only basic competition and gamification are not enough to motivate a student in studying and learning. Marks have been observed to be a great driving factor of motivation for most students in almost all educational institutes. A small portion of bonus mark can be added for the students scoring highest and being in the top places of the leader board which can significantly enhance the motivation of students to ask questions and get them into the habit of questioning and learning. Figure 4 shows a flowchart showing the integration of technology in the classroom following the QuBAN method.

The application awards bonus marks based on four criteria. The first criterion was being in the top three of the leader board. The second and third criteria were for the highest-scored pre-question and the highest-scored subsequent questions (questioning questions), respectively, every class days. Students were graded every class days based on the highest scores of the day in each question category, with one point awarded to the top three scorers. These daily points were accumulated to create a cumulative total score for each student. The total score served as a benchmark, allowing us to adjust scores for students who achieved the highest scores relative to their total scores. The fourth criterion was reaching a threshold score of 7000+ points where each question can score a maximum of 100 points. This ensures a fair and competitive scoring system which allows for higher motivation in questioning.

3.1.6 Challenges & Solutions

During the development of the application, certain challenges may arise, such as attempts to exploit the system for bonus marks. To address this issue, we propose the use of Natural Language Processing (NLP) techniques in conjunction with Machine Learning (ML) or Artificial Intelligence (AI). By utilizing NLP, we can identify similarities between questions using Levenshtein distance or something similar and discard or reject questions that have more than 80% similarity. This will prevent students from abusing the system by submitting similar questions, which does not aid their

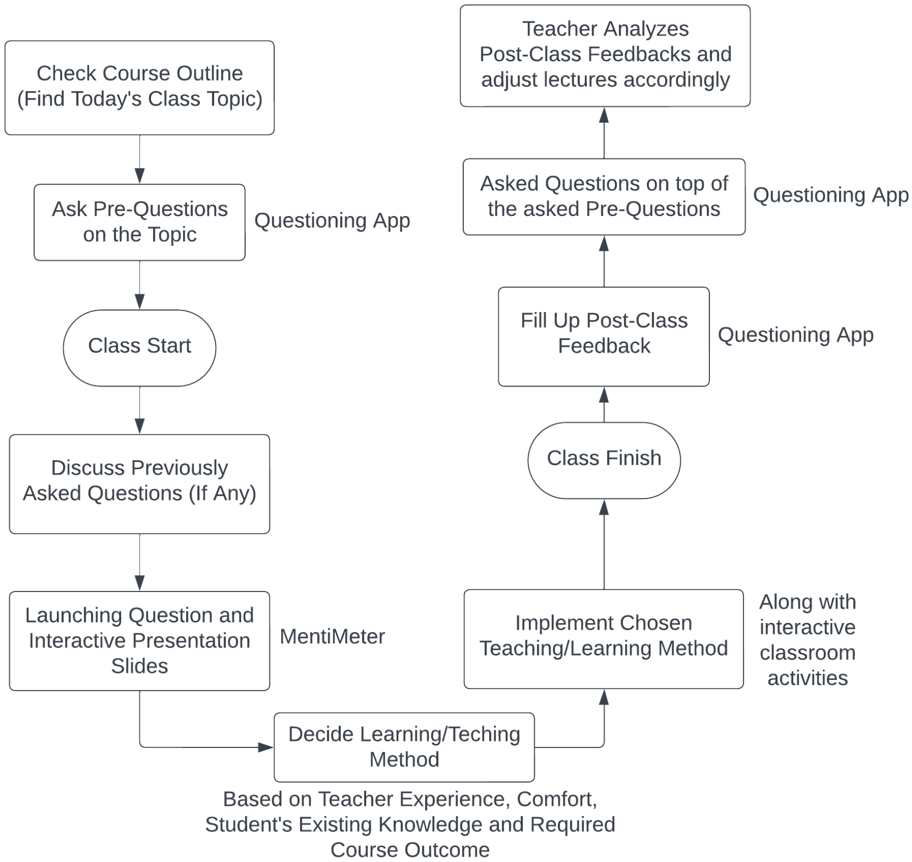

Fig. 4 QuBAN method workflow in a classroom.

learning in any way. Another challenge is the possibility of students asking off-topic or irrelevant questions or possibly even using profanity in their questions. For filtering out inappropriate language, we can use a library of profanity and slang keywords, and filter out any questions containing these keywords, even potentially giving negative scoring to demotivate such questions. To address off-topic and irrelevant questions, we can implement an AI or ML model that automatically categorizes questions into pre-defined topics. However, a labelled dataset of questions for a given course is required to train such a system. This dataset needs to be created manually, which is a time-consuming and difficult task. However, by using the proposed system, this process can be expedited as the students are asking questions by selecting the classroom topics and from there the off-topic and irrelevant questions can be filtered out much easily. The bloom's taxonomy questions scoring system also makes ranking the questions easier for training the algorithm. This dataset of categorized and ranked questions [31] can then be used to train the AI/ML model to automatically categorize further questions in the application. Subsequently, further questions can be used to expand the dataset for better accuracy and reliability. In a similar method, such dataset [31] can also be created for other courses as well.

3.1.7 Question Verification Process

In the question verification process, initially, a profanity filter is applied to the question to eliminate any unwanted content. Next, the question validator analyses the filtered question to ensure that it begins with a 5W (who, what, when, where, why) or 1H (how) keyword and ends with a question mark. Once validated, the question is then compared to other questions using Levenshtein distance with an 80% similarity threshold to identify unique questions. These unique questions are then categorized using an Artificial Intelligence (AI) / Machine Learning (ML) model, which will be the focus of future research. Once categorized, the questions are assigned to relevant topics. The questions are then scored using Bloom's taxonomy to determine their level, and a score is assigned accordingly. The scored questions are stored in a cloud database and reflected on the student dashboard along with their ranks derived from their scores. The proposed question verification process has been shown in Figure 5.

3.1.8 Ethical Considerations

Although technology has proven to be highly effective in improving learning and motivation, it can also pose ethical, privacy, and security concerns when used in education. To address these concerns, our system only collects minimal data from students, including their student ID and a password of their choice, which is automatically encrypted and stored in a secure cloud database. The data collected from students, such as questions and scores, is also be stored in the same cloud database. To respect student's privacy, the application also provides an option for students to remain anonymous by using an alias instead of their actual names when participating. This feature enables students to protect their privacy and engage in learning by asking questions without revealing their identities. The application also obtains user consent before sharing any data. This ensures that their privacy and security are protected while still allowing them to benefit from the advantages of technology in education. Additionally, it is crucial to obtain student's consent before collecting their data as it is an ethical matter. Therefore, their permission has been taken to ensure their willingness to participate in the QuBAN method classroom.

3.1.9 Practical Aspects

When incorporating e-learning into QuBAN method, several practical factors need to be considered carefully. These factors include the cost of the application, its maintenance, feasibility, and scalability. The website's maintenance cost is low, as it only requires information about the courses and sections offered, along with the topics covered in each semester to be updated and ready to use. The server cost may vary depending on the number of students. This application can be integrated into any

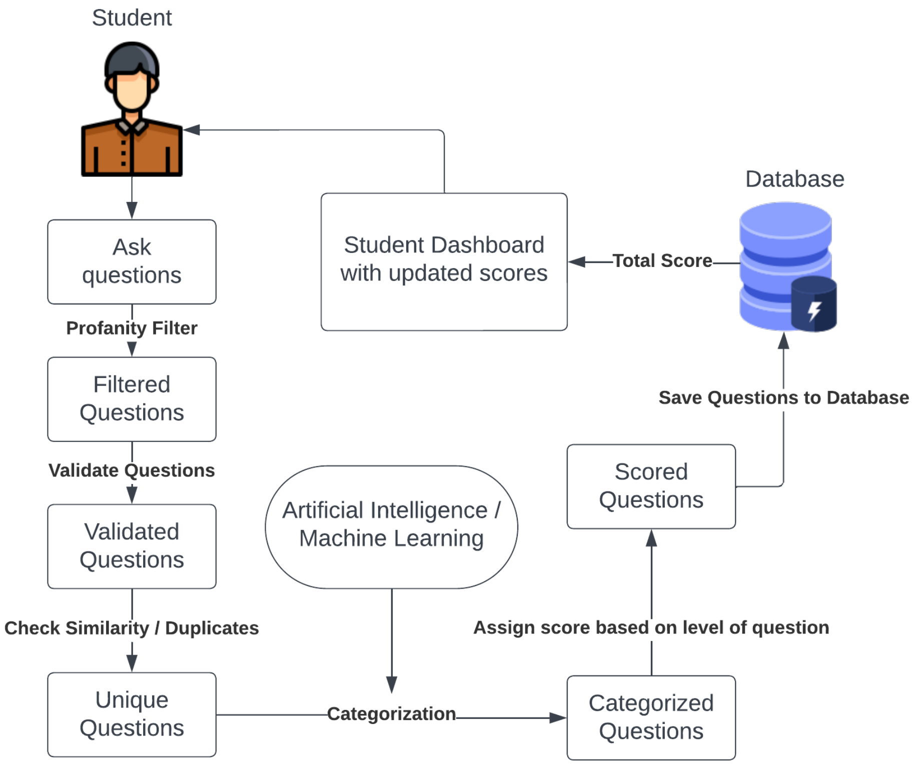

Fig. 5 Question Verification Process.

classroom with access to technological devices and the Internet. Technological advancements have made this feasible for most classrooms, particularly in higher education as technological devices are readily available nowadays. The progressive nature of the web application allows the system to be run on any device and operating system. The application stores data securely in a cloud database and can be scaled automatically to accommodate any number of students. Additionally, it can be integrated into classrooms covering a wide range of topics and courses across various departments. The real-time nature of the application allows users to post their questions and see other student's questions in real-time like a chat room creating a better user experience. Figure 6 shows a demo of the user interface of the questioning questions feature of the application.

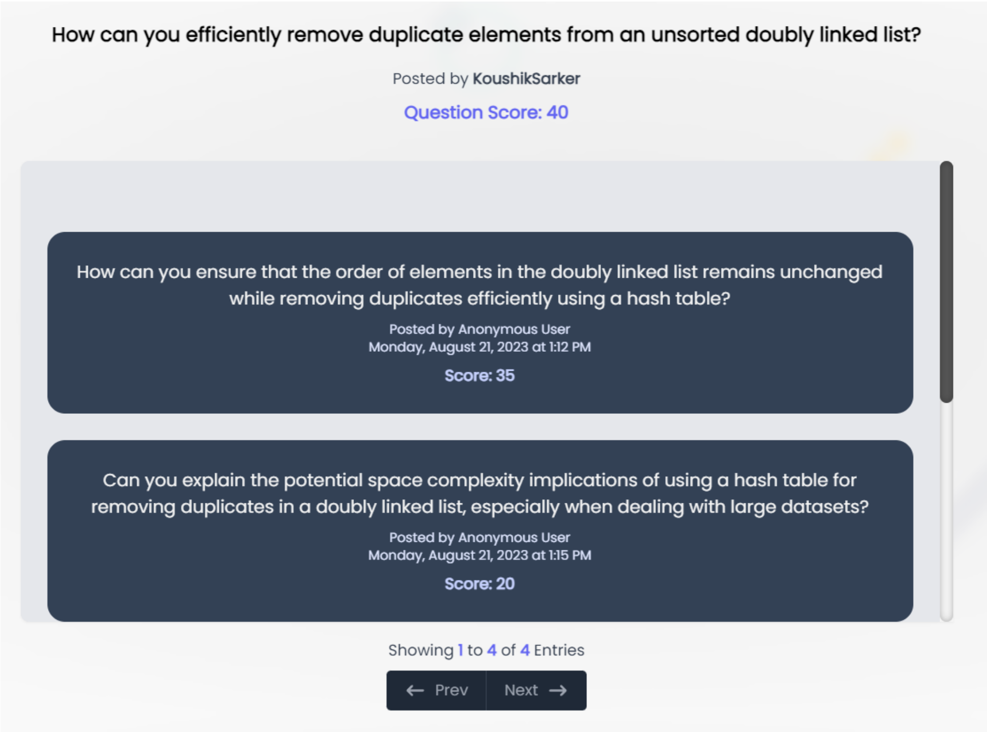

Fig. 6 Snippet of the user Interface of the questioning questions functionality of the application.

4 RESULT AND DISCUSSION

From this experiment, we have found that the Technology-Integrated QuBAN method is effective in improving student's confidence, motivation, critical thinking skills, questioning habits and also memory retention.

4.1 Effectiveness Across Courses

During the experiment, a total of 9,358 questions were asked by 126 students from four different sections. From these questions, 3,280 questions were related to the topic being studied, while 6,078 questions were general off-topic or irrelevant questions. Specifically, 7,784 questions were asked from Fundamentals (CIS101) course, and 1,574 questions were asked from Data Structure (CSC203) course. The questions were validated both automatically and manually, and they were categorized manually so that they could be used for training an AI/ML model for further research and analysis. Table 2 shows the comparison of the data from which we can determine that more topic-related questions are asked in highly technical courses compared to basic introductory courses. The next step is to determine if asking more questions about highly technical courses benefits students.

	Questions	Classes Exp.	Avg. Rel. Questions	Avg. Irr. Questions	% Avg. Rel. Questions
CIS101	7784	3	610	1985	29.6
CSC203	1574	1	1450	124	70.4
Total	9358	4	2060	2109	49.4

Table 2 Comparison of Relevant and Irrelevant Questions in CIS101 and CSC203 courses

In order to determine the benefits of e-learning using QuBAN method, we have observed the effect on the experimental group's academic performance in relation to the score determined by the application. The analysis has shown a positive impact on student's academic performances in relation to their scores which also means that students were able to retain the information taught in class leading to higher memory retention rates. In the CIS101 course a weak positive correlation of approximately 0.272 was observed while in the CSC203 course, a moderate positive correlation of approximately 0.409 was observed. In both courses, there's a positive relationship, meaning that as the score determined by the application increase, the overall course marks tend to increase as well. However, the strength of the relationship is stronger in the CSC203 course compared to the CIS101 course which indicates that the QuBAN method is more effective in highly technical (coding) courses. However, the academic performance between the experimental group and control group was not observed due to student's data and privacy restrictions.

4.2 Effect on Confidence & Motivation

At the start of the course, a questionnaire was administered to gather information about student motivation and confidence in the course topics. The purpose of the questionnaire was to evaluate the effectiveness of the QuBAN method in comparison to the existing learning methods used in conventional classes. After the final exam, another questionnaire was administered to compare motivation and confidence in QuBAN method. The same two questionnaire was given to the control group at the same time to measure the motivation and confidence in the same courses following existing conventional learning methods.

The data from the control group has shown a significant drop in motivation after using the existing learning methods, with only 6% of students responding that they look forward to electing similar courses in the future, compared to 46% before the course. However, in the experimental group, there was a positive change in motivation. Before the course, 44% of students responded that they look forward to learning in the course very much, and after using the QuBAN method, 53% of students responded that they look forward to similar courses in the future. The confidence level in the control group decreased significantly from 47% to 13% whereas the confidence level in the control group increased only slightly from 54% to 56%.

This shows that the QuBAN method has been effective in maintaining student motivation and confidence instead of improving it which is still a significant change compared to existing methods. Once students get used to the method the positive effects can be potentially better as the first time they are exposed to the method, it might seem overwhelming and a new concept of learning is not easily accepted by everyone. Motivation is however, affected by several factors such as emotions, environment, personal experience, and even innate personality traits along with several other factors which are difficult to control. However, motivation and confidence are a type of emotion and are dependent on the existing knowledge in the brain [32]. Since QuBAN utilizes a question-based approach to accessing neurons containing knowledge in the brain, the learning method significantly contributes to changes in student motivation and confidence. Figure 7 shows the change in motivation and confidence in the experimental and control groups.

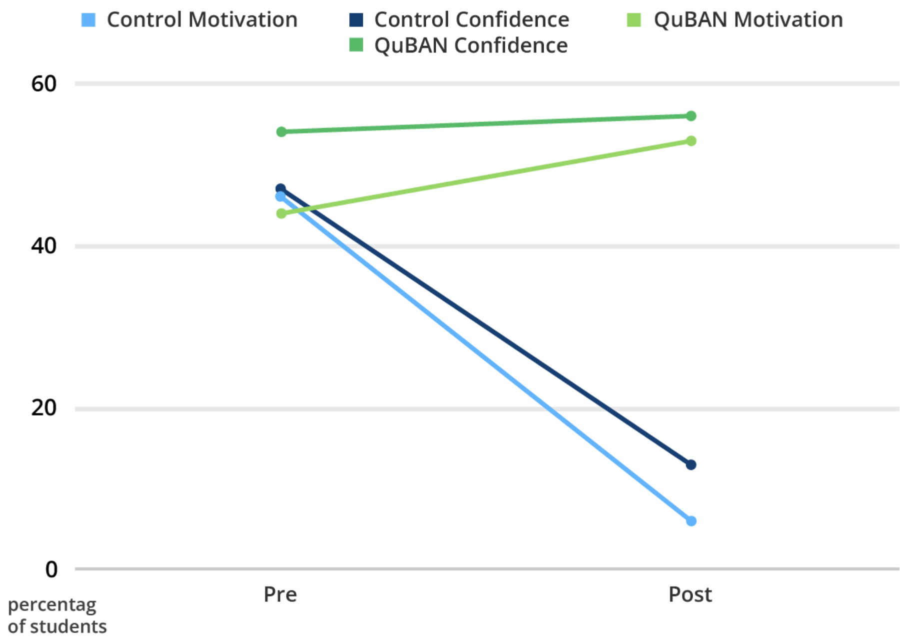

Fig. 7 Difference in motivation and confidence between the experimental and control group.

4.3 Impact on Questioning Habits

The QuBAN method has also had a significant impact on the questioning habits of students, leading to improved motivation, confidence, and memory retention. While other methods have also shown an increase in questioning habits, the rise has been minimal at 3%. In contrast, the QuBAN method has led to a 12% increase in student questioning habits, based on data collected from questionnaires in both the experimental and control groups. This increase in questioning habits has not only been in terms of quantity but also quality, with students asking more high-level and versatile questions instead of just basic ones. Figure 8 shows the percentage of different types of questions asked by students following the QuBAN method, based on Bloom's taxonomy.

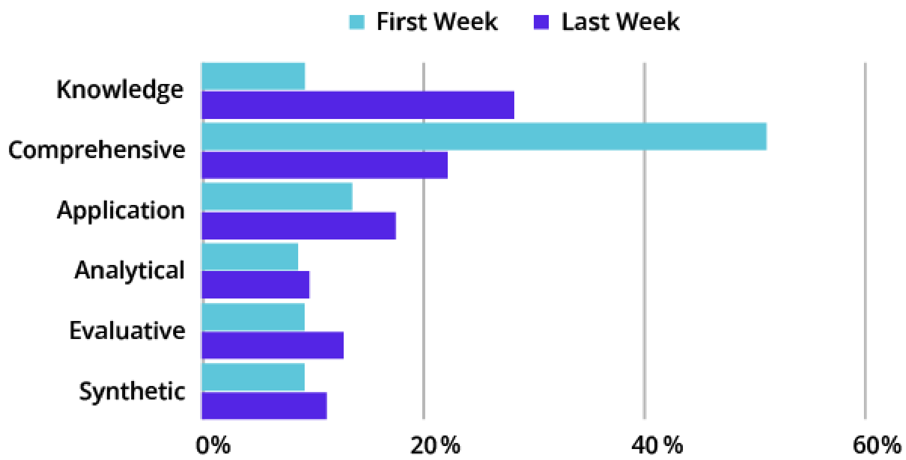

Fig. 8 Comparison of the percentage of the types of questions asked by experimental group.

4.4 Student's Attitude Towards QuBAN

It can be challenging to implement a new learning method and change students' learning habits and styles, even if it may be beneficial. Our observations have shown that 83% of students in the control group were hesitant to switch to a new learning method, and 7% of students completely rejected the idea. Only 10% of students expressed interest in switching to a new learning method, while the remaining students did not have any opinions. The student believes that the main reason for the resistance to change in learning methods is due to the familiarity and comfort with the current method. Adopting new methods could be challenging and time-consuming for both teachers and students, especially if they are unfamiliar with it.

A way to tackle this barrier to to slowly inject the concepts and ideas of the new learning method into both teacher's and student's minds. As both teachers and students gradually become accustomed to and understand the concept and benefits of the QuBAN method or any other learning methodology, they begin to realize its potential to enhance the learning system and embrace the new approach.

Additionally, the use of smart phones or other technological devices in classrooms is a concern for teachers who fear that it might act as a distraction for students. However, our literature review indicates that the use of these devices (only when the teacher grants permission or asks the students to use them) can significantly enhance learning. Therefore, this concern can be addressed by permitting the use of technological devices only when necessary in the classroom. Also, it may seem daunting to provide a technological device for QuBAN, but in today's world, technology is easily accessible everywhere. Most universities and institutions offer computer labs, and students often borrow devices from their friends. Therefore, the cost factor is not a significant challenge in integrating technology into the QuBAN method.

5 Conclusion

This paper delved deep into the exploration of diverse learning methods and their inherent limitations, particularly in fostering student's motivation, confidence, and memory retention. Recognizing the transformative potential of technology in today's digital age, we have integrated technology into the QuBAN method. This hybrid approach, leveraging the power of questions as a learning tool, is grounded in the neuroscience of learning, and is further enhanced by a technologically integrated progressive web application. Furthermore, the amassed data from the QuBAN platform presents a promising dataset for AI/ML applications, paving the way for predictive analytics and personalized learning pathways. QuBAN's primary objective is to rejuvenate the innate human curiosity for learning by intertwining questions with the learning process. By aligning with modern technological trends, harnessing the potential of AI/ML, and understanding the neuroscience behind learning, the QuBAN method not only addresses the gaps of existing learning methodologies but also positions itself as a forward-thinking solution for the evolving educational landscape.

Declarations

Abbreviations

QuBAN	- Query-Based Access to Neurons
IBL	- Inquiry-Based Learning
SLM	- Socratic Learning Method
PBL	- Project-Based Learning
FCM	- Flipped Classroom Method
BBL	- Brain-Based Learning
LLM	- Large Language Model
NLP	- Natural Language Processing
ML	- Machine Learning
AI	- Artificial Intelligence

Funding

This work was self-funded by the authors.

Competing interests

The authors declare that they have no competing interests.

Ethics approval

The data was collected from students and teachers and has been used with their permission.

Consent to participate

The experiment involved participation from both students and teachers who gave their consent.

Consent for publication

The consent was obtained to publish the data in an anonymous manner.

Availability of data and materials

The data set is available at https://doi.org/10.5281/zenodo.10032368.

Code availability

The code for the web application is available at https://github.com/reyanzaman/Question-Based-Learning

Authors' contributions

Khandoker Ashik Uz Zaman wrote the manuscript and developed the web application for the experiment. The experiment was conducted by all the authors and the manuscript was approved and finalized by Yusuf Mahbubul Islam and Md Abu Sayed.

References

[1] Michel, N., Cater III, J.J., Varela, O.: Active versus passive teaching styles: An empirical study of student learning outcomes. Human Resource Development Quarterly, vol. 20(4), pp. 397-418 (2009). https://doi.org/10.1002/hrdq.20025

[2] Shreyasi Shubhendu Paul: Active and Passive Learning: A Comparison. GRD Journal for Engineering, vol. 2(9), Year 2017. ISSN: 2455-5703.

[3] Edelson, D.C., Gordin, D.N., Pea, R.D.: Addressing the Challenges of Inquiry-Based Learning Through Technology and Curriculum Design. Journal of the Learning Sciences, vol. 8(3-4), pp. 391-450 (1999). https://doi.org/10.1080/10508406.1999.9672075

[4] Oyler, D.R., Romanelli, F.: The fact of ignorance: revisiting the Socratic method as a tool for teaching critical thinking. Am J Pharm Educ, vol. 78(7), pp. 144 (2014). https://doi.org/10.5688/ajpe787144

[5] Le, T.: Project-based Learning in 21st Century: A Review of Dimensions for Implementation in University-level Teaching and Learning. In: Proceedings of the 4th ICEAC International Conference on English Across Cultures. Bali, Indonesia (2018).

[6] Zainuddin, Z., Halili, S.H.: Flipped Classroom Research and Trends from Different Fields of Study. The International Review of Research in Open and Distributed Learning, vol. 17(3) (2016). https://doi.org/10.19173/irrodl.v17i3.2274

[7] Newton, C.: Closing the Gap Brain Based Teaching and Learning Techniques. Master's thesis, St. John Fisher University (2010). Available at: https://fisherpub.sjf.edu/education_ETD_masters/12

[8] Islam, Y.M., Nashikh, U.M.: Questioning Questions: Can Questions Help Build Neuron Clusters? In: Hussain, I.A. (eds) Multifaceted Development, pp. 169–199. Palgrave Macmillan, Singapore (2023). https://doi.org/10.1007/978-981-99-1798-3_9

[9] Tofade, T., Elsner, J., Haines, S.T.: Best Practice Strategies for Effective Use of Questions as a Teaching Tool. American Journal of Pharmaceutical Education, vol. 77, art. 155 (2013). https://doi.org/10.5688/ajpe777155

[10] Center for Teaching Innovation (2023). *Using Effective Questions*. Cornell University. Available at: https://teaching.cornell.edu/fall-2020-course-preparation/engaging-students/using-effective-questions. Accessed August 2023.

[11] Chakravarthy, S.: Instincts in Children. Journal of Clinical Medicine Case Studies, vol. 2(4) (2017). Available at: https://www.rroij.com/open-access/instincts-in-children-.php?aid=86625. Accessed October 23, 2023.

[12] Deng, Z., Cheng, A., Ferreira, P., Pavlou, P.A.: From Smart Phones to Smart Students: Learning versus Distraction with Smartphones in the Classroom. (2023). https://doi.org/10.1023/A:1022609809036 Fox School of Business Research Paper Forthcoming. Available at SSRN: https://ssrn.com/abstract=4028845 or http://dx.doi.org/10.2139/ssrn.4028845

[13] Tam, M.: Constructivism, Instructional Design, and Technology: Implications for Transforming Distance Learning. Educational Technology & Society, vol. 3(2) (2000). ISSN: 1436-4522.

[14] Ndiku Makewa, L.: Constructivism Theory in Technology-Based Learning. In: [Editor(s) Name(s)], Book Title, pp. 268-287. ISBN: 9781522559160, DOI: 10.4018/978-1-5225-5915-3.ch015 (2019).

[15] Andrini, V.S.: The Effectiveness of Inquiry Learning Method to Enhance Students' Learning Outcome: A Theoretical and Empirical Review. Journal of Education and Practice, vol. 7(3), pp. 38-42 (2016). ISSN: 2222-1735

[16] Chengay, F.B.: Inquiry - Based Learning: Its Impact to Students Problem Solving Performance in Series. Journal of Education and Practice, Preprint version 1, 10 April 2023. https://doi.org/10.21203/rs.3.rs-2760659/v1

[17] Qurat-ul-Ain, Shahid, F., Aleem, M., Islam, M.A., Iqbal, M.A., Yousaf, M.M.: A Review of Technological Tools in Teaching and Learning Computer Science. Eurasia Journal of Mathematics, Science and Technology Education, vol. 15(11) (2019). https://doi.org/10.29333/ejmste/109611

[18] Le, N-T.: How Do Technology-Enhanced Learning Tools Support Critical Thinking? In: Proceedings of the Frontiers in Education, Frontiers Media SA, vol. 4, Digital Education section (2019). https://doi.org/10.3389/feduc.2019.00126

[19] Rosé, C.P., Law, N., Cress, U., et al.: Highlighting tools and technologies for collaborative learning. Intern. J. Comput.-Support. Collab. Learn, vol. 14, pp. 1–6 (2019). https://doi.org/10.1007/s11412-019-09297-z

[20] Sayed, M.A., Zaber, M., Ali, A., Mosharaf, P.: Enumerating the Obstacles of Accelerating the Use of Digital Classroom: Lessons from Bangladesh (2017). Available at: https://ssrn.com/abstract=3044273 or http://dx.doi.org/10.2139/ssrn.3044273

[21] Sayed, M.A., Zaber, M.I.: Just-in-Time Educational Aid to Deliver Instant Help for Students in Developing Countries. Recent Trends in Information Technology and its Application, vol. 3(3), pp. 1-19 (2020).

[22] Zhang, D., Nunamaker, J.F.: Powering E-Learning In the New Millennium: An Overview of E-Learning and Enabling Technology. Information Systems Frontiers, vol. 5, pp. 207-218 (2003). https://doi.org/10.1023/A:1022609809036

[23] Rubens, N., Kaplan, D., Okamoto, T.: E-Learning 3.0: Anyone, Anywhere, Anytime, and AI. In: Chiu, D.K.W., Wang, M., Popescu, E., Li, Q., Lau, R. (eds) New Horizons in Web Based Learning. ICWL 2012. Lecture Notes in Computer Science, vol 7697, Springer, Berlin, Heidelberg (2014). https://doi.org/10.1007/978-3-662-43454-3_18

[24] Chin, C., Osborne, J.: Students' questions: a potential resource for teaching and learning science. Studies in Science Education, vol. 44(1), pp. 1-39 (2008). https://doi.org/10.1080/03057260701828101

[25] Rogers, T., Green, J.L., Nussbaum, N.R.: Asking Questions about Questions. In: Perspective on Talk & Learning, pp. 73-95. ISBN: 0-8141-3524-2 (1990).

[26] Yoon, C., Kensington-Miller, B., Sneddon, J., Bartholomew, H.: It's not the done thing: Social norms governing students' passive behaviour in undergraduate mathematics lectures. International Journal of Mathematical Education In Science & Technology, vol. 42(8), pp. 1-16 (2011). http://dx.doi.org/10.1080/0020739X.2011.573877

[27] Tawfik, A.A., Graesser, A., Gatewood, J., et al.: Role of questions in inquiry-based instruction: towards a design taxonomy for question-asking and implications for design. Education Tech Research Dev, vol. 68, pp. 653–678 (2020). https://doi.org/10.1007/s11423-020-09738-9

[28] Mabonga, G.: Children's prior knowledge is very important in Teaching and learning in this era of constructivism (2021). https://doi.org/10.13140/RG.2.2.28470.22083

[29] Ramirez, A., Arbuckle, M.R.: Synaptic Plasticity: The Role of Learning and Unlearning in Addiction and Beyond. Biol Psychiatry, vol. 80(9), pp. e73-e75 (2016). https://doi.org/10.1016/j.biopsych.2016.09.002

[30] Hoffeld, D.: Want To Know What Your Brain Does When It Hears A Question? Fast Company (2017). Available at: https://www.fastcompany.com/3068341/want-to-know-what-your-brain-does-when-it-hears-a-question

[31] Zaman, K.A.U., Islam, Y.M., Sayed, M.A., Independent University Bangladesh: Categorized Questions Dataset QuBAN. Data set, (2023). https://doi.org/10.5281/zenodo.10051055

[32] Attar, E.: Self-confidence and its Relationship with Motivation for Achievement among Female Students at King Abdul- Aziz University. Journal of Education and Practice, vol. 8(19) (2017). ISSN: 2222-1735.