DEVELOPMENT OF AN EFFECTIVE GAME THEORETIC FRAMEWORK FOR ACADEMIC EVALUATION

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August 2023

Declaration of Authorship

I, hereby declared that the presented work in the thesis entitled "Development of an Effective Game Theoretic Framework for Academic Evaluation" in fulfilment of degree of Doctor of Philosophy (Ph. D.) is outcome of research work carried out by me under the supervision of Dr. Munish Bhatia, working as Assistant Professor, in the School of Computer Science and Engineering of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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Certificate

This is to certify that the work reported in the Ph.D. thesis entitled "Development of an Effective Game Theoretic Framework for Academic Evaluation", submitted in fulfillment of the requirement for the reward of degree of **Doctor of Philosophy (Ph.D.)** in the Computer Science and Engineering, is a research work carried out by Avneet Kaur, 41900287, is bonafide record of his/her original work carried out by her under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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Abstract

In recent years, the role of education, which propagates knowledge is becoming increasingly important due to the fulminating expansion of knowledge. Meanwhile, the paradigm of instructional method is undergoing a transition in which the basic learning for students has to be performed in various ways. The quality of learning process can be improved by constantly checking and assessing different students' state and activities through information sensing tools and information processing platforms to provide feedback on the learning processes of diverse students. Annually, millions of individuals seek higher studies by enrolling in educational institutions across the world. However, only 55% of students complete the study. Over the past several decades, the number of educational institutions globally has increased significantly. It has manifestly diminished educational quality, leading to an increase in dropouts. In the last several decades, many governments have seen the resolution of such challenges to be of paramount significance. It has led to the increased focus on research in the area of smart classrooms to provide a constructive educational environment.

This thesis presents an effective framework for an optimal evaluation of students and teachers. Specifically, Quantum Game-Theoretic (QGT) decision making is incorporated for determining the academic enhancement of students. In addition, a student performance indicator and teacher performance indicator is computed to assess student performance over time. The presented system is evaluated utilizing various experimental simulations on challenging datasets and simulation results are contrasted with various state-of-the-art techniques to estimate the overall efficiency of the presented framework. A comparative study demonstrates that the given model has superior statistical values for Precision (94.56%), Sensitivity (94.14%), and Specificity (93.45%). Additionally, upgraded values of performance estimators such as reliability (96.16%) and stability (85.00%) were computed to represent the proposed system's overall efficiency. The effectiveness of the suggested framework has also been illustrated through mathematical analysis.

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Contents

Declaration of Authorship **i**

Certificate **ii**

Abstract **iii**

Acknowledgements **iv**

List of Figures **ix**

List of Tables **xi**

Abbreviations **xii**

1 Introduction **1**
- 1.1 Background Theory . . . 3
  - 1.1.1 ICT based Academic Environment . . . 4
  - 1.1.2 Integrating Machine Learning into Smart Academic Assessment 7
- 1.2 Game Theory . . . 11
  - 1.2.1 Categorization of Games in Game Theory . . . 12
  - 1.2.2 Hybrid Game Models . . . 16
  - 1.2.3 Need for Hybrid Game Models . . . 21
- 1.3 Research Motivation . . . 22
- 1.4 Research Gaps . . . 24
- 1.5 Research Objectives . . . 25
- 1.6 Research Contribution . . . 26
- 1.7 Proposed Research Methodology . . . 27
- 1.8 Thesis Organization . . . 29

2 Literature Review **31**

2.1 Background 31
2.2 Introduction 31
2.3 Scientometric Review 33
2.4 Search Methodology 35
2.5 Search Findings 36
2.5.1 Publication Trends 37
2.5.2 Citation Trends 39
2.5.3 Keyword Co-Occurrence Analysis 44
2.6 Systematic Review 48
2.7 Search Methodology 51
2.8 Findings 52
2.8.1 Smart Education Framework 52
2.8.2 Tehnological and Keyword Co-occurrence Analysis 54
2.8.3 Acceptance Studies and Teaching 57
2.8.4 Student Perspectives 59
2.8.5 Conceptual Framework 59
Smart Material 60
Material Preparation 61
Material Presentation 62
Material Distribution 62
Providing Assistance to Students 63
Modeling Student Participation 63
Student Participation Improvement 64
Smart Evaluation 64
Attendance 65
Smart Physical Classroom 66
2.9 State-of-the-Art Decision-Making Models 66
2.9.1 Bayesian Belief Network (BBN) Model 67
2.9.2 Game Theoretic Decision-Making 68
2.9.3 Artificial Neural Network Decision Modeling 69
2.9.4 Decision Tree (DT) Model 71
2.9.5 Quantum Computing based Decision-Modeling 72
2.10 State-of-the-Art Research Gaps 74
2.11 Research Methodology 76
2.12 Discussion 77
2.13 Inferences 78

3 A Framework for Academic Evaluation 79
3.1 Introduction 79
3.2 Proposed Framework 80
3.3 Data Acquisition and Pre-processing (DAP) Layer 81

3.4 Data Classification (DC) Layer: Fog Level . . . 81
3.4.1 Dataset Classification . . . 84
3.4.2 Classification based on Bayesian Belief Network (BBN) Model 85
3.5 Data Mining (DM) Layer . . . 86
3.5.1 Temporal Mining Formulation . . . 86
3.6 Quantum Gametic Decision Modeling (QGDM) . . . 89
3.6.1 Strategy Set . . . 89
3.6.2 Game Parameters . . . 89
3.6.3 Game Utility . . . 90
3.6.4 Utility Tree . . . 92
3.6.5 Game Equilibrium . . . 93
3.6.6 Algorithmic Description . . . 94
3.7 Mathematical Analysis . . . 95
3.8 Inferences . . . 98

4 Experimental Simulation 99
4.1 Introduction . . . 99
4.2 Data Collection . . . 99
4.3 Exploratory Data Analysis (EDA) . . . 101
4.4 Dataset Description . . . 101
4.4.1 Datatypes . . . 103
4.5 Data pre-processing . . . 104
4.5.1 Missing Values . . . 106
4.5.2 Approach for Handling Missing Data . . . 107
4.5.3 Feature selection and Correlation Heatmap . . . 107
4.6 Performance Evaluation Metrics . . . 110
4.7 Inferences . . . 111

5 Results and Discussion 113
5.1 Introduction . . . 113
5.2 Implementation Analysis . . . 114
5.2.1 Simulation Environment . . . 114
5.2.2 Temporal Delay . . . 115
5.2.3 Classification Efficiency . . . 116
5.2.4 Prediction Efficacy . . . 118
5.2.5 Reliability Analysis . . . 120
5.2.6 Stability Analysis . . . 122
5.2.7 Discussion . . . 123
5.3 Inferences . . . 124

6 CONCLUSION AND FUTURE WORK 126
6.1 Conclusion . . . 126

6.2 Future Directions 127

REFERENCES **129**

PUBLICATIONS **161**

List of Figures

1.1 IoT Growth Rate . . . 2
1.2 A Futuristic Aspect of Internet of Education (IoE) . . . 5
1.3 Classification of Machine Learning . . . 8
1.4 Types of Games in Game Theory . . . 12
1.5 Extensive Form Game . . . 14
1.6 Sequential Form Game . . . 15
1.7 Quantum Bit . . . 17
1.8 Fundamental SGN Graph . . . 19
1.9 Smart Academic Environment: Conceptual Framework . . . 27
1.10 Schematic Diagram of Research Methodology . . . 28
1.11 Chapter-Wise Thesis Organization . . . 29

2.1 Main Areas of Study in Smart Academics . . . 33
2.2 Broad Themes in Smart Academics . . . 34
2.3 KCoN of Smart Environment related Keywords (M_k=3, D_k=313, and C_k=38) . . . 46
2.4 KCoN of Education Mode related Keywords (M_k=4, D_k=2263, and C_k=103) . . . 47
2.5 KCoN of Education Level related Keywords (M_k=4, D_k=2050, and C_k=78) . . . 48
2.6 Count of Papers published between 1995-2021 . . . 52
2.7 KCoN of Technical Advancement related Keywords (M_k=10, D_k=5698, and C_k=138) . . . 56
2.8 Technological Advancements Year-Wise (M_k=10, D_k=5698, and C_k =138) . . . 57
2.9 Classification of Smart Classroom Literature . . . 60
2.10 Smart Material Preparation, Presentation and Distribution . . . 61

3.1 Modular Design of the Proposed Framework . . . 80
3.2 Processing and Classification of Data . . . 84
3.3 Temporal Abstraction . . . 87
3.4 Utility Tree . . . 93

4.1 Categories of data . . . 103

4.2 Attributes and their Datatypes 105
4.3 Data Preprocessing 108
4.4 Correlation Result of Dataset 109

5.1 Temporal Delay Efficiency (a) SP Dataset, (b) SAP Dataset, (c) SPP Dataset,(d) SPA Dataset 116
5.2 Prediction Efficacy (a,b,c,d):- Precision of Dataset SP, SAP, SPP, and SPA (e,f,g,h):- Accuracy of Dataset SP, SAP, SPP, and SPA (i,j,k,l):- Sensitivity of Dataset SP, SAP, SPP, and SPA 119
5.3 Reliability Analysis 121
5.4 Stability Analysis 122

List of Tables

1.1 Publications Regarding Research in Different Subject Areas of Education . . . 7

2.1 Research Areas in Smart Education . . . 36
2.2 Bidimensional Analysis of Document Count in Broad Themes and Research Areas of Smart Education Domain . . . 37
2.3 Growth Rate of Publications in Smart Education Research Areas . . . 39
2.4 Citation Distribution of Publications of Different Sub-Themes . . . 40
2.5 Sub-Theme-Specific Highly Influential Journals (NA Not Available) 41
2.6 Reviews in Smart Classroom: An Overview (2011-2021) . . . 50

3.1 Classification of Data Sets for Performance Evaluation of Student and Teacher along with Procedure for Feature Acquisition . . . 83
3.2 SPI and TPI Computation Method . . . 88
3.3 Notations for Calculating Student Achievement . . . 88
3.4 Game Metrics . . . 90
3.5 Algorithmic Description . . . 94

4.1 Parameters of Dataset . . . 102

5.1 Classification Efficiency; (Pr Precision, Sp Specificity, Se Sensitivity) 118
5.2 Error Rates . . . 120
5.3 Results of Various Performance Metrics . . . 120

Abbreviations

ACM	Association for Computing Machinery
AI	Artificial Intelligence
AISHE	All India Survey on Higher Education
ANN	Artficial Neural Network
AR	Augmented Reality
ARS	Audience Response System
BBN	Bayesian Belief Network
BD	Big Data
CC	Cloud Computing
CO_2	Carbon Dioxide
CS	Computer Science
CNN	Conventional Neural Network
CRS	Classroom Response System
DAP	Data Acquisition and Preprocessing
DC	Data Classification
DM	Data Mining
DT	Decision Tree
EC	Explicit Class
ECC	Elliptic Curve Cryptography
EDA	Exploratory Data Analysis
EER	Education Educational Search
Engg.	Engineering

ESS	Evolutionary Stable Strategy
GDM	Gametic Decision Modeling
GPS	Global Positioning System
GQC	Genetic Quantum Computing
GT	Game Theory
HL	Higher Level
IC	Implicit Class
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineering
IF	Impact Factor
IoT	Internet of Things
IT	Information Technology
KCoN	Keyword Co-Occurrence Network
K-NN	K-Nearest Neighbor
LAN	Local Area Network
LMS	Learning Mangement Systems
LTE	Long Term Evolution
MAE	Mean Absolute Error
MAS	Mean Absolute Shift
MCQ	Multiple Choice Question
ML	Machine Learning
NFC	Near Field Communication
NO_2	Nitrogen Dioxide
OCR	Optical Character Reader
OE	Online Education
OMR	Optical Mark Reader
OSE	On-Site Education
PDA	Personal Digital Assistant
PI	Performance Index

PoP	Probability of Performance
PSL	Primary/Secondary Level
Q-bit	Quantum Bit
QGDM	Quantum Gametic Decision Modeling
QGT	Quantum Game Theory
QP	Quantum Probability
RAE	Relative Absolute Error
RE	Replicator Equation
RFID	Radio Frequency Identification Device
RMSE	Root Mean Square Error
RRSE	Root Relative Squared Error
SA	Smart Academics
SAP	Student Academic Performance
SC	Smart Campus
SCR	Smart Classroom
SD	Student Dataset
SGN	Stochastic Game Net
SL	Smart Learning
SLE	Smart Learning Environment
SP	Student Performance
SPA	Student Performance Analysis
SPI	Student Performance Index
SPNs	Stochastic Petri Nets
SPP	Student Predictive Performance
SSL	Secure Socket Layer
ST	Smart Teaching
STEM	Science, Technology, Engineering, and Mathematics
SVM	Support Vector Machine
TC	Telecommunications

TD	Teacher Dataset
TI	Title Search
TPI	Teacher Performance Index
UNDP	United Nations Development Program
VOC	Volatile Organic Compound
VOS	Visualization of Scientific Landscapes
VR	Virtual Reality
WEKA	Waikato Environment for Knowledge Analysis
WLAN	Wireless Local Area Network
WMS	Weather Monitoring System
WoS	Web of Science
WSN	Wireless Sensor Networks

Dedicated to my beloved family…

Chapter 1

Introduction

Information Technology (IT) performs a vital role in the lives of all individuals. The development of information technology has entirely altered the human way of life. Numerous industries, such as healthcare, agriculture, cooperative banks, education, and entertainment, are affected by significant resources, i.e., storage, processing capacity, and network bandwidth. The requirement for these IT resources continues to rise daily. Various computing technologies, including utility computing, parallel computing, grid computing, and cloud computing, have come into existence in response to the rising demand for IT resources. Among these technological innovations, cloud computing is a relatively recent development that allows end users with instant access to IT resources from anywhere, at any time, and with various sorts of service provider engagement.

Internet of Things (IoT) is a novel paradigm in the sphere of telecommunications. IoT is the interconnection of physical objects, devices, vehicles, and other things that are endowed with software, electronics, network connectivity, and sensors, enabling these objects to collect information and interact with each other. IoT has altered the meaning of education because learning possibilities are no longer constrained by specialists and are available from any location. IoT has played a vital role in the education industry by delivering solutions to enhance academic

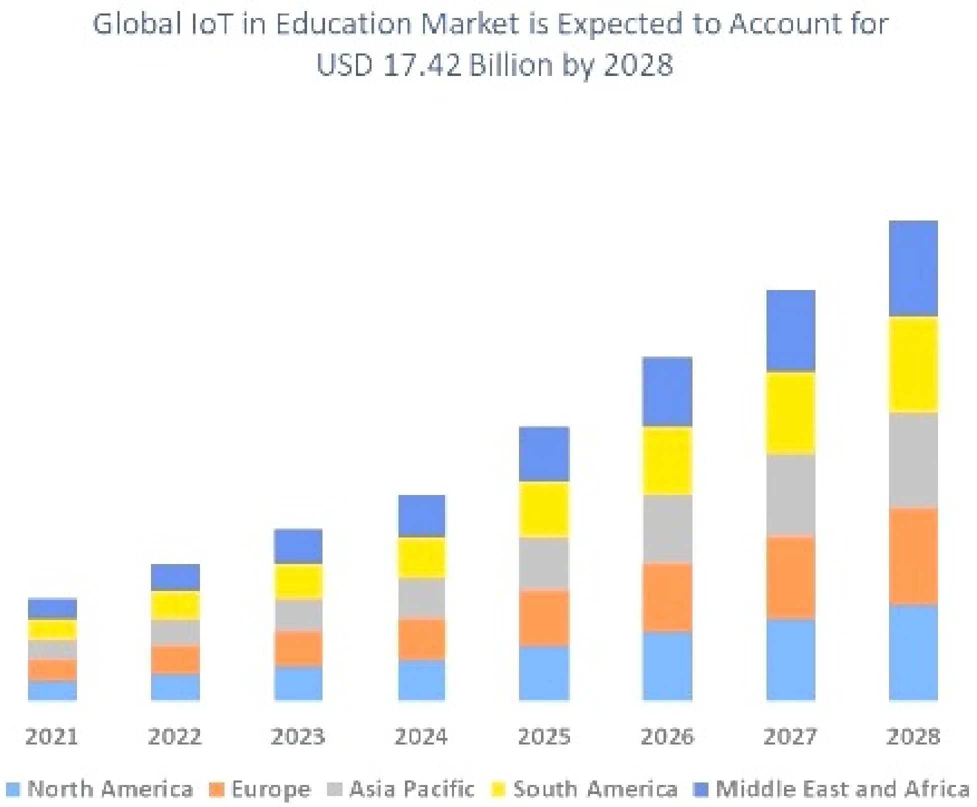


Figure 1.1: IoT Growth Rate

learning, education quality, campus safety, and interactivity via the use of smart sensors and devices. According to a research study, "IoT in Education Market"by Markets and Markets, the global market size is expected to "grow from \$4.8 billion in 2018 to \$11.3 billion by 2023 ". Figure 1.1 depicts an overview of IoT growth rate[1].

Fog computing is another emerging innovation that puts cloud services closer to the "Things", such as sensors, mobile devices, and systems that are embedded. In comparison to cloud computing, fog computing positions computing and processing capacity closer to IoT devices or mobile phones, thereby reducing latency and communication overhead. This is because the physical distance between IoT devices and fog nodes is shorter and requires a minimum response time for real-time decision making.

[1]https://www.databridgemarketresearch.com/reports/global-iot-in-education-market

Education is an important area to be managed effectively and efficiently for any nation's development. In recent times, there has been a growing need for immediate analysis of user data as well as real-time decisions without any delay. So, cloud, IoT, and fog technology can be combined to develop smart frameworks for academic performance assessment that can perform better than existing frameworks.
This chapter is organized into various sections. Section 1.1 describes the background of the education sector. Game Theory and its types are detailed in Section 1.2. The motivation for the research work is given in Section 1.3. Section 1.4 describes the Research Gaps. Research objectives are identified in Section 1.5. Section 1.6 determines the Research Contributions. Section 1.7 describes the methodology followed in the current research. The layout of thesis is represented in Section 1.8.

1.1 Background Theory

Academic institutions are the foundation of each nation. The rise of technological trends such as Big Data Mining, IoT, and ICT seems to have a substantial impact on the availability of academic institutions. Access to learning information at any time and from any location on the globe is expanding ubiquitous learning's potential [1]. The inefficacy of traditional education and the antiquated way of assessing performance have led to an inadequate academic evaluation of learners. Annually, millions of people seek higher studies by enrolling in educational institutions across the world. Nevertheless, only 55% of students finish the course[2]. From 2014 to 2015, dropout rates in India, United States, United Kingdom, and China were 23%, 87%, 57%, and 39% respectively[3]. According to 2019 survey data, there were 2.1 million dropouts[4]. More than 51,534 educational institutions provide education to students[5]. In addition, the number of educational institutions have been increased

[2]Source:https://www.usnews.com/education/best-colleges/articles/2019-03-20/

[3]Source:https://www.livemint.com/Education/Trends-in-school-enrolment-and-dropout-levels.html

[4]Source:https://nces.ed.gov/pubs2019/2019144.pdf

[5]Source:http://mospi.nic.in/statistical-year-book-india/2017/198

significantly in recent years. The present expansion in the number of educational institutions has worsened education quality, resulting in a high surge in the dropout percentage. According to the AISHE 2018-19 report[6], there were approximately 29,829,075 students enrolled in degree programmes, but only 9,091,898 completed the course. Due to the increase in attrition rates caused by the existing curriculum and poor student performance evaluation programs, a revised strategy is required. Due to traditional ways of evaluating student performance, the significant decrease in the number of students graduating has left the student confused. So, it is getting more and more important for governments to put education and schooling research at the top of their lists. Based on the aforementioned aspects, hypothesis is formulated addressing some of the following points:

1. IoT has the ability to transform education industry for quality assessment.
2. Game-Theoretic environment is an effective technique for academic analysis in real-time.

IoT facilitates individualized learning that meets the requirements of all students. IoT also enables the creation of an intelligent monitoring system for students and teachers. It helps students become adapt and self-assured users by applying cutting-edge sensory devices and gadgets to apply basic information and skills in everyday life. Moreover, IoT data quantifies student and teacher performance evaluation effectively.

1.1.1 ICT based Academic Environment

In recent years, the significance of education in disseminating knowledge has become increasingly crucial due to the rapid expansion of knowledge. Meanwhile, the paradigm of the instructional method is undergoing a transition in which basic

[6]Source:https://mhrd.gov.in/sites/uploadfiles/mhrd/files/statisticsnew/AISHE20Final20Report20 2018-19.pdf

learning for students has to be performed in various ways. Therefore, it supports the environment for smart education. This integrates various communication and information systems to enable the process of learning and respond to specific student's and teachers' needs. The quality of the learning process can be improved by constantly checking and assessing the different students' states and activities through information sensing tools like Radio Frequency Identification (RFID) and information processing platforms to provide feedback on the learning processes of diverse students. RFID is utilized in determining the location of an individual or an item. Through a wide-ranging local connected network of smart devices or sensors, IoT has the potential to allow extensions and improvements to critical services in various fields while introducing a new application ecosystem leading to the concept of Internet of Education (IoE). Applying the concept of IoE in any educational context will increase the efficiency of an educational process because students will learn easily and teachers will do their job effectively. Figure 1.2 shows a futuristic part of the Internet of Education.

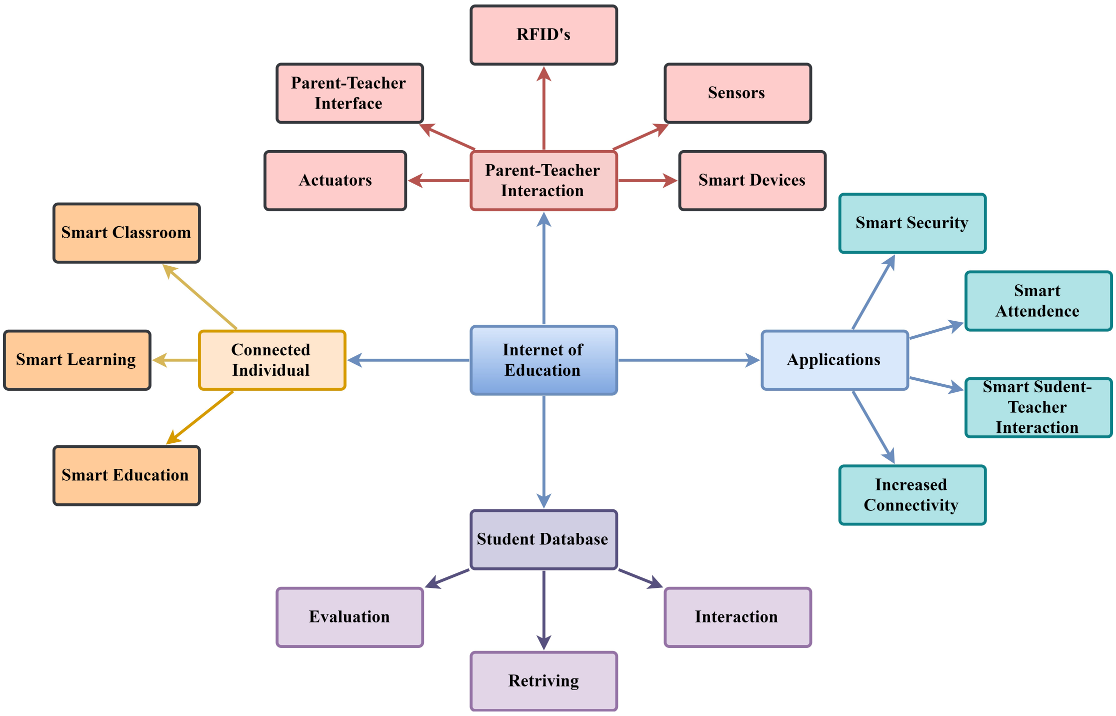


Figure 1.2: A Futuristic Aspect of Internet of Education (IoE)

Research, design, and development of smart academic institutions, classroom learning environments, conceptual pedagogical skills, e-learning, and academic assessment have become crucial components of numerous domestic and international activities, global economic governance proposals, organizational philosophies, and strategic plans. Work on the intelligent education is extensively advocated to improve academic settings that include and empower students, instructors, and administrators more effectively. Despite the development of intelligent technology to improve education systems, approaches continue to face obstacles due to insufficient theoretical and technological underpinnings. IoT is utilised as an emerging technology in several fields, including Healthcare [2], Transportation [3], Agriculture [4], and Security [5]. Additionally, IoT is playing a significant role in the education industry by delivering solutions to improve student performance, academic productivity, campus security, and connectivity via sensors and other smart devices. [6][7] indicates that smart education is gaining popularity as a result of the fact that it offers practical answers to challenges in the education industry. According to a 2001 report by the UNDP[7], ICT plays a significant role in enhancing the standard of living in the fields of health [8], business [9], tourism [10], and education [11][12]. In the notion of smart academics, education-related difficulties are handled via the conceptual application of technological breakthroughs. Many nations are investing energy and resources in the smart education domain as a result of the development of technological trends and the increasing popularity of smart education [13][14]. In recent years, IoT revolution is contributing significantly to the increase in smart education research publications. Table 1.1, depicts the share of educational research that has been published and the average growth over the past 30 years in a number of different fields. Table 1.1 is developed based on the research carried out in the Advance Search Field of Web of Science (WoS) database.

[7] Source:https://www.un-ilibrary.org/economic-and-social-development/human-development-report-20012e565da3-en

Table 1.1: Publications Regarding Research in Different Subject Areas of Education

Subject Area	**1990-94 (%)**	**1995-99 (%)**	**2000-04 (%)**	**2005-09 (%)**	**2010-14 (%)**	**2015-19 (%)**	**Average Growth (%)**
Computer Technology Information System	0	2.740	1.316	1.630	0.405	0.070	0.431
Physical Sciences	5.166	6.196	6.259	5.938	4.556	3.622	4.702
Arts and Humanities	12.028	11.250	10.821	12.198	11.114	9.565	10.703
Technology	13.967	17.751	23.085	22.926	19.123	18.608	19.385
Life Sciences and Biomedicine	45.675	46.234	43.061	39.275	34.449	27.451	34.775
Science Technology	58.829	62.366	65.022	59.948	51.454	45.706	52.932
Social Sciences	74.033	70.865	65.887	68.641	70.042	69.052	69.396

1.1.2 Integrating Machine Learning into Smart Academic Assessment

Machine learning is a subset of artificial intelligence (AI) that enables computer systems to learn and improve from experience without being explicitly programmed. Figure 1.3 demonstrates the classification of machine learning approaches into four main types: supervised, unsupervised, semi-supervised, and reinforcement learning. These techniques can be grouped into three categories: reinforcement learning, unsupervised learning, and supervised learning. In reinforcement learning, the algorithm receives feedback based on its performance while navigating the problem space. This type of learning is well-suited for tasks like playing games or driving a car.

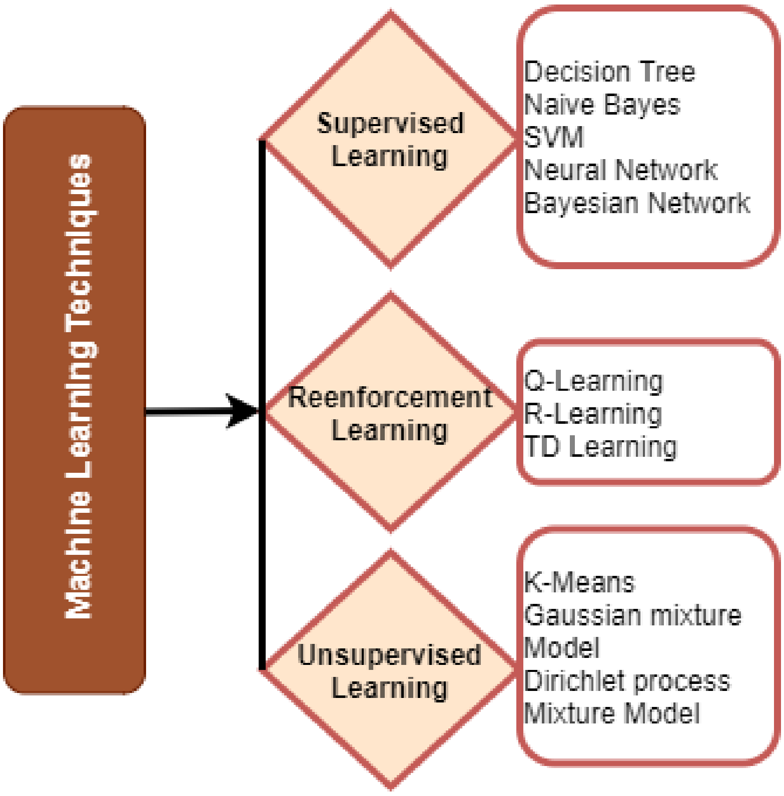


Figure 1.3: Classification of Machine Learning

On the other hand, unsupervised learning involves learning from unlabeled data without specific output labels. The frequently utilized unsupervised learning algorithms include K-means clustering, K-nearest neighbor clustering, hierarchical clustering, and principal component analysis. On the other hand, in supervised learning, the system is trained using labeled data instances. The most prevalent and effective supervised learning algorithms are SVM, Decision Tree, and J48. These algorithms follow a data-driven approach, using historical data to make predictions for the future. Deep Learning (DL) is a specialized area within machine learning and computational science. In DL, deeper neural networks are employed, utilizing multiple convolutions to create a hierarchical representation of data. This approach enables enhanced learning capacity, leading to improved performance and accuracy. Various deep learning algorithms, such as Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), and Recurrent Neural Networks (RNN), are currently being investigated for their predictive applications. It has proven to be a valuable tool in various fields, including education and academic assessment. Below are the various ML and DL algorithms:

1. J48: J48 is a decision tree algorithm that extracts the training dataset while considering a range of features and attributes. It categorizes and determines data based on the attribute values of the provided data. The algorithm uses internal nodes to determine possible outcomes for observed samples and classifies data according to its hierarchical structure. J48 sequentially separates normalized data into leaf nodes, significantly reducing the time required for searching sorted elements. However, its weakness lies in the requirement of data sorting as a pre-processing step.

2. SVM (Support Vector Machine): SVM is a type of classifier used to generate binary classifiers. Instead of relying solely on the input space, it utilizes the geometric properties of the training dataset. SVM's effectiveness depends on the selection and usage of appropriate kernels. It can accurately model complex non-linear decisions and is capable of handling soft margins. However, the primary drawback is its algorithmic complexity and the challenge of selecting suitable kernels.

3. Artificial Neural Network (ANN): ANN consists of multiple perceptrons or neurons arranged in layers. It processes inputs in a feed-forward manner, passing through several input nodes. ANNs can have hidden node layers, simplifying their operation. They exhibit a high tolerance for errors and can work with partial knowledge. However, one limitation of ANNs is the difficulty in explaining the network's behavior.

4. Convolutional Neural Network (CNN): CNN is a variation of the multilayer perceptron, which links or pools multiple convolutional layers together. These

layers capture portions of the data, which are then processed nonlinearly in rectangular sections. CNN can automatically detect relevant features or properties from data without human intervention. However, it requires a substantial amount of training data for the model.

5. Recurrent Neural Network (RNN): RNN is a more complex algorithm where processing nodes are saved and reinserted into the model as information is not only passed in one direction. It can predict the outcome of a layer, and if its forecast is incorrect during backpropagation, the system self-learns and adjusts for accurate predictions. RNNs are particularly useful in time series prediction tasks as they can remember previous inputs.

6. Bayesian Belief Network (BBN): A Bayesian belief network, also known as a Bayesian network or a probabilistic graphical model, is a graphical representation of probabilistic relationships between a set of variables. It is a powerful tool used for reasoning under uncertainty and making predictions based on available evidence. Bayesian networks can aid in decision-making under uncertainty by analyzing the probabilities associated with different actions and their outcomes. The advantage of using Bayesian belief networks lies in their ability to handle uncertain and incomplete information effectively.

With the integration of machine learning with IoT, ICT, and QGT, the proposed smart academic assessment framework can revolutionize the education industry by providing personalized, data-driven, and real-time solutions for academic evaluation and decision-making. This holistic approach holds the potential to address the challenges of high dropout rates and inadequate academic evaluations, ultimately leading to improved educational quality and student success rates.

1.2 Game Theory

The study of the decision-making processes of competing players in a conflict setting constitutes "game theory ". The Theory of Games and Economic Behavior [15] was created in the 1930s within the context of economic theory by Von Neumann and Morgenstern. Since then, a lot of work is done on game theory, and it is now a well-developed field that is used in fields like the social sciences, biological sciences, and engineering.

In situations involving uncertain choices, there are competitive scenarios in which two (or more) opponents are vying for an advantage at the expense of the others. The theory governing these types of decision problems is game theory. It is a body of knowledge that deals with making decisions. Key elements of Game Theory are:

1. Player:- A player can be a person, a group of individuals, or an organization.
2. Strategy:- A player's strategy is the list of all conceivable actions he will do for every possible payoff (outcome).
3. Utility:- The utility of a game outcome for a player is a quantitative measure of that event's desirability to the player.
4. Payoff Matrix:- It quantifies the player's utility for all possible game outcomes. It is believed that participants will attempt to maximize their benefit within the parameters of the game's rules.

The game theory incorporates strategic thinking, in which players decide by considering numerous views and the perspectives of other participants, as well as by assessing their actions and reactions in specific scenarios. Game theory is used extensively in various collective bargaining or negotiation activities involving several parties or participants. For instance, when employees are on strike or in a lockout, various discussions to raise salaries occur involving managers and employees. By looking at several possibilities for pay and benefits that can optimize the well-being of both staff and management, both sides can employ game theory to determine the best course of action, which is to raise wages. Salary negotiation is yet another instance of game theory.

1.2.1 Categorization of Games in Game Theory

In game theory, several sorts of games are utilized to analyze various types of situations. The numerous sorts of games are distinguished by the number of players engaged, the symmetry of the game, and player collaboration. Figure 1.4 depicts various types of games in game theory.

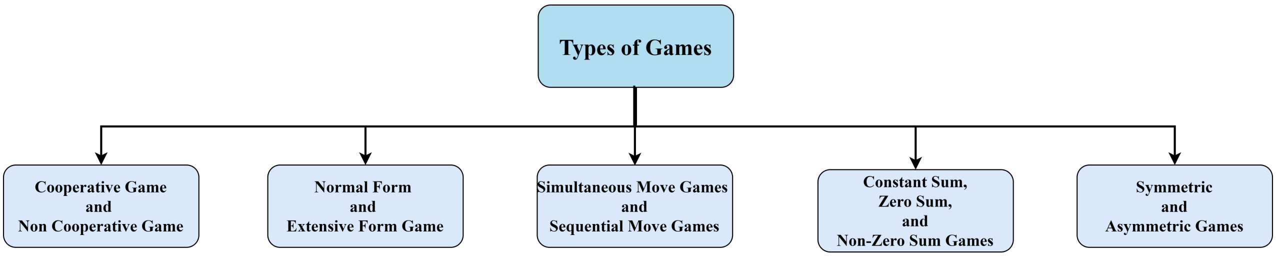


Figure 1.4: Types of Games in Game Theory

1. **Cooperative and Non-Cooperative Games:** Cooperative games are those in which participants are persuaded to adopt a specific strategy via conversations and agreements. Non-cooperative games, on the other hand, are those in which participants choose their method for maximizing their profit [16]. Non-cooperative games yield precise outcomes [17]. This is because, in non-cooperative games, an issue is analyzed in great depth.

   Prisoner Dilemma is ideal illustration of both cooperative and non-cooperative games. A prisoner dilemma is a scenario in which one of the decision-makers have an opportunity to decide on choices that result in an unfavorable result for everyone involved in the entire group. For instance, there are 2 prisoners. If they are able to communicate with each other, they must have opted to keep silent. As a result, their discussion would have aided in the resolution of the situation, leading to the formulation of cooperative game. In case of non-cooperative games, prisoners decide on their own to achieve maximum profit.

2. **Normal Form and Extensive Form Games:** Normal-form games relate to the matrix-based description of a game. In other words, normal-form games are those whose payoffs and tactics are expressed in a tabular format. In normal-form games, the matrix depicts the strategies employed by the several players and their potential outcomes [18]. In extensive form games, on the other hand, the rules are shown in the form of a decision tree. The use of extensive form games facilitates the portrayal of random events. These games have a tree-like structure in which the player identities are represented by distinct nodes [19]. For example, there are 2 companies namely, company-A and company-B. Assume that company A wishes to join a new market, and the company B is already present in that market. There are two options available to company A: either enter the market and compete for survival, or stay out of the market and forgo the potential profits. Company B has a comparable two-pronged strategy, either to battle for survival or to work with company A. In Figure 1.5, company A initiates the action, which is then followed by company B. If company A doesn't enter the market, then there will be no rewards. But if it does, company B will be completely responsible for the market's conditions. Both would lose 3, if engaged in a pricing war. Company B, on the other hand, would gain equal earnings if both worked together. In this scenario, the ideal choice is for Company A to jump into the market and Company B to collaborate.

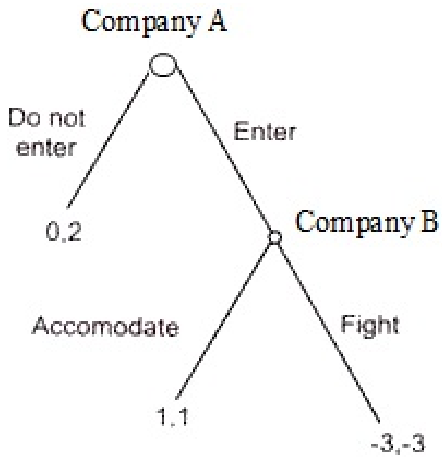


Figure 1.5: Extensive Form Game

3. **Simultaneous Games and Sequential Games:** Simultaneous games are those in which the strategies chosen by both players at same time. In simultaneous games, players are unaware of the strategies of other players [20]. Rock-paper-scissors is an illustration of a simultaneous game in which each player chooses at the same moment without knowing which of the three options are selected by the opponent.

   In contrast, participants in sequential games are aware of the movements of other players who have already selected a strategy. In sequential games, however, participants lack a comprehensive understanding of the strategies of other players [21][22]. For example, there are 2 companies, company X and company Y. Consider that company X is the first to determine whether or not to outsource its advertising activities. In Figure 1.6, company X makes the initial move, while company Y decides based on company X's decision. However, the outcome is contingent on the decision made by company Y. In this situation, the second player knows what the first player decided.

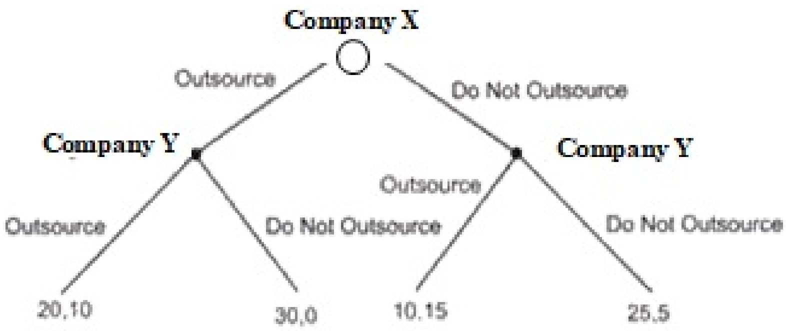


Figure 1.6: Sequential Form Game

4. **Constant Sum, Zero Sum, and Non-Zero Sum Games:** Constant sum game is a game wherein the aggregate of the results of all participants stays unchanged, even if the outcomes are diverse [23]. A zero-sum game is a sort of constant-sum game in which the total outcomes of all participants are zero. In a zero-sum game, various player's strategies do not affect the existing resources [24]. In addition, the gain of one player in a zero-sum game is always equivalent to the loss of the other player. Non-zero-sum games, on the other hand, are those in which the sum of all player's outcomes is greater than zero [25].

   Games with zero sum outcomes include chess and gambling. In these games, one player's success leads to the other's failure. Non-zero games, on the other hand, are cooperative games. This is due to the fact that in cooperative games, either every participant succeeds or fails.

5. **Symmetric and Asymmetric Games:** In symmetric games, all players employ identical strategies. Symmetry may occur in short-term games solely because the number of possibilities available to a player rises in long-term games. The decisions in a symmetric game are determined by the strategies employed, not the participants. In symmetric games, the decisions stay the same even if the participants are swapped [26]. Prisoner's dilemma is an example of a symmetric game.

   Alternatively, asymmetric games are those in which participants employ diverse strategies. In asymmetric games, the approach that is advantageous for one player may not be advantageous for the other. Nonetheless, decision making in asymmetric games is contingent on the many strategies and decisions of the participants [27]. On the contrary, asymmetric games are those in which participants pursue various strategies. In asymmetric games, a tactic that benefits one player may not help the other. However, decision making in asymmetric games is influenced by the various types of strategy and player decisions. Entry of a new firm into a market is an instance of an asymmetric game since various business organizations utilize various approaches for entering the same sector.

1.2.2 Hybrid Game Models

1. **Quantum Game Theory (QGT):-**In response to the growing interest in quantum computers and quantum information theory, attempts have been made to recast classical game theory using quantum probability amplitudes and to examine the impact of quantum superposition, interference, and entanglement on the optimum strategies of agents. In addition to unresolved issues in quantum information theory [28], the quantum game theory may apply to the study of quantum communication, which may be seen as a game whose purpose is to optimize effective communication. Workers in the emerging discipline of mathematical economics, econophysics, have sought to simulate markets and auctions under the assumption that traders can employ quantum protocols [29][30]. In this case, a quantum strategy, which represents a superposition of trading choices, can provide an advantage over conventional approaches [31]. Meyer's key work on quantum game theory analyzed a simple coin-tossing game and demonstrated how a player employing quantum superposition may win with absolute certainty versus a conventional player [32]. QGT is a notion derived from quantum computing in which data is described both indefinitely and definitively. The state of the system is

shown using a quantum description of data. The fundamental QGT notions are as follows:

(a) **Q-bit:** It is a basic unit of information stored in a quantum computer with 2 states. The possible states of q-bit are state-0, state-1, and the superposition of these 2 states. Figure 1.7 illustrates the quantum bit.

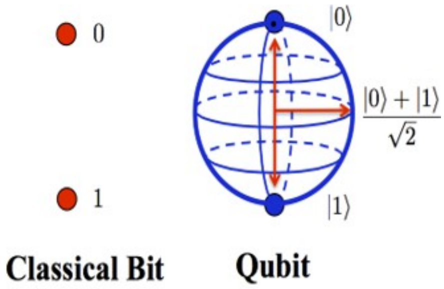


Figure 1.7: Quantum Bit

The q-bit state is represented as follows:

$$|\omega> = \gamma|0> + \theta|1> \tag{1.1}$$

where γ and θ are complex integers representing the probabilities of their respective states. γ and θ define the probability of a qubit being in the 0|state and 1|state respectively. The relational formulas illustrate the normalizing of state to unity as

$$\gamma^2 \ + \theta^2 = 1 \tag{1.2}$$

(b) **Individual Q-bit:** It is characterized as a string composed of many qubits. This is illustrated as follows:

$$\begin{bmatrix} \gamma_1 & | & \gamma_2 & | & \cdots & | & \gamma_{\mathrm{m}} \\ \theta_1 & | & \theta_2 & | & \ldots & | & \theta_{\mathrm{m}} \end{bmatrix} \tag{1.3}$$

where m is the number of Q-bits that comprise a single Q-bit. Individual Q-bits can represent distinct states by linear superposition of q-bits. Consider the following 3-bit quantum person as an example.

$$Q_1 = \begin{array}{c} \mathbf{0} \rightarrow \\ \mathbf{1} \rightarrow \end{array} \left[\begin{array}{c} 1/2 \\ \sqrt{3}/2 \end{array} \middle| \begin{array}{c} 1/\sqrt{2} \\ -1/\sqrt{2} \end{array} \middle| \begin{array}{c} -1/\sqrt{2} \\ -1/\sqrt{2} \end{array} \right] \tag{1.4}$$

The Q-bit structure described above provides information on eight distinct states. In other words, the above representation indicates the probabilities associated with each state of the system, -$\frac{1}{4}$|000>-$\frac{1}{4}$|001>+$\frac{1}{4}$|010>+$\frac{1}{4}$|011>-$\frac{\sqrt{3}}{4}$|100 >-$\frac{\sqrt{3}}{4}$|101>+$\frac{\sqrt{3}}{4}$|11>+$\frac{\sqrt{3}}{4}$|111>.
In addition, the linear superposition of the system state yields the probabilities of each state. The probabilities of a system being in the states |000>, |001>, |010>, |011>, |100>, |101>, |110>, |111>are 1/16, 1/16, 1/16, 1/16, 3/16, 3/16, 3/16, 3/16 respectively. Consequently, just 1 qubit, or Q_1, is required to represent the eight states (000), (001), (010), (011), (100), (101), (110) and (111), respectively. In general, the entire system may be assessed on the probability of

$$Q_{\mathrm{j}} = <\sum_{i=1}^{2^n} (\eta_i * \xi_i | \eta_i, \xi_i)> \tag{1.5}$$

(c) **Q-bit population:**The collection of individual qubits is referred to as the q-bit population. The formula for the Q-bit population with n distinct qubits of length m is as follows:

$$\left[\begin{array}{c} \gamma_{11} \\ \theta_{11} \end{array} \middle| \begin{array}{c} \gamma_{12} \\ \theta_{12} \end{array} \middle| \begin{array}{c} \cdots \\ \ldots \end{array} \middle| \begin{array}{c} \gamma_{1\mathrm{m}} \\ \theta_{1\mathrm{m}} \end{array} \right] \left[\begin{array}{c} \gamma_{21} \\ \theta_{21} \end{array} \middle| \begin{array}{c} \gamma_{22} \\ \theta_{22} \end{array} \middle| \begin{array}{c} \cdots \\ \ldots \end{array} \middle| \begin{array}{c} \gamma_{2\mathrm{n}} \\ \theta_{2\mathrm{n}} \end{array} \right], \ldots, \left[\begin{array}{c} \gamma_{\mathrm{m}1} \\ \theta_{\mathrm{m}1} \end{array} \middle| \begin{array}{c} \gamma_{\mathrm{m}2} \\ \theta_{\mathrm{m}2} \end{array} \middle| \begin{array}{c} \cdots \\ \ldots \end{array} \middle| \begin{array}{c} \gamma_{\mathrm{mn}} \\ \theta_{\mathrm{mn}} \end{array} \right] \tag{1.6}$$

(d) **Q-gate:** It is the modification variable that modifies each Q-bit to conform to the normalising state, $\gamma'^2 + \theta'^2 = 1$, where γ' and θ' are the modified values of q-bit. Q-gate is sometimes referred to as a reversible gate and is indicated by the unitary operator Y. $Y^T X = YY^T$ where Y^T is the Hermitian Adjoint of Y. There are several quantum gates, including Rotation gates, NOT gates, controlled-NOT gates, and Hadamard gates. It is vital to highlight that when a quantum state is seen, the entire system collapses into a single state. A Rotation Gate is represented as follows:

$$Q - Gate(\Delta\theta_j) = \begin{bmatrix} cos(\Delta\theta_j) & -sin(\Delta\theta_j) \\ sin(\Delta\theta_j) & cos(\Delta\theta_j) \end{bmatrix} \tag{1.7}$$

where $\Delta\theta_j$ denotes the angle of rotation that is prefixed during actual deployment.

2. **Stochastic Game Net (SGN):-**SGN is a binary graph G = (V, E) where V represents vertices or places and E represents direct edges. Transitions to vertices are connected by directed edges and vice versa. The input edge connects vertices to the transition, whereas the output edge connects the transition to vertices. Figure 1.8 illustrates a fundamental SGN Graph. It is defined by Wang et al. [33] using 9 tuples as given below:

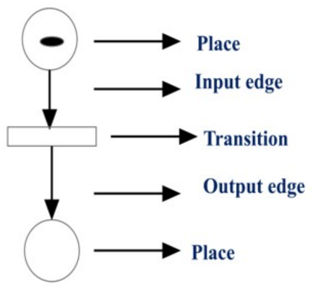


Figure 1.8: Fundamental SGN Graph

$$SGN = (N, P, T, F, \pi, \lambda, R, U, M_0) \tag{1.8}$$

Each of these tuples is described as;

(a) "$N = (1, 2, 3, \ldots, n)$ denotes the set of players,

(b) P is a finite set of places,

(c) $T = T_1 \bigcup T_2 \bigcup T_3 \bigcup \ldots \bigcup T_n$ is a finite set of transitions where T_k is the set of transitions with respect to player k such that kϵN,

(d) π= T$\rightarrow$[0,1] is a routing policy representing the probability of choosing a particular transition,

(e) $F \subseteq I \bigcup O$ is a set of arcs, where $I \subseteq (P \times T)$ and O $\subseteq$(T $\times$ P) such that P $\cap$T = ϕ and P $\bigcup$ T= ϕ where ϕ is a empty set, for a convenience, we denote $\bullet$x = {y |(y, x) ϵ F} the pre-set of x. Similarly, x$\bullet$ = {y |(x, y) ϵ F} the post-set of x,

(f) R(R^1, R^2, ..., R^N) is a reward function for the players taking each transition, where i $\in$ (-∞, + ∞) for i $\in$ N,

(g) $\lambda = \{\lambda_1, \lambda_2, \ldots, \lambda_x\}$ is a set of transition firing rates in the transition set, where x is the number of transitions,

(h) U is the utility function of players,

(i) M_0 denotes the initial state of the players".

Classical game theory and quantum game theory are two different approaches to study strategic interactions among rational agents. While classical game theory focuses on analyzing games involving classical (non-quantum) systems, quantum game theory extends the framework to incorporate quantum phenomena and players that can exploit quantum strategies. Some key differences between classical game theory and quantum game theory are:-

1. Mathematical Framework: Classical game theory is based on the classical probability theory and utilizes concepts namely, strategic games, extensive games, and mixed strategies. QGT, on the other hand, employs mathematical formalism of the quantum mechanics, including unitary transformations, and quantum superposition.

2. Strategy Space: In classical game theory, players have a finite set of pure strategies and can mix them probabilistically to form mixed strategies.

QGT allows players to use quantum strategies. Quantum strategies can be superpositions of pure strategies, enabling players to exploit quantum phenomena such as entanglement and interference.

3. Information and Entanglement:- Classical game theory assumes complete information, where players have perfect knowledge of the game and their opponents' strategies. In quantum game theory, players can be in a state of quantum entanglement, where their actions become correlated.

Overall, quantum game theory extends classical game theory by incorporating quantum principles and strategies, allowing for a richer and more nuanced analysis of strategic interactions. In context to smart academic evaluation, QGT is utilized for evaluating the performance of students and teachers, which is discussed in detail in the upcoming chapters.

1.2.3 Need for Hybrid Game Models

The use of hybrid game models can help researchers make decisions that include compromise and disagreement and lead to the best possible outcome. The hybrid game paradigm is motivated by various factors:

1. Innovation and Novelty: By combining features from the actual world with those from the virtual world, hybrid games offer an interesting and new strategy for gaming.
2. Enhanced Immersion: Players may engage with physical components in the real world while enjoying dynamic and engaging virtual material. This connection makes the experience more interesting and immersive.
3. Educational and Experiential Value: Hybrid games have a great deal of potential for practical and educational learning. They can give hands-on

experiences and practical applications of information by adding physical aspects.

4. Technological Advancements: Technological advancements such as Augmented Reality (AR) and Virtual Reality (VR) have considerably aided in the creation of hybrid games. Because these technologies allow for the seamless integration of virtual and real aspects, the hybrid game concept becomes more readily available and attractive.

Overall, the hybrid game model is motivated by the aim to provide players with distinctive, absorbing, and socially engaging experiences that strengthen the connection between the real and virtual worlds.

1.3 Research Motivation

IT provides effective methods to collect, process, analyze, store, and electronically transfer performance-related information for each student. IT and QGT integration offer an innovative approach to gathering, processing, and making decisions in real-time based on omnipresent data [34]. Smart gadgets, which consist of wireless sensors, control devices, and actuators, can detect and send time-sensitive data to remote devices [35]. On the other hand, QGT is applied for automated decision making in smart environments [36]. Enhanced data processing tools, such as AI and ML, enable smart academic philosophy to be implemented with the utmost effectiveness [37]. Based on the performance evaluation of students and teachers, the current study presents a quantum game model for academic decision-making [38].

The ability to use data collected by smart devices as the basis for making appropriate decisions on the academic accomplishments of students as well as the professional competence of their instructors is the core idea underlying the provided architecture. In addition, using a QGT-based automated decision-making system makes it possible to attain precision when rating the performance of both instructors and students. The suggested framework's quantum game-based model is used to develop cognitive decision-making. In this thesis, the main motivation is to study the integration of IT and QGT for academic assessment applications to provide smart academic environment support to teachers and students. In addition, the development of smart gadgets and intelligent technologies have given rise to the necessity of a smart environment for the accurate evaluation of the academic achievement of students [39].

In traditional education practices, identifying and addressing problems such as the dropout rate can be challenging due to the limitations of conventional assessment methods and the lack of data analysis. However, by leveraging the capabilities of IT and QGT, a new approach to decision-making in academia emerges. To illustrate the potential benefits, let's consider a hypothetical scenario: Imagine a traditional classroom setting where students' academic performance is evaluated based solely on periodic exams and subjective assessments by teachers. In this scenario, it may be difficult to detect early signs of disengagement or struggling students, leading to a high dropout rate that goes unnoticed until it becomes a significant issue. By integrating IT and QGT, a smart academic environment can be created. Smart gadgets equipped with wireless sensors, control devices, and actuators can collect data on various aspects of student performance, such as attendance, participation, and engagement. This data is then processed, analyzed, and stored using IT tools and techniques, including AI and ML, which enable more effective evaluation and decision-making. The QGT-based model introduced in the current study provides a framework for leveraging the collected data to make informed decisions about the academic accomplishments of students and the professional competence of their instructors. For example, the system can identify patterns of student disengagement or struggling performance and trigger automated interventions or personalized support strategies. Similarly, it can assess the effectiveness of different teaching methods and provide feedback to instructors for continuous improvement. The integration of QGT with IT is crucial in this context. QGT allows for the modeling of complex decision-making scenarios, considering multiple variables and potential outcomes simultaneously. By combining the IT and QGT, the suggested framework provides a more precise and comprehensive approach to academic assessment and decision-making. It addresses the limitations of traditional methods by leveraging data, advanced analytics, and automated decision-making to identify and tackle problems like the dropout rate proactively. The integration of smart gadgets and intelligent technologies further enhances the accuracy and effectiveness of evaluating academic achievements.

1.4 Research Gaps

Despite the numerous decision-making techniques employed in academic evaluation, there is a lack of research focusing on game-theoretic frameworks to intelligently assess the performance of student and teacher. Some key research gaps are formulated in the current research.

1. Literature Review and State of the Art: The first research gap would be to conduct a thorough literature review to analyze the existing state-of-the-art decision-making techniques for academic evaluation. This involves identifying and reviewing relevant papers, research articles, and academic evaluation models that have been proposed.

2. Game-Theoretic Framework: Developing an effective game-theoretic framework for intelligent evaluation in academics requires careful consideration of various factors, such as the stakeholders involved (e.g., students, teachers, administrators), the objectives of the evaluation, and the strategies employed. A research gap may exist in understanding how to design and implement such a framework that accounts for the complex interactions and dynamics in the academic evaluation process.

3. Integration of AI and Decision-Making: Integrating artificial intelligence (AI) into the proposed game-theoretic framework. A research gap might exist in determining the most appropriate AI techniques to use (e.g., machine learning, reinforcement learning) and how to effectively incorporate them into the decision-making process for academic evaluation.

4. Performance Metrics: Establishing appropriate performance metrics to evaluate the effectiveness of the proposed game-theoretic framework can be challenging. Determining the right metrics to capture the various aspects of academic evaluation accurately is crucial, and a research gap may exist in identifying and defining such metrics.
   Addressing these research gaps will be crucial for advancing the field of academic evaluation and creating an intelligent decision-making framework that can effectively contribute to improving educational outcomes.

1.5 Research Objectives

Based on the motivations suggested in Section 1.3, the study conducted in this thesis aim to develop a smart academic assessment framework for predicting the performance of students with effective integration of ICT and QGT for effective decision-making capabilities. Advances in ICT laid a solid foundation for promoting creative solutions in a variety of industries, including healthcare, logistics, transportation, and agriculture [1][40]. Moreover, services such as data perception, analysis, and real-time prediction can be obtained with high efficacy using AI techniques [41]. Based on these motivations, the research objectives of the study conducted in this thesis are as follows:

1. To analyze the existing state of art decision-making techniques for Academic Evaluation.

2. To propose an effective game-theoretic framework for intelligent evaluation in academics.

3. To evaluate the effectiveness of the proposed model in comparison to other state-of-the-art decision-making techniques.

1.6 Research Contribution

The inefficiency of traditional methods of education combined with an antiquated method of evaluating students' performance has led to an unsatisfactory assessment of student's academic abilities. The idea of a smart academic industry is created as a result of the enormous potential offered by IoT technology, fog-cloud computing, and predictive analytic techniques like AI and ML [42]. As a result, the current research offers an effective framework for an intelligent learning environment. Figure 1.9 explains the conceptual foundation that underpins the approach that is provided for estimating student and teacher performance. It depicts that sensored data is acquired from an online repository. The acquired data is processed on a fog computing device for information analysis. Then the information from the fog node is connected to cloud storage for detailed analysis of student and teacher performance by monitoring officials. The evaluation of student and teacher performance enhances the learning and decision-making capacities of both students and instructors. Game theory is used for decision-making. The present research specifically focuses on the following aspects:

1. Acquisition of IoT-based classroom and ambient environment data in real-time to improve the education quality and performance-based decision making.

2. Using the probabilistic Bayesian Belief Network (BBN) technique to evaluate student performance in terms of Probability of Performance (PoP).

3. Utilizing Data Mining (DM) techniques to conduct a temporal analysis on IoT data segments to effectively quantify the Student Performance Index (SPI) and Teacher Performance Index (TPI).

4. To evaluate the SPI and TPI indicators for the smart academic framework, a 2-player QGT framework for effective decision modeling is developed.

5. Validating the proposed framework by defining performance indicators and comparing them to cutting-edge decision-making approaches.

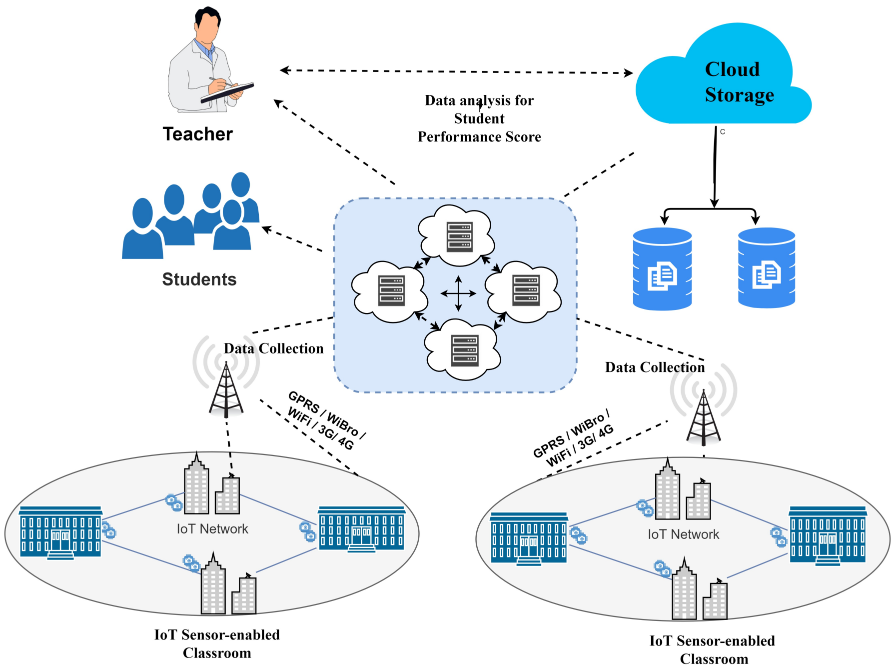


Figure 1.9: Smart Academic Environment: Conceptual Framework

1.7 Proposed Research Methodology

Research methodology is a way to solve the research problem systematically. It is a procedure used by researchers to describe their work, data extraction, and explanation of the phenomenon. The methodology followed in the current research is schematically depicted in Figure 1.10.

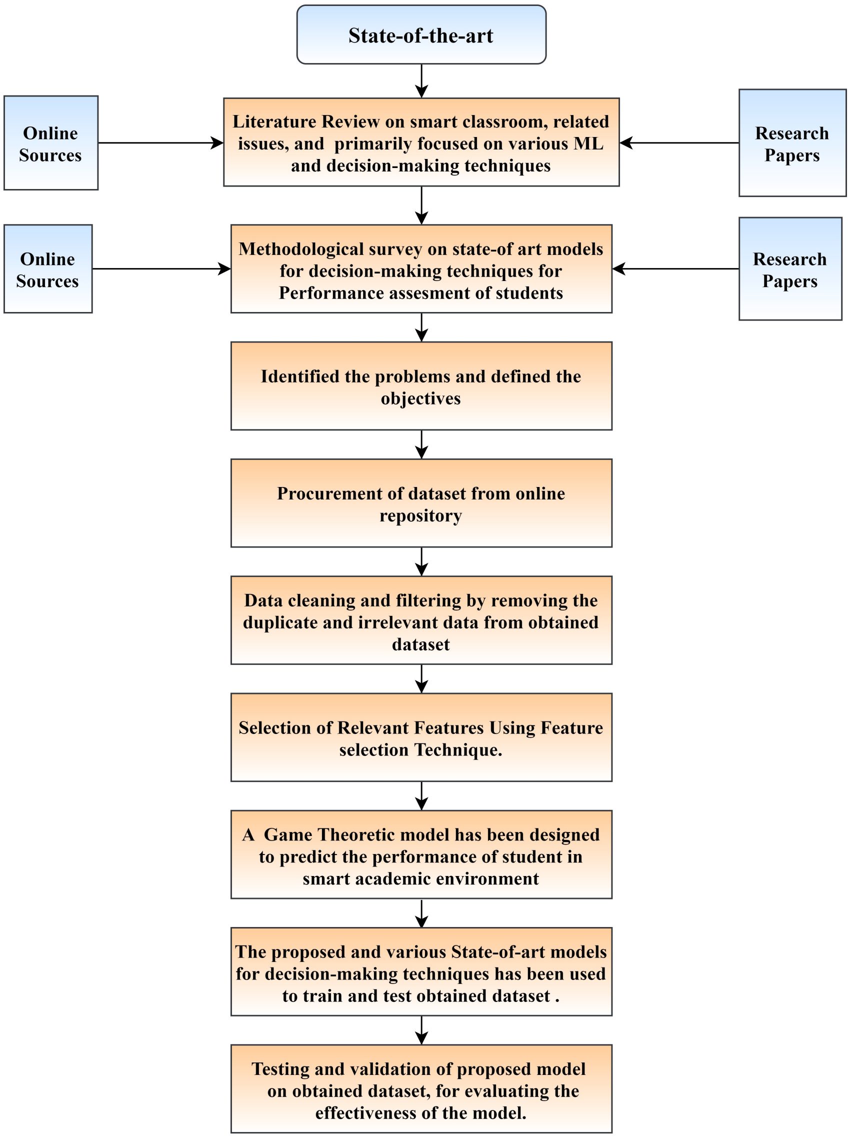


Figure 1.10: Schematic Diagram of Research Methodology

1. To accomplish the first objective, we examined a variety of well-known state-of-the-art decision-making approaches that are used to evaluate the performance of the student.

2. To meet the second objective, the dataset on student performance parameters is acquired from the UCI repository. The dataset is categorized into different classes using the efficient classification technique. In addition, data analysis is done and the data is cleaned. Moreover, Temporal analysis is carried

out on data-segments utilizing mining techniques for effective quantification of Performance Index measures. Furthermore, a novel game-theoretic framework for smart academic evaluation is presented. The presented framework comprises of 4 layers. The suggested framework determines the probability of performance of student and teacher. To illustrate the efficacy of suggested model, it is assessed in comparison to other cutting-edge baseline decision-making approaches.

3. Finally, to achieve the third objective, several parameters such as Precision, Sensitivity, Specificity, Error Rates, Reliability, and Stability are investigated to determine the effectiveness of the proposed technique. To further illustrate the effectiveness of the suggested framework, a mathematical analysis is done.

1.8 Thesis Organization

The thesis is organized into 6 chapters, as shown in Figure 1.11.

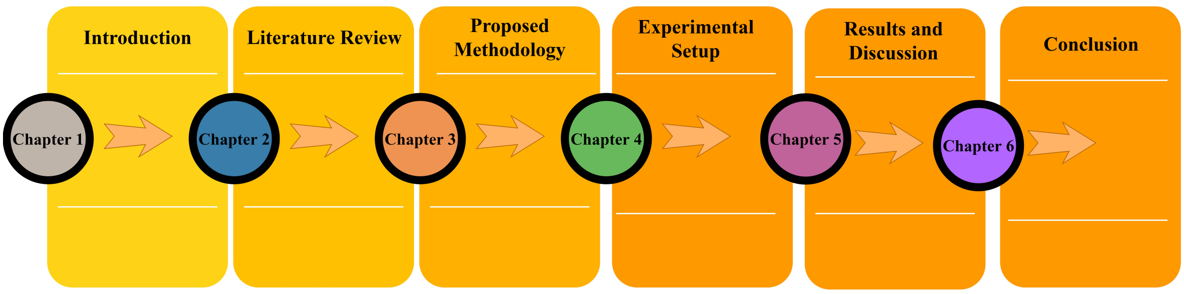


Figure 1.11: Chapter-Wise Thesis Organization

Chapter 2 deals with the state-of-the-art literature review on a smart classroom, various aspects of smart education, and various decision-making models for predictive analysis. Specifically, various sections are made to indicate numerous works performed by researchers around the world in the current domain of study.

Chapter 3 discusses the proposed methodology and layered framework of the model. The framework has been divided into different layers, and these are detailed in this chapter.

Chapter 4 comprises the experimental setup for the research work. It consists of the data collection methodology, the exploratory data analysis technique, data pre-processing technique in detail.

Chapter 5 describes the results and discussion. The various baseline ML algorithms are applied and compared in this chapter. The results of the proposed methodology are registered in the chapter.

Chapter 6 concludes the thesis by highlighting the prime outcomes of the current research of the author and the significant contribution of the thesis. The scope for future research in this area is also notified.

Chapter 2

Literature Review

2.1 Background

This chapter provides a comprehensive overview of the smart learning environment in terms of publication patterns, citation trends, co-occurrence evaluation of keywords, and technological advancements. According to an analysis of publication patterns, smart learning research is becoming a more popular and promising topic. An examination of published sources indicates that interdisciplinary research focuses on the confluence of education and technology, with smart learning research being a specific example. In addition to this, various state-of-the-art decision-making models are also detailed in the further subsections.

2.2 Introduction

The research and development process is usually guided by words and phrases. New concepts are presented to outline advancements, frequently accompanied by definitions. The term Smart Education is used to reflect technological advancements in education. In addition, advancements in ICT have expedited global efforts towards the concept of intelligent education. In recent years, a substantial number of research contributions are made in the field of smart education as a result of a global increase in interest and popularity. Consequently, the significance of contemporary study entails a quantitative evaluation of whole examination of the academic structure and progress. In addition, work on smart education is extensively recommended to improve academic settings that include and empower students, instructors, and administrators more effectively. Despite the development of intelligent technology to improve education systems, approaches continue to face obstacles due to insufficient theoretical and technological implications. Moreover, with continuous research being done by researchers around the world, new opportunities are being identified regularly for global development. This chapter provides 2 types of review (i) a Scientometric Review of smart academics literature and (ii) a Systematic Review. Moreover, a subsection is made to review some of the state-of-the-art models for decision-making.

Statistically, a large number of research papers, articles, patents, and books are referred from past decades in carrying out the current research. Figure 2.1 depicts the main areas of study in the field of a smart academic environment. To acquire the research articles various libraries were assessed. These included Scopus, ACM, Web of Science (WoS), Digital Library, Google Scholar, Wiley Online Library, ScienceDirect, and IEEE Xplore Digital Library. All these libraries provided a plethora of innovative research articles which are significantly useful in carrying out the current research. In addition to these, some of the articles are manually acquired of the respective authors. The following sub-sections describe the detailed contributions of researchers and innovators around the world.

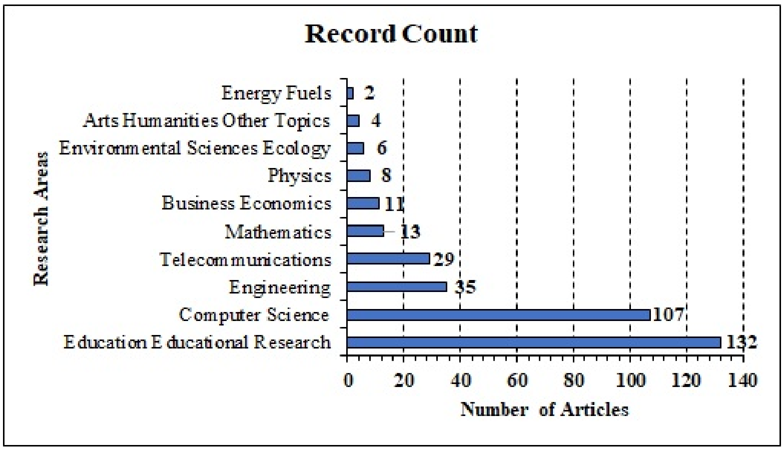


Figure 2.1: Main Areas of Study in Smart Academics

2.3 Scientometric Review

The quantitative evaluation of scientific and technical literature is called *scientometric* [43]. Mulchenko and Nalimov [44] originally developed the term '*scientometric*' in 1969. It statistically assesses the progress of science and technology and serves as the essential foundation for addressing and selecting future research objectives. It encourages the development and expansion of the research domain. In addition, it provides analytical measures for evaluating the quantitative scientific performance of a research topic and corresponding subfields. It includes observing publishing patterns, citation trends, keyword co-occurrence analysis, technical advancements, and different quantitative studies from 2010-2021. The scientometric analysis is essentially a method for measuring the advancement of technology through scientific review. It is conducted in various fields, such as geographic information technology [45], cloud computing [46], logistics [47], regenerative medicine [48], disaster management [49], and advisory systems [50]. Aside from a substantial number of publications, no bibliometric study has been undertaken on the topic of smart education that may throw light on the current domain and quantitatively represent its evolution, status quo, and research findings. Figure 2.2 represents the entire academic categorization. It allows for a thorough examination of every area of smart education.

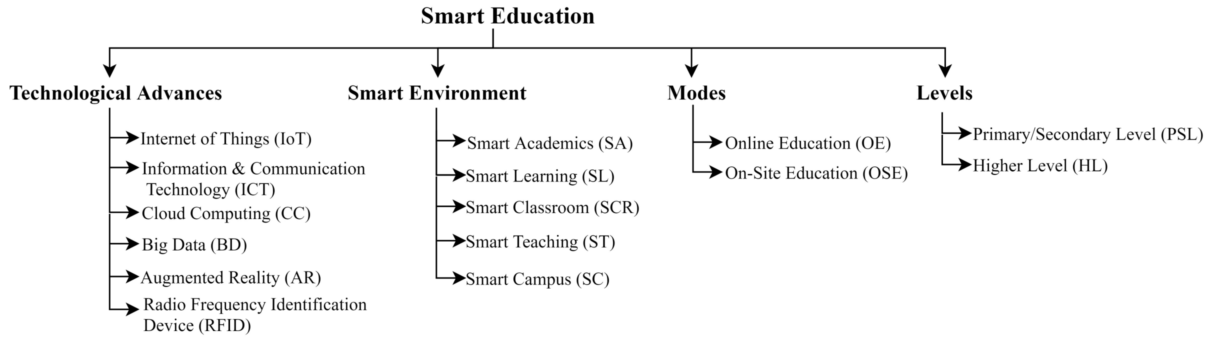


Figure 2.2: Broad Themes in Smart Academics

This study explores the smart education-related research articles indexed in the Web of Science (WoS) database. WoS presents exhaustive and standardized search approaches, web-based diagnostic resources, and a comprehensive review of relevant journals in a wide range of fields, like biological sciences and biomedicine, arts and humanities, engineering, social sciences, and computer science. It includes a broader range of publications and has a faster indexing technique, making it simpler to locate more recent research papers. A further advantage of utilizing WoS is its superior interdisciplinarity in comparison to other well-known databases. The presented study acquires the data from WoS database for period between 2010 and 2021. In addition, the articles are evaluated to determine the expansion of the smart education research topic worldwide. In the current study, the innovative characteristics offered by the researcher are studied to show futuristic theme fields for future research. The present 2-dimensional scientometric review proposed 3 critical elements based on these parameters.

1. *Publication Trends:* It depicts the topic domains within the current area of research in terms of the number of global publications. This thesis describes key characteristics of a smart academic setting based on current trends identified in related literature.

2. *Citation Trends:* It signifies the expansion of the specific study domain in the present topic. The current study demonstrates the quality of smart education research conducted by scholars worldwide. In addition, it allows researchers to identify the most important research fields and outstanding challenges that may be tackled efficiently.

3. *Keyword Co-occurrence Analysis:* This portion of the current study illustrates the co-occurrence analysis of particular keywords and associated technological trends. The co-occurrence analysis reveals worldwide research publications on a particular subject of smart education.

2.4 Search Methodology

According to a wide range of papers, manual examination of bibliographic data is both time-consuming and costly [51]. Due to its ability to handle and analyze systematic published work using in-house analytical tools, the WoS database has been regarded as being superior to other bibliographic databases. It offers various insights as well as yearly, author-wise, source title-wise, affiliation-wise, country/region-wise, document-type-wise, and domain-wise distribution of published articles. However, a basic disadvantage of utilizing the WoS database is that the exported bibliographic information takes a large amount of time for processing and refining before the relevant data can be processed, especially if thousands of articles are to be reviewed. Consequently, Microsoft Excel is used in this instance [52]. Exploring various commonalities and hidden tendencies within the provided bibliographic data can aid the scientometric study in ensuring a more accurate interpretation of the systematic structure of the offered research. Several data visualisation tools, such as VOSviewer (Visualization of Scientific Landscapes) [53][54], CiteSpace [55], Gephi [56], and CiteNetExplorer [57] are readily available. In the current survey, VOSviewer is used for co-occurrence analysis and keyword

visualization to analyze technical advancements. VOSviewer is a free and open source Java-based tool that can explore and test many platforms.
The database is searched using the following query: TI=("Smart Teaching" OR "Smart Education" OR "education" OR "Smart Pedagogy" OR "E-Learning" OR "Smart Classroom" OR "Smart Learning") in the WoS Advance Search Field. The study period for scientometrics is limited to 2010-2021. There were a total of 2,82,704 documents found throughout the search (as of July 2021). To investigate the quantitative bidimensional analysis in the Smart Education study, the obtained data is classified according to the subthemes and research topics depicted in Figure 2.2 and Table 2.1. Based on the thorough analysis, specific subthemes that cover modern technological breakthroughs have been developed [58][59].

Table 2.1: Research Areas in Smart Education

S.No.	**Research Areas**
1.	Education Educational Research (EER)
2.	Computer Science (CS)
3.	Engineering (Engg.)
4.	Telecommunications (TC)

2.5 Search Findings

In order to explore the bidimensional quantitative analysis in the Smart Education domain, the entire data is subdivided into sub-themes and research areas. Table 2.2 illustrates a bidimensional depiction of the publication numbers that are acquired and filtered during the search carried out in WoS. There are entries for papers, patents, meetings, abstracts, reviews, and books in the obtained data. Therefore, these items are filtered to reduce the amount of data. Following filtering, a total of 1,86,897 documents are collected.

Table 2.2: Bidimensional Analysis of Document Count in Broad Themes and Research Areas of Smart Education Domain

Sub-Themes	**Retrieved Documents**					**Filtered Documents**				
	EER	**CS**	**Engg.**	**TC**	**Total**	**EER**	**CS**	**Engg.**	**TC**	**Total**
IoT	233	264	194	125	470	71	49	26	13	140
ICT	2378	965	362	104	3278	1127	389	112	26	1627
CC	498	585	326	152	820	164	162	59	13	225
BD	595	348	200	84	1126	284	71	36	17	575
AR	485	428	246	126	777	247	143	56	24	358
RFID	14	80	75	69	97	8	9	4	5	15
SA	122	69	47	12	203	60	26	13	04	117
SL	1133	1042	807	384	2067	458	230	104	58	578
SCR	191	182	126	92	361	80	44	16	10	134
ST	365	300	240	174	743	183	74	33	21	337
SC	26	31	30	18	62	5	5	6	2	19
OE	824	648	430	283	1504	463	204	35	12	698
OSE	249	61	54	13	398	193	33	17	0	306
PSL	113	21	15	3	211	79	9	4	0	152
HL	17539	3407	1906	246	27533	11101	1374	771	60	18089

2.5.1 Publication Trends

Table 2.2 depicts the number of publications among the various subthemes and research topics for a more accurate depiction of progress in the Smart Education domain. As stated previously, a total of 2,82,704 records are extracted, and 1,86,897 records from 2010 to 2021 are screened. Table 2.2 shows that higher education has the most articles (18,089), followed by ICT in technological trends (1627) and SL (578), while RFID in technical trends (15) has the fewest publications, followed by smart campus (19). When the publishing trend is investigated, it is discovered that the EER publications have the largest proportion of publishing (55.67%) and the TC publications have the lowest percentage (4.92%). Despite a paucity of publications, the subthemes and research fields reflect the broad scope of study in those areas.

The overall evaluation of subtheme-wise publishing growth shows that higher education level publications have risen with the highest possible average growth (71.04%), while OSE mode publications have expanded with the lowest possible average growth (9.56%). None of the subthemes registered a cumulative decline, demonstrating that the use of ICTs in education across a variety of disciplines is on the rise. According to a review of publication trends, more studies are being undertaken in the education field in connection to higher education levels, ICT technical trends, and smart learning settings, but less research is being done in smart educational environments such as smart campuses, smart academics, smart classrooms, and OSE mode. The pattern reflects the study's emphasis on these fields where the least amount of effort is invested. As the notion of intelligent environments pervades every subject, it will be critical to follow the number of publications in each of these subthemes over the next ten years.

Table 2.3 depicts the growth analysis of publications from the perspective of various scientific disciplines. It may be observed that EER discipline has experienced expansion. In contrast, CS and Engineering have varying growth throughout time. Similarly, the growth of the TC industry fluctuates till 2017 and then increases thereafter. Despite having the fewest TC and Engineering publications, the discipline has recorded the highest average increase (20.57%) and overall growth (207.78%), indicating the increasing significance of Engineering and TC in smart education research.

Table 2.3: Growth Rate of Publications in Smart Education Research Areas

Research Area	**2010-2011** (%)	**2012-2013** (%)	**2014-2015** (%)	**2016-2017** (%)	**2018-2019** (%)	**2020-2021** (%)
EER	56.96	56.93	56.74	57.29	57.36	58.04
CS	6.33	6.23	5.52	5.89	5.93	4.19
Engg.	3.50	3.58	2.92	2.79	2.86	2.62
TC	0.66	0.62	0.58	0.47	0.67	0.76

2.5.2 Citation Trends

The quality of research is determined by the number of literature citations [60]. As indicated in Table 2.4, the distribution of published citations is examined from the perspective of the educational subthemes in the current review. According to the survey, every subcategory has 10–25% of papers with one citation, except for AR (7.63%), RFID (7.52%), SA (9%), and OSE (1.92%). It has been noticed that the proportion of articles with one citation and four to ten citations is significant in each subcategory. The subtheme SA has the largest proportion of papers with 41–100 citations (38.60%). The current investigation indicates that the subcategory of AR has the most publications with more than 100 citations.

Effective communication is made possible by selecting the right medium. Similar to this, the effect and reach of researcher's scientific writing depend on the publication they choose. To classify the most influential journals in a particular field, a scientometric analysis must examine the citation trend of the journals. Table 2.5 displays the most cited journals in each subtheme, including the total number of citations (TCC), the total number of publications (C), the ratio of citations to publications (CP), and the proportion of publications (C %), along with their respective IF. The analysis demonstrates that **Computers and Education** and **Computer Applications in Engineering Education** Journals have a significant impact on numerous subthemes. **Computers and Education** journal has the highest number of citations in the subthemes ICT (1210) and AR (1399). Computer Applications in Engineering Education journal

Table 2.4: Citation Distribution of Publications of Different Sub-Themes

Sub-Theme	1	2	3	4-10	11-20	21-40	41-100	>100
IoT	22.63	8.39	9.47	30.52	31.05	0	0	0
ICT	18.51	8.32	4.94	22.85	10.41	15.55	13.56	5.82
CC	20.05	9.21	7.85	29.17	11.20	8.85	13.64	0
BD	24.70	6.41	7.27	17.90	10.16	12.11	11.18	10.24
AR	7.63	3.39	2.30	12.33	10.23	9.14	12.38	42.56
RFID	7.5	0	3.75	15	0	0	73.75	0
SA	9	4.63	2.45	11.18	13.77	20.32	38.60	0
SL	13.95	6.21	4.52	19.52	17.35	15.72	15.93	6.76
SCR	17.53	7.95	4.62	22.24	13.63	14.85	19.15	0
ST	21.84	10	5.52	30.78	12.23	19.60	0	0
SC	23.93	13.24	6.29	23.01	13.11	17.70	2.68	0
OE	23.93	10.39	6.46	23.93	10.81	19.06	5.38	0
OSE	1.92	3.84	5.76	50	38.46	0	0	0
PSL	23.33	16.06	25	35	0	0	0	0
HL	17.87	8.44	5.74	23.57	16.35	11.83	16.15	0

has the highest citation count within the subtheme of CC (25). **Computers and Education** has the greatest impact in the AR subtheme with the highest average citations per publication (139.9) compared to all other journals in each subtheme. The **HIGHER EDUCATION** journal has the most citations (5785), as well as the most publications (349), in the HL subtheme and overall. This study demonstrates that the HL subtheme is the most prevalent, and that the **HIGHER EDUCATION** publication is likely the most sought-after by academics in any subtheme within the Smart Education sector.

Table 2.5: Sub-Theme-Specific Highly Influential Journals (NA Not Available)

Theme	Sub-Theme	Name of the Journal	TCC	C	CP	C(%)	IF
Technical Trends	IoT	International Journal of Emerging Technologies in Learning	10	4	2.5	2.85	1
		Computer Applications in Engineering Education	8	3	2.66	2.14	0.856
		International Journal of Online and Biomedical Engineering	5	3	1.66	2.14	0.156
	ICT	Information Technologies and Learning Tools	22	31	0.70	1.84	0.150
		Computers and Education	1210	29	41.72	1.72	5.296
		British Journal of Educational Technology	223	20	11.15	1.18	2.951
	CC	International Journal of Emerging Technologies in Learning	37	13	2.85	5.37	1
		Computer Applications in Engineering Education	25	8	3.13	3.30	0.856
		Education and Information Technologies	33	6	5.5	2.47	2.010
	BD	Journal of Learner-Centered Curriculum and Instruction	1	11	0.09	1.72	1.50
		Educational Sciences Theory Practice	0	7	0	1.09	0.532

		International Journal of Advanced Computer Science and Applications	13	7	1.86	1.09	1.324
	AR	Computers and Education Advances in Experimental Medicine and Biology Computer Applications in Engineering Education	1399 7 10	10 7 6	139.9 1 1.66	2.79 1.95 1.67	5.296 2.45 0.856
	RFID	Computer Applications in Engineering Education Concurrency and Computation Practice and Experience Eurasia Journal of Mathematics Science and Technology Education	5 18 1	1 1 1	5 18 1	7.14 7.14 7.14	0.856 1.447 0.903
Smart Environment	SA	Journal of Korean Association for Educational Information and Media	1	5	0.2	4.27	NA
		Asia Pacific Journal of Multimedia Services	0	3	0	2.56	NA
		Journal of Korean Association of Information Education	0	3	0	2.56	NA
	SL	Journal of Digital Convergence Journal of Korean Association of Information Education	13 1	20 18	0.65 0.06	2.55 2.30	0.74 0.01

		Journal of Korean Association for Educational Information and Media	2	13	0.15	1.66	NA
	SCR	British Journal of Educational Technology	64	4	16	2.98	2.951
		IEEE Access	32	4	8	2.98	3.745
		Computers and Education	48	3	16	2.23	5.296
	ST	Journal of Korean Practical Arts Education	0	8	0	2.37	0.07
		Journal of Digital Convergence	3	7	0.43	2.07	0.74
		Journal of Learner Centered Curriculum and Instruction	0	6	0	1.78	1.50
	SC	Journal of Korean Institute of Information Technology	0	2	0	10.52	0.11
		The Korean Journal of Japanese Education	0	2	0	10.52	NA
		Applied Sciences	4	1	4	5.26	2.474
Mode	OE	International Review of Research in Open and Distributed Learning	266	18	14.78	2.57	2.297
		American Journal of Distance Education	29	8	3.63	1.14	0.90
		Computers and Education	198	7	28.29	1.003	5.296
	OSE	Journal of Social Work Education	11	2	5.5	2.63	0.845
		Australian Journal of Educational Technology	3	1	3	1.81	1.956
		BMC Emergency Medicine	7	1	7	1.81	1.48

Level	PSL	Australian Journal of Educational Technology	5	2	2.50	1.31	1.956
		BMC Public Health	46	2	23	1.31	2.521
		Cultural Historical Psychology	0	2	0	1.31	0.29
	HL	Higher Education	5785	349	16.58	1.83	2.856
		Studies in Higher Education	5146	328	15.69	1.72	3.000
		Higher Education Research Development	2253	168	13.41	0.88	2.129

2.5.3 Keyword Co-Occurrence Analysis

Keywords effectively and abstractly depict the details covered in academic study. From the perspective of meta-data, keywords highlight the significance of including the essential concepts and elements. The presence of keywords in a scientific publication often serves to identify the pertinent study subjects within a certain area. The current study extracts author and index terms from articles. The essential terms in an article are not always described by the author; as a result, the missing key phrases are chosen as index keywords by fully skilled indexers using numerous thesauri.

Keyword analysis enables the researchers to find the critical concerns and study facets of intelligent education. The examination of keyword co-occurrences can uncover links and interrelationships between certain viewpoints. Thus, using VOSviewer, co-occurrence patterns of several educational subthemes are created. In VOSviewer, author keywords are chosen instead of all keywords, and fractional counting is used instead of complete counting. The Keyword Co-occurrence Network (KCoN) in VOSviewer only accepts keywords that match the minimum number of occurrences (M_k) criteria. The function D_k indicates keyword count. The value of

M_k is set to obtain an understandable co-occurrence network of a certain keyword (C_k). A node of a given size represents the keyword in the network. The greater the node area and the frequency of a keyword, the greater the significance of that keyword or technology. The distance between nodes represents the co-occurrence number of these terms. The frequency of co-occurrences between two keywords increases, the distance between them decreases, and a deeper interrelationship between particular phrases or technologies is uncovered. The common descriptors of the keywords are ignored.

1. The KCoN in the subtheme of the **Smart Environment** is described in Figure 2.3. The complete visualization network is divided into **6** clusters-:**C1:** DM, education data mining, Engg., learning analytics, Nigerian university, SC, sustainable education, and undergraduates; **C2:** classification, IoT, machine learning, smart education, SLE, and smart learning object; **C3:** CC, deep learning, mobile learning, SL, and technology acceptance; **C4:** education, interdisciplinary, IoT, learning motivation, and smart classroom; **C5:** smart learning ecosystem and smartness detection; and **C6:** adaptive learning and higher education.

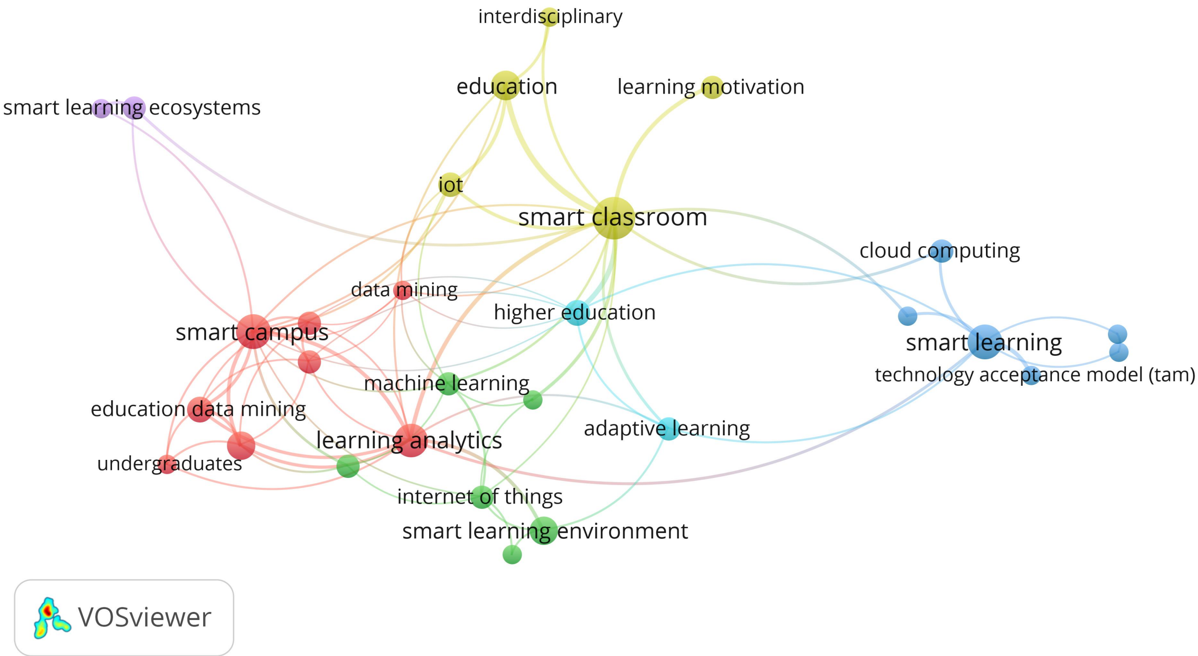


Figure 2.3: KCoN of Smart Environment related Keywords (M_k=3, D_k=313, and C_k=38)

2. The KCoN in the subtheme of **Education Modes** is described in Figure 2.4. The complete visualisation network is divided into **17** clusters-: **C1:** adult learning, collaborative learning, computer-mediated communication, graduate education, learning communities, professional education, and student satisfaction; **C2:** active learning, flipped classroom, online education, satisfaction, self regulated learning, statistics education, and student learning; **C3:** communication, digital education, higher education, open education, social media, and teacher training; **C4:** dental education, e-learning, inter-professional education, medical education, and undergraduate medical; **C5:** distance learning, professional development, faculty, quality of education, and social work education; **C6:** blended learning, continuing education, LMS, pedagogy, and science education; **C7:** distance education, online learning, student success, teacher education, and teaching methods; **C8:** AR, education technology,

Engineering education, and learning analytics; **C9:** assessment, course design, and student engagement; **C10:** curriculum development, evaluation, and MOOC; **C11:** e-assessment, gamification, and motivation; **C12:** nursing and online teaching; **C13:** academic integrity and virtual classroom; **C14:** virtual schools; **C15:** readability; **C16:** qualitative research; and **C17:** academic achievement.

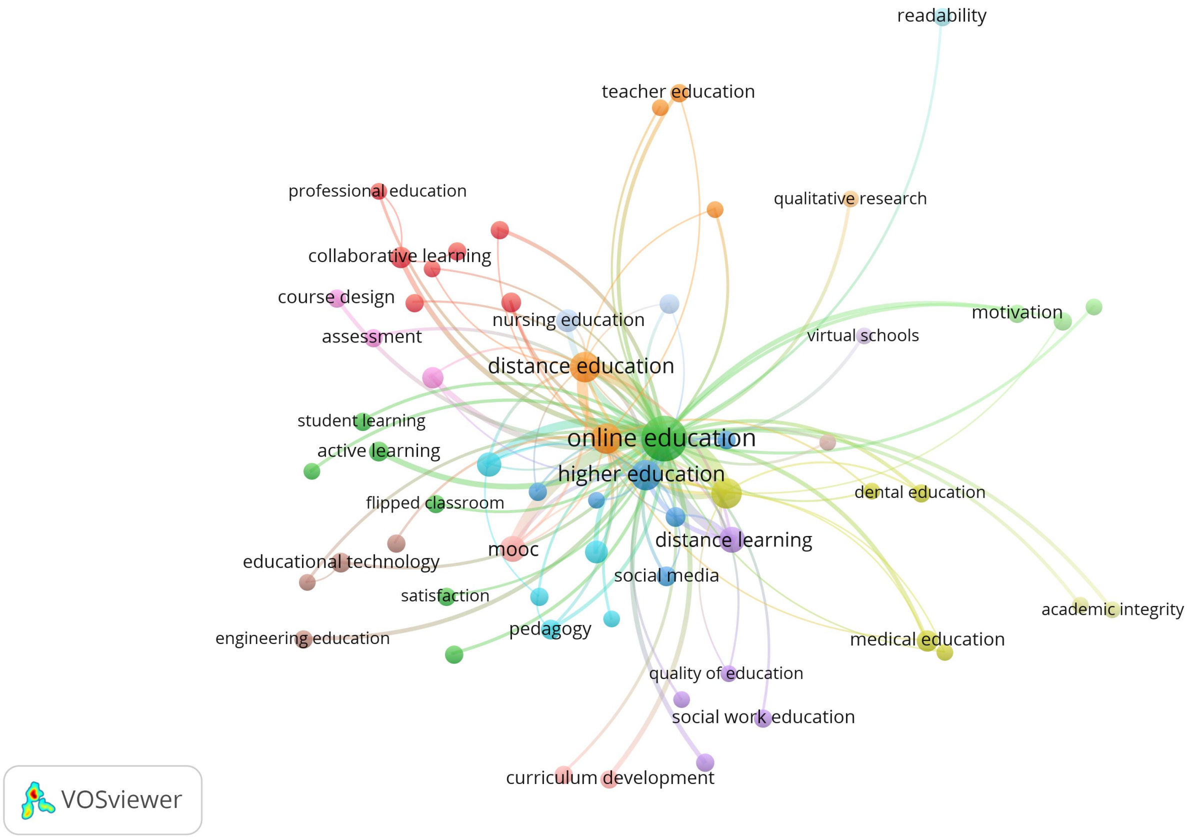


Figure 2.4: KCoN of Education Mode related Keywords (M_k=4, D_k=2263, and C_k=103)

3. The KCoN in the subtheme of **Education Levels** is described in Figure 2.5. The complete visualization network is divided into **9** clusters-: **C1:** education for sustainable development, environmental education, inclusive education, knowledge, school, teacher education, and teacher training; **C2:** education

level, educational attainment, mortality, parental education, socioeconomic factors, and socioeconomic status; **C3:** e-learning, education policy, higher education, inequality, and teaching; **C4:** educational inequality, maternal education, social inequality, and socio-economic status; **C5:** education, occupation, social class, and socioeconomic position; **C6:** primary education, secondary education, and tertiary education; **C7:** poverty; **C8:** cognitive reserve; and **C9:** lifelong learning.

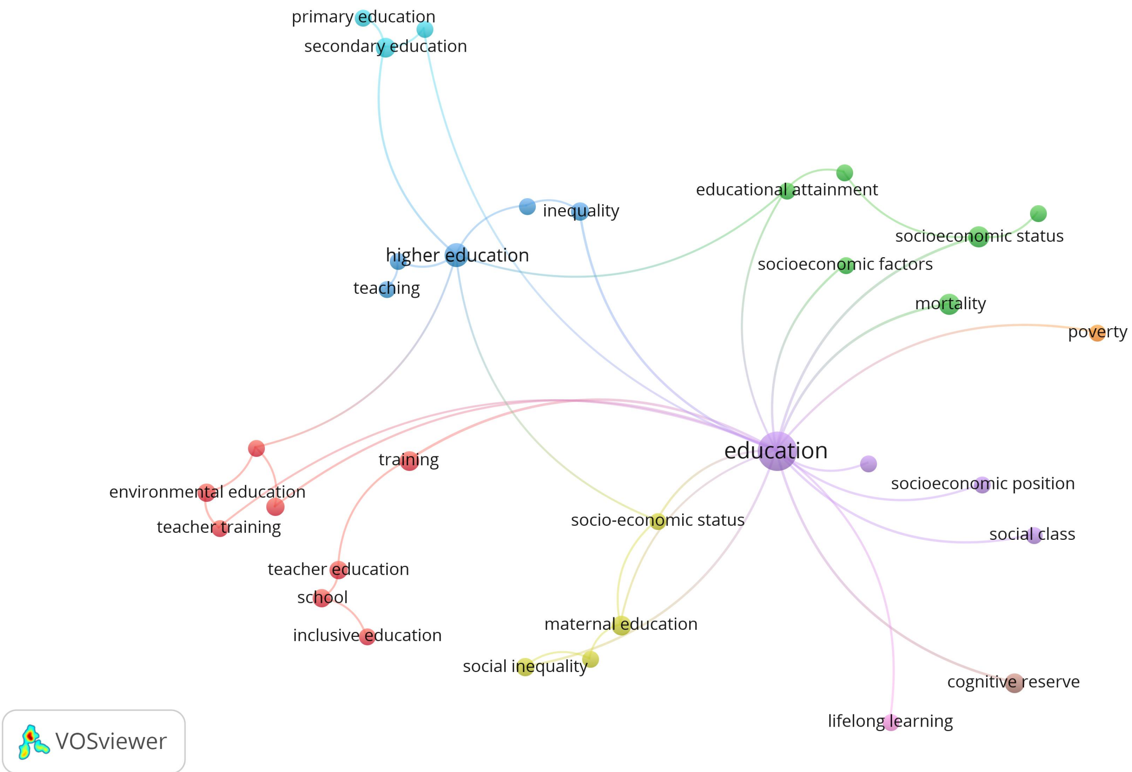


Figure 2.5: KCoN of Education Level related Keywords (M_k=4, D_k=2050, and C_k=78)

2.6 Systematic Review

Systematic literature reviews are employed to synthesize the literature, minimize bias, and identify research gaps [61]. There are several strategies to undertake systematic reviews [62][63]. It includes an organised review that focuses on commonly used methods, concepts and structures [64], Theme-based reviews [65][66], Framework-based reviews [67][68], and a Meta-Analysis review [69][70], Bibliometric reviews [71][72], and Structured reviews [73]. Similar to Goyal and Kumar [74] and Caputo et al. [75], the current chapter combines bibliometrics with a systematic review. Bibliometrics is the most prevalent technique for tracing the knowledge structure of a study topic and analyzing key studies [76][77].

The objective of the current systematic review is to provide quantitative and qualitative knowledge about the emergent concept of the smart classroom using a methodological approach. Numerous review papers centered on studies in specific fields, resulting in a vast array of recommendations. Ryens and Brown [78] analyzed 6-year studies of primary research to assure developments in the area. However, because domain research is diverse, establishing connections across complementary research endeavors and developing a holistic understanding of smart classroom research, in general, is challenging.

Table 2.6 lists some of the most important research papers and related fields of study. None of them attempt to capture the essence of the smart classroom concept. In addition, there are no studies that investigate the intellectual setups of smart classrooms. The aforementioned limits forced this study to use quantitative and qualitative methodologies to synthesize the current material and establish a road map for future work.

Table 2.6: Reviews in Smart Classroom: An Overview (2011-2021)

Authors	**Scope of the Review**	**Type of Study**
Gikandi et al. (2011) [79]	Higher Education Online Formative Assessment	Systematic Review
Iulian Radu (2014) [80]	Positive and Negative of Augmented Reality	Review+Meta Analysis
Chen et al. (2017) [81]	Role of AR in Education	Review
Lbanez and Kloos (2018) [82]	AR for STEM Learning	Systematic Review
Bdiwi et al. (2019) [83]	Impact of Teacher Role	Review
Saini and Goel (2020) [84]	How smart are high-tech classrooms?	Review
Zhang and Long (2021) [85]	Cognitive Pedagogy for Technology-Enhanced Education	Review
Nagowah et al. (2021) [86]	Semantic Models	Review
Hsu et al. (2021) [87]	Smart Learning Environment	Review
Gambo and Shakir (2021) [88]	Self Regulated Learning	Review
Kaur and Bhatia (2021) [89]	Smart Learning	Scientometric Review
Li and Wong (2021) [90]	Research Methodology Trends and Patterns	Review
Chen et al. (2021) [91]	Topic based Analysis	Review
Tabuneca et al. (2021) [92]	Abilities and vital aspects of a SLE	Review
Alfoudari et al. (2021) [93]	Socio Technological Challenges of Smart Classroom	Systematic Review
Pan et al. (2021) [94]	Difficulities in implementing Game-based learning	Review

2.7 Search Methodology

The current review acquired scientometric data from the WoS database on ICT based education research papers (2021). WoS has a database of conceptual and abstract research publications. The search method retrieves documents using boolean syntax by combining keywords with various boolean operators [95]. WoS delivers exhaustive and standardized search strategies, web-based diagnostic tools, and comprehensive analysis of relevant journals in several fields, including biological sciences and biomedicine, management, arts and humanities, engineering, social sciences, and computer science. It covers a wider variety of journals and employs a faster indexing technique, making it simpler to discover more recent research publications [96][97]. Another advantage of utilizing WoS is that it gives greater interdisciplinarity than the other well-known databases. The database search is conducted using the query TI=("Smart Academics" OR "Smart Pedagogy" OR "Smart Education" OR "Smart Classroom" OR "Smart Learning" OR "Smart Teaching") in WoS's Advanced Search Field. Title Search is represented by the symbol TI in the search field. It fetches a record of various document types in response to a query word in double quotation marks. The boolean operator 'OR' is used to combine several sets. It extracts both double-quoted records and records shared by all double-quoted phrases. In all, 1,176 papers were uncovered throughout the search. Entries for meetings, abstracts, reviews, books, and a variety of other types of papers are among the data that is retrieved. Out of 1,176 total results, 1,161 are papers, patents, conferences, or reviews. All of these entries are filtered to standardize the data. In all, 572 items are obtained after filtering. The search was then limited to articles written in English, giving 187 results. The relevance of the publications is determined by reading the abstracts, and full-length articles are retrieved if there is any doubt as to their applicability. To ensure the inclusion of relevant studies, those articles are chosen for final analyses that either focuses on publications linked to the smart classroom or smart education methods for enhancing the knowledge or dealt with a concept referred to as *smart classroom*. In addition, several publications are obtained directly from the respective authors.

2.8 Findings

The current study examines key elements in a modern learning environment based on publication patterns. Figure 2.6 displays the growth of publications on smart classrooms available in WoS data from 1995 to 2021. There is a rise in the number of publications, with only one article published in 1995 rising to 56 articles by 2021. Since 2014, research on the smart classroom has increased dramatically. The primary cause for the growth is the increased use of technology enhancements in education since 2010. Since then, there is a notable increase in the number of publications on the subject.

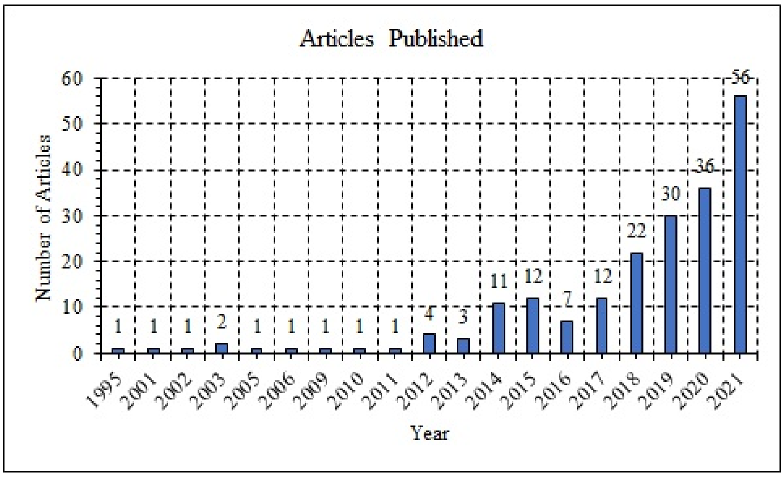


Figure 2.6: Count of Papers published between 1995-2021

2.8.1 Smart Education Framework

Developing a framework to enable Smart Education includes 4 primary goals: **Identification**, **Data Handling**, **Information presentation**, and **Establishing Virtual Environments**.

Regarding systems designed for **Identification**, Nsunza et al. [98] designed a cloud-based e-learning architecture for intrusion detection with CNN. Authors demonstrated that the method was 82.83% accurate in detecting intrusions. Liu et al. [99] developed a model for the smart classroom that employed a smartphone, microphone, and wearable devices to identify the behavioral reactions of students. Elhoseny et al. [100] created a system that evaluates and forecasts students' behaviors utilizing sensing devices and cellphones to determine the upcoming activity. The framework aims to ease the administration and execution of teaching in smart education settings. Soltanpoor et al. [101] devised a method for recognizing student personality factors to evaluate real-time performance. Savov et al. [102] developed a system for detecting student moods using microphones and cameras. Agbo et al. [103] did a bibliometric examination of an SLE. The study examined research topics, thematic emphasis, and prospects within the subject of smart education.

Arora et al. [104] addressed research pertaining to **Data Processing**. The primary objective was to reduce the number of time teachers spend enrolling individuals. To do this, the authors employed a multi-touch sensor device to record the fingerprints of students as they entered the classroom. Dutta et al. [105] offered a smart approach for analyzing and enhancing the classroom environment. Simulations demonstrated that noise pollution was greatly decreased. In addition, the authors in [106] and [107] developed intelligent data management frameworks for the smart education environment.

In relation to **Information Presentation**, the authors in [108][109] created intelligent frameworks for real-time student performance evaluation and reading assessment.

Similarly, Verma et al. [110] presented a system for assessing student performance utilizing interaction technique for **Virtual environment**. The authors have assessed student performance using data mining. Fahim et al.[111] developed a method to improve the student learning practices. Capuano and Toti [112]

suggested a smart learning system based on Knowledge Discovery and Cognitive Computation techniques that enables the common people, law students, and legal experts to submit legal challenges in simple English and obtain legal insight and assistance. Bhatia and Kaur [113] developed a paradigm inspired by quantum computing for assessing student and teacher performance in smart classrooms. The proposed methodology employs game-theoretic decision modeling to evaluate the performance of both students and teachers.
Recent research has examined a variety of smart classroom-related features. To get a comprehensive understanding of the state of the art, it is necessary to examine many works under one roof. The current assessment reveals various deficiencies in smart classrooms, indicating the need for a complete smart classroom solution. Several survey publications on various areas of intelligent classrooms are analyzed. A literature evaluation of published primary surveys, divided into Technological Analyses, Acceptance Studies, Teaching, and Student Perspectives, is elaborated in the further sections.

2.8.2 Tehnological and Keyword Co-occurrence Analysis

Zawacki-Richter et al. [114] examined the work done on numerous aspects of distance learning and suggested that additional attention to be placed on student multicultural difficulties. Ferguson [115] describes learning analytics approaches. The phrase "learning analytics" refers to the study of student behavior to measure academic achievement and forecast future consequences. Student conduct consists of online networking connections, tests, assignments, and discussion forum updates. On the other hand, Romero and Ventura [116] concentrated on educational data mining analysis. Papamitsiou and Economides [117] focused on some of the most current efforts on learning analytics and its applications. Taking attendance requires a great amount of time. There have been several studies undertaken on automatic attendance. Patel and Priya [118] specifically examined facial-recognition-based student attendance and RFID solutions. Keleş et al. [119] produced a study report on Distance Learning and LMS. In recent years, AR is becoming increasingly popular in high schools. Chen et al. [81] did a study on the adoption of AR in smart classroom environment.

In smart education research, it is essential to evaluate the technological pattern based analysis of connected terms. Consequently, 2 aspects of technological advancements are analyzed in this section:

1. The exploration of the technical keyword co-occurrence network;
2. The average publication year of each term pertinent to technological developments.

1. As illustrated in Figure 2.7, the network is built for keyword co-occurrence network analysis using technology-related terms from all publications. The network visualization in Figure 2.7 depicts several essential technologies as well as the interdependence between those technologies. In network visualization, unimportant keywords such as plurals of previously existent keywords and keywords with the same meaning are ignored. The whole visualisation network is separated into **8** clusters, as follows: **C1:** digital competence, education policy, educational innovation, ICT in education, mathematics education, online learning, pre-service teachers, professional development, science education, teacher education, teacher training, and technology integration; **C2:** collaborative learning, educational research, educational software, evaluation, higher education, music education, physical education, students, and training; **C3:** AI, BD, data science, digital technologies, engineering education, IoT, learning analytics, special education, ML, and teaching; **C4:** country-specific development, elementary education, improving classroom teaching, interactive learning environment, lifelong learning, pedagogical issues, post-secondary education, teaching/learning strategies, and virtual reality; **C5:** AR, computer literacy, information technology, medical education, mobile devices, mobile learning, and primary education; **C6:** blended learning, flipped classroom, environmental education, gamification, ICT education, learning, and

virtual classroom; **C7:** CC, distance education, distance learning, e-learning, and online education; and **C8:** assessment, basic education, curriculum, and mathematics.

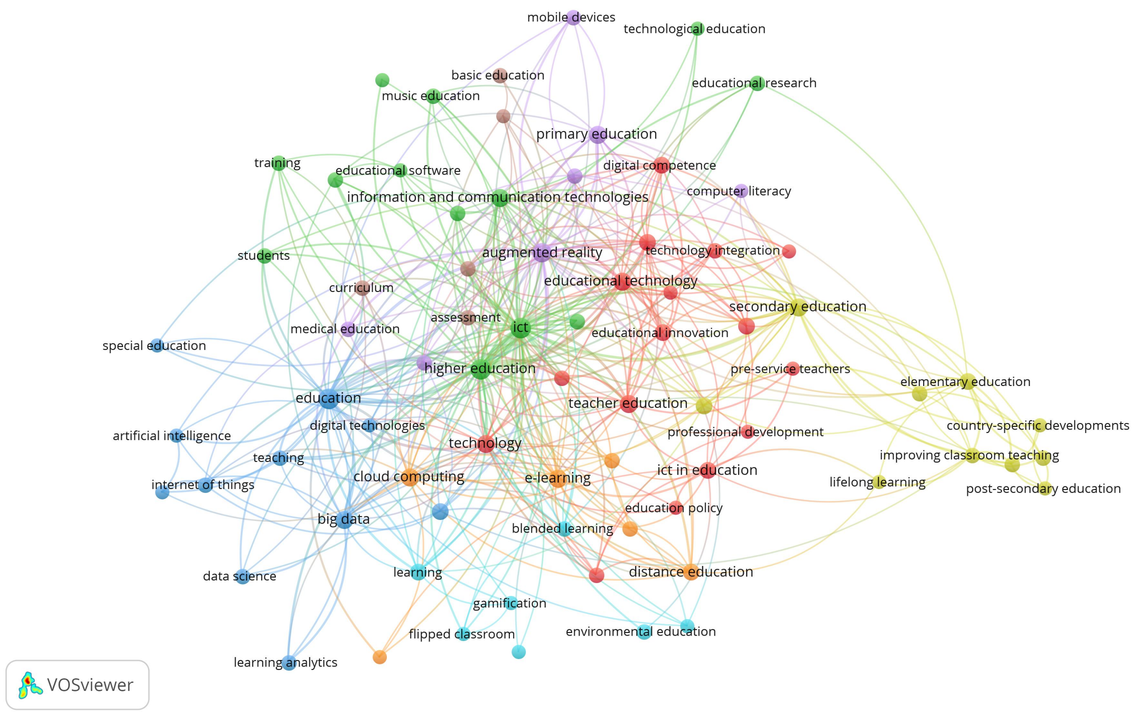


Figure 2.7: KCoN of Technical Advancement related Keywords (M_k=10, D_k=5698, and C_k=138)

2. The keyword co-occurrence network important to technological breakthroughs is depicted utilizing the context of each term's average publishing year, as shown in Figure 2.8, through a year-by-year technical pattern evaluation. The visual depiction helps the researcher to comprehend historical and current technology improvements in the smart education industry. It shows that the study in the first year, 2015, was focused on elementary education, lifelong learning, strengthening classroom teaching, and post-secondary education. However, from the middle of 2015 to the beginning of 2016, the study concentrated on basic education, secondary education, education policy, pre-service teachers, and an educational software. Furthermore, BD, CC, learning analytics, AI, the IoT, data science,

flipped classrooms, ICT, higher education, medical education, special education, and gamification have emerged as research trends since 2016.

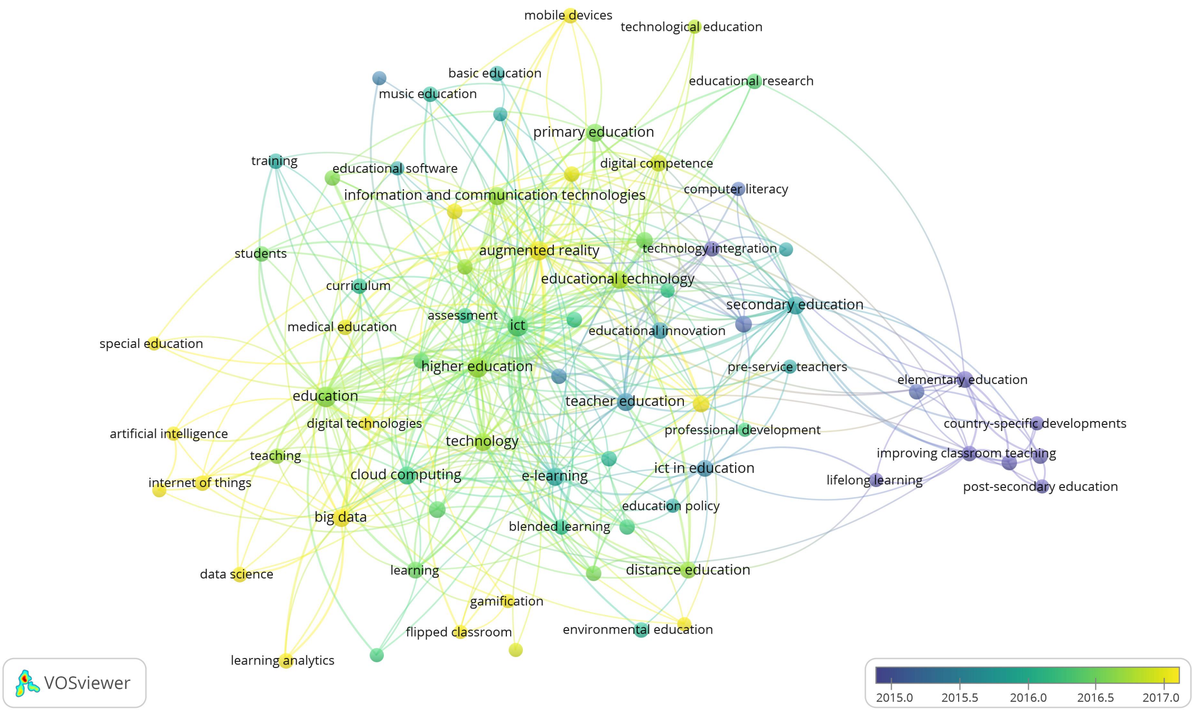


Figure 2.8: Technological Advancements Year-Wise (M_k=10, D_k=5698, and C_k =138)

2.8.3 Acceptance Studies and Teaching

Teaching is a time-honored discipline since some approaches and instructions have always existed and been effective. Due to technological improvements, teaching methods have developed. On the other side, technology may hinder learning. Consequently, it is essential to evaluate the effect of new technologies on learning as a whole. Only technology with a positive impact on the learning environment may be permitted. In addition, a lot of research on the influence of various technologies on learning outcomes has previously been undertaken. The emphasis of Glover et al. [120] was the influence of digital content on classroom instruction. Higgins et al.

[121] conducted the survey that uncovered early indications of digital whiteboard acceptability. Martin et al. [122] carried out research on digital whiteboard usage among consumers. As per the study carried out, it is concluded that the majority of teachers use digital whiteboards. Raman et al. [123] inferred that the majority of teachers can employ virtual whiteboards effectively in the classroom.

Fies and Marshall [124] examined the shortcomings of Classroom Response Systems (CRS). Online, students delivered their comments to the teacher using a normal CRS. The instructor gathers and examines student replies. Kay and LeSage [125] did a similar study to determine how Audience Response Systems (ARS) affect individuals. In ARS, after the questions have been shown electronically, the audience answers using a mobile device. In addition to the ubiquitous utilization of mobile computing devices including tablets, notebooks, and smartphones, Yigit et al. [126] presented mobile learning. Wu et al. [128] found that mobile learning is more prevalent in secondary schools than in primary schools. According to Abachi and Muhammad [129], both students and teachers choose to use mobile-learning technology. Ha and Kim [130] concluded that embracing Twitter for academic engagement improves student achievement. Parker and Burnie [131] carried out research on the usage of digital and internet technology in business schools. Business schools usually embrace Multimedia technological advancements since it improves both instructor and student performance. According to Zhou [132], the deployment of interactive technology in smart classrooms increases the performance of students. Several research on smart classroom environments for student learning have been undertaken [133][134].

Consequently, new teaching paradigms and classrooms equipped with technology have emerged. The most prevalent instructional strategies include e-learning, blended learning [135], and the flipped classroom. In E-Learning, students are given digital course materials for independent study. Through E-Learning, students have the choice of training at their own pace. The acceptability of group learning was evaluated by Songsangyos et al. [136] in a survey. In a flipped classroom, aspects normally accomplished in class, such as presentations, are relocated to the home, while elements previously performed as homework, such as assignments, are brought back into the classrooms. A study is carried out on the impact of flipped classroom teaching practices and their implementation [137][138].

2.8.4 Student Perspectives

ICT plays a key role in facilitating teaching and learning. ICT has revolutionized how individuals interact and how education is conducted in the classroom. In addition, rather than the conventional strategy of instructor speaking and students listening, ICTs have made the approach more collaborative and participative. Language acquisition with ICT, on the other hand, is more successful than conventional methods. In education, device-based learning that facilitates creativity is a distinct possibility. By leveraging cutting-edge sensors and technologies, ICT enables students to utilize essential skills in their daily lives, so enabling them to become an expert and confident users. Teachers can utilize video conferencing to train or supervise student's learning process, even if they are geographically separated [139]. Unlike conventional offline classrooms, aforementioned programs enable a large number of students to attend lectures simultaneously [140].

2.8.5 Conceptual Framework

The architectural concepts of a smart classroom are intended to narrow the gap between teacher and student and to empower the instructor with tools to facilitate successful and effective teaching. A smart classroom is a closed environment that employs technology improvements to enhance the entire learner-instructor experience. A conventional smart classroom has better presentation [141], student attention [142], improved interaction [143], and improved physical environment [144]. The same system may be used to record attendance, analyze data, and provide real-time reviews [145]. Figure 2.9 depicts the categorization of research on smart classrooms.

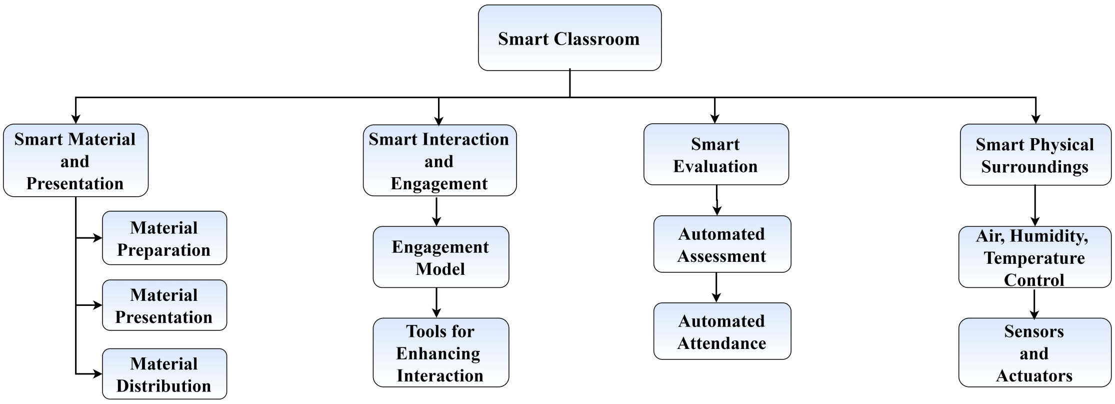


Figure 2.9: Classification of Smart Classroom Literature

In the literature review, the teaching and learning experience is described by 4 fundamental aspects:

1. *Smart Material:-* Smart data consists of the creation, distribution, and dissemination of rich and engaging digital content.
2. *Smart Interaction and Engagement:-* It consists of student communication, teacher-student engagement, and student engagement in class.
3. *Smart Evaluation:-* It entails a thorough study of both student learning and instructional quality.
4. *Smart Physical Classroom:-* A smart classroom must provide a suitable physical environment, including optimal temperature and humidity levels. In the current study, a complete overview of research efforts and technological achievements in each area is offered.

Smart Material To educate, a teacher requires 2 types of materials. The first is a textbook, while the second is lecture-supported content [146][147]. Smart classroom technology focuses on supporting materials. In a traditional classroom, the lecturer scribbles or writes on the blackboard while students take notes in notebooks [148]. The educator in a smart classroom uses technology to develop, arrange, and deliver the material. Digital media has replaced scribbles on the board in presentations [149], film [146], graphics [150], and virtual worlds [133]. Digital material also has the advantage of being easy to spread over the internet [146]. A single teacher may now train a large group of students at the same time, regardless of their geographical location [151]. The detailed study of smart content creation, presentation, and distribution is conducted. Figure 2.10 demonstrates how the content is created, presented, and disseminated to students through the use of various technologies.

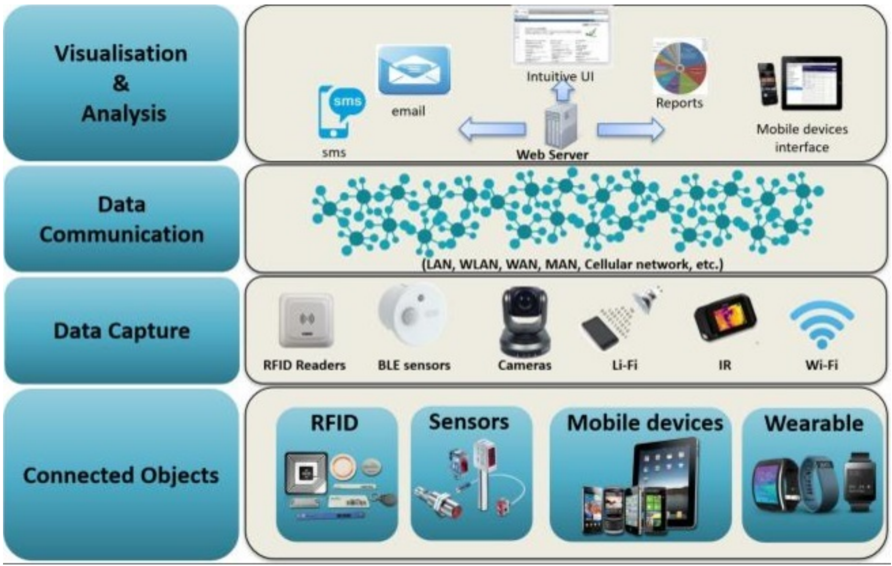


Figure 2.10: Smart Material Preparation, Presentation and Distribution

Material Preparation Music, video, images, text, and animations, among other multimedia components, are routinely used to generate smart content. It saves the instructor time and makes the object more reusable. A teacher can offer a more realistic portrayal of the information being learned by using graphical components. The information is prepared in advance, saving valuable teaching time. Prezi and other web-based presentation tools are ideal for generating story presentations. Web-based applications facilitate collaboration by saving material in the cloud [152]. Educational animations may be created using tools such as Animwork, Mixeek, and Wideo. The use of AR and VR in the classroom has recently gained popularity, especially in primary schools [153][154].

Material Presentation Most occupations require a visual representation to supplement an instructor's oral exposition of a subject. Pipelining and data flow comprises a graphic depiction of computer architecture. The whiteboard and blackboard are two traditional methods for graphically displaying material in the classroom. As projection technology advanced in the 1990s, TVs and projectors were employed in schools [155][156]. The teacher utilizes a projector to display data, movies, photos, maps, and bullet points on a huge screen [141]. Several projection displays are used to create an engaging environment for courses like geography [142]. A projector may also be used to exhibit students' progress (such as answer sheets or student responses), teaching tools (such as mindmaps), and class academic status (such as grades) [157]. As the session evolves, the instructor flips through the slides in a PowerPoint presentation. The teacher must minimize moving around the desktop while using a monitor or laptop to flip the slides. Chang et al. [158] used Kinect to observe and alter slides in the study using gestures. Therefore, the instructor may switch slides from any location in the classroom with a simple motion. Chen et al. [159] used a voice recognition command to flip slides in the same way. The system may also search the slide for keywords.

Material Distribution According to Kim et al. [160], the vast majority of educational resources are now available online. As a result, efforts have been made to increase the efficiency and convenience of digital content distribution. Yau et al. [161] used PDAs to convey instructional information in one of their early endeavors. PDAs are used by students to construct an ad-hoc network and synchronize instructional content. Students can view the instructor's content since the instructor's laptop is still linked to the same ad-hoc network. Smartphones are gradually replacing PDAs as a consequence of significant advancements in communications technology [160]. Bluetooth, WLAN, LAN, 4G, 5G, and LTE are among the newest networking systems being explored for electronic user interface [162]. Maria et al. [163] created an ontology that contains a wide range of smart classroom laws. Depending on the scenario, the necessary rules are activated. Nevertheless, the significance (conversation and location) is manually decided. Bargaoui and Bdiwi [164] demonstrated a device gateway that easily connects tablets, projectors, and laptops. The strategy is to improve student-teacher engagement and material exchange. It is not always the case that educational materials get stale. The teacher can make changes or enhancements.

Providing Assistance to Students When there are a large number of students in a classroom, digital materials become crucial. In a normal classroom, the teacher and student share the same physical space [165]. When a huge number of students are separated by a significant distance, they may be required to join multiple classes. These classes are often held in distinct campuses. Moreover, students may concurrently listen to the same or other lectures [166]. Students have the option of staying home rather than going to school [167][151].

Modeling Student Participation Researchers identified doodling, fidgeting, and yawning as significant indicators of lack of attention in the classroom [168]. It is typical to use video and image recognition to automatically identify these factors. Yang and Chen [169] employed eye and facial recognition to determine whether or not students were alert or asleep. Yu et al. [170] employed a PTZ camera to monitor student engagement via head nods. It is believed that student permission shown as a head node demonstrates their attentiveness. To provide immediate feedback to the instructor, the level of student involvement is shown on a grid. According to Gligoric et al. [171][145], fidgeting and noise are two prominent signs of student apathy. Eye contact may be monitored in the classroom to indicate student alertness [172][173]. Chunyan et al. [174] determined a student's level of engagement by observing the posture of his or her head and shoulders.

Student Participation Improvement To increase student engagement, the researchers concentrated mostly on making lessons interesting. Student-instructor communication, student-student communication, and direct student engagement with the text are the three modes of interaction in the classroom. Teachers and students should be more involved in the classroom. According to Ratto et al. [175], the majority of students are too anxious to engage in class. Students believe that the questions they are putting are too simple and will influence their grades. The authors created the Active Class Framework to enable students to ask open-ended questions and receive immediate feedback via mobile devices [175]. Bargaoui and Bdiwi [164] designed an electronic interface for teacher-student interactions. Liu et al. [142] created a tablet-based solution that gives students real-time feedback. Students represent an array of different nationalities. In this situation, language becomes a significant obstacle to communication. Ishida [176] used software translation to enhance communication between diverse and multicultural learners. The relationship between the teacher and the students may also be influenced by the teaching strategy. Increasing student involvement is another method for capturing students' attention. Dufresne et al. [155] presented class discussion as a tool for student participation. It includes a projector, networking equipment, a desktop computer for the teacher, and palm-top laptops for the students. Students use their portable devices to respond to questions that are displayed on a tablet.

Smart Evaluation Students gain experience through a process of progressive accumulation as they attend consecutive lectures. Daily evaluation is necessary to guarantee that knowledge is effectively built and mastered. Students may submit teacher comments if they feel a certain teaching style is too complex to employ for the whole course.

The smart evaluation is crucial for two reasons: first, it informs the instructor on the students' level of comprehension of the material covered in class; and second, it awards grades to the students [177]. Consequently, several attempts are made to simplify the evaluation based on the type of student interaction. Multiple-Choice Questions (MCQs) are the most efficient and practical method of testing. Moodle [178] and Google Forms [179] are 2 online platforms that may be utilized to automatically analyze MCQs. A web server saves student responses and compares them to the correct answers provided by the teacher for each question. The instructor will also deduct points for each incorrect response. On a paper-based examination with objective-type questions, students will record their responses on an OCR [180] or OMR sheet [181]. On the sheet [182], the system will automatically calculate the number of correct vs incorrect responses.

Attendance A roll call is the standard method for collecting attendance. It has several disadvantages, including the wasting of valuable class time for a roll call, the additional labor required for collation, and the possibility of proxy attendance. Consequently, several efforts are made to correctly record student attendance in the classroom. Using smartcards to automate attendance is one technique. Smartcards, which resemble stickers, hold student identity information. RFID tags are typically employed to monitor student attendance [183–187]. Another technological advancement [188] used smartcards to monitor attendance (via near field communication (NFC)) [189–195]. To record attendance, students place their RFID/NFC-enabled smartcard near the card reader. A card reader transmits attendance data to a server. Acadly [196] is a software technology that utilizes Bluetooth, WiFi, and GPS sensors to improve the efficiency and precision of the attendance system. When using biometric attendance methods, students do not need to wear additional equipment. Students must touch a fingerprint scanner to indicate their presence in the fingerprint-based attendance system [197][198].

Smart Physical Classroom Classes held outside would provide distractions for the students as well as disruptions for other people. Additionally, it is hard to take classes outside in bad weather like rain or extreme cold. Consequently, the majority of lectures are delivered in confined settings, such as classrooms. Inside the classrooms, efforts are made to maintain the optimal physical environment, which is essential for effective learning [199]. Air quality is frequently assessed using VOCs [200], NO_2 [201][202], CO_2 [203][204], and airborne contaminants [199][205][206][207]. The sensors were positioned at an elevation of 1.1 meters above the ground. Hu and Huang [208] created a WMS for managing the physical climate of a classroom using a Raspberry Pi. Similarly, Gong et al. [209] used WSNs to collect safety data using a smoke sensor, temperature/humidity sensor, and protection sensor [210][211]. If the area was considered unsafe, the writers utilized ZigBee technology to send out an alert. External influences may also affect the air quality in a classroom. According to Mendell and Heath [199], pollutants from the surrounding, such as cars, fuel combustion, and industry, may also contribute to the degradation of air quality. The sound level in the classroom should be loud enough for all students to hear well, but not so loud as to cause discomfort or echo [212].

2.9 State-of-the-Art Decision-Making Models

Smart decision-modeling applications require quick and efficient decision-making for obtaining time-sensitive effective results. This section reviews some of the important state-of-the-art decision-making mechanisms that have been put forth by researchers in recent times.

2.9.1 Bayesian Belief Network (BBN) Model

Bayesian Belief Networks (BBN) based decision-making provides a natural, and efficient mechanism to represent probabilistic dependencies among events or datasets. For these reasons, numerous researchers around the world explored the utilization of BBN's models as a tool for knowledge representation and probabilistic classification of data values in several applications. In 2021, Sakib et al. [213] provide a Bayesian Network (BN) model for predicting and assessing catastrophes in the Oil and gas industry based on 7 key factors: technological, economic, societal, governmental, security, ecology, and regulatory. BBN is a probabilistic graphical model that is commonly used in risk analysis to evaluate the probabilistic correlations between various variables. Sensitivity analysis and belief dissemination are utilized to get relevant management insights into the suggested model. According to the findings, technical variables have the greatest influence on oil and gas industry catastrophes, whereas legal and political issues have the least. In 2020, Delen et al. [214] proposed the approach correctly forecasting individual students' dropout probability using a Bayesian Belief Network-driven probabilistic framework. The outcomes indicate that the suggested probabilistic graphical/network technique can predict student dropout with an Area Under the Receiver Operating Characteristics Curve (AUC) of 84%. The findings demonstrate that the extremely unbalanced dataset produces similar prediction performance in detecting at-risk students feature extraction, which is the process of determining and eliminating redundant predictors, generates simplified, quite comprehensible, understandable, and implementable outcomes without affecting prediction task correctness. In 2020, Li et al. [215] presented a bayesian wellness indicator technique for determining power transformer perceived age. In contrast to the traditional weighted-score-sum based index value, the probability-based wellness index is derived as a data fusion outcome of several types of transformer conditions monitored using a proposed BBN. The actual age not only represents a transformer's entire health state, but it is also useful for classifying a transformer fleet based on the projected actual age or drawing comparisons among transformer fleets. To determine the effectiveness of the proposed system, several implementations were performed. Based on the implementations, enhanced results were achieved. Kammouh et al. [216] introduced a unique method for assessing the time-dependent resiliency of technical systems employing resilience metrics. To manage the connections between the indicators, a Bayesian network (BN) technique is used. BN is well-known for its capacity to handle causal relationships between variables in probabilistic terms. The authors used the Dynamic Bayesian Network (DBN) to address the time component in their study. DBN extends the traditional BN by including a time dimension. It allows for varying engagement at various time stages. It may be used to follow the evolution of a system's performance given evidence from a prior time step. This enables the prediction of a system's resilience state given its starting condition.

2.9.2 Game Theoretic Decision-Making

Game Theory (GT) is employed in several decision-modeling frameworks by authors. In 2020, Kashoash and Hayder [217] developed the Game Theoretic Congestion Control Framework (GCCF), a new and easy way for congestion control. In support of IoT application needs, the suggested architecture takes into account node and system preferences. In addition, the suggested method is evaluated in two situations on the Contiki 3.0 operating system and compared to standard algorithms in terms of performance improvement. In 2019, Huang et al. [218] proposed a gametic paradigm for cost decision modeling in cyber-physical systems. The provided methodology generates an accurate revenue matrix to improve service quality, increase customer appeal, and maximize profit. The experimental study indicates that the game-based method provided is more successful than conventional scenarios. In 2019, Mohammadi and Rabinia [219] conducted a complete analysis of GT in many application areas, including Smart Grids and Transportation Networks. The authors explored a variety of topics, including enhancing system dependability, distributing resources in a wireless system, and resolving power related issues. In 2018, Rawat et al. [220] created a three-layer game model for successful IoT-based architecture decision modeling. The suggested approach is utilized to find optimal player strategies. In addition, the authors explained the presence of equilibrium by deriving a mathematical equation from gametic decision making. In 2017, Bhatia and Sood developed an IoT-based system to identify suspicious behavior within the military department by studying the behaviors of individuals. The authors employed a gametic approach to decision-making to limit information leakage. During the experimental application of the method, mathematical analysis was performed to represent its overall efficacy. In 2017, Sandhu and Sood [221] introduced a Stochastic Game Net (SGN)-based model for decision-modeling in smart environments. The authors combined SPNs with GT to create SGN for an intelligent environment. A person's home-based activities are monitored using the described framework. The given approach has been validated for smart homes where effective outcomes are seen. In 2016, Liang et al. [222] used game theory to the monitoring of decision-modeling for green retrofits in various occupancy categories. The authors employ Nash equilibrium to illustrate inhabitants who are reluctant to accept green retrofit initiatives. In 2016, Turnwald et al. [223] developed a GT-based decision-making model for comprehending the behavior of many persons. This technology fixes collisions and illuminates the rationale underlying human avoidance behavior. The experimental evaluation of the suggested system demonstrates that the game theory produced correct decision-making outcomes.

2.9.3 Artificial Neural Network Decision Modeling

Artificial Neural Networks (ANN) are among the most widely used prediction models in a variety of applications. In addition to providing accurate results, these predictive models can also provide results in a timely and efficient manner. In the education sector, ANN and its variants are broadly adopted by researchers throught the globe in order to provide various services. Several prediction methods employ ANN, with the majority utilizing student evaluation data. Throughout the course, a feed-forward ANN was trained to estimate test results based on partial findings. A neural network trained on the Cumulative Grade Point Average (CGPA) predicted eighth-semester academic performance [224]. Two ANN models (Generalized Regression Neural Network and Multilayer Perceptron) were compared to determine which was more accurate in predicting students' performance [225]. Finally, in the area of clinical education, the multivariate LR model and ANNs' predictive ability were examined [226]. In 2019, Khalil et al. [227] created an artificial neural network model for estimating the temperature control requirements of a building depending on a dataset for building energy consumption. The key input parameters are comparative compaction, roof area, total elevation, surface area, glazing area dispersal of a structure, and inclination and the output values are the heating and cooling requirements of the building. The training database comprises data from multiple residential structures discussed in the literature. During model training and validation, the most critical elements impacting heating and the cooling load were found, and the accuracy rate was 99.60%. Lau et al. introduced a method that combined traditional statistical analysis with neural network modeling/prediction of student performance. Traditional statistical assessments are being used to uncover the characteristics that are most likely to influence pupils' performance. There are 11 input variables, 2 levels of hidden neurons, and 1 output unit in the neural network model. As the backpropagation training rule, the Levenberg Marquardt algorithm is used. With restrictions, the neural network model obtained a reasonable predictive performance of 84.8%. In e-learning contexts, ANNs are viewed as a useful technique for forecasting student success. Performance forecasts based on student results are frequently generated in research using artificial neural networks, but students' utilization of LMS is not highlighted. In 2019, Aydogdu estimated the performances of around 3500 students who were studying and fully engaged in LMS in terms of identity, material scores, hours spent on the subject matter, number of entries to material, assignment rating, number of online classes attended, overall time spent in class streams, and overall hours invested in archived programs. ANN developed as a consequence of the study has an accuracy of 80.47%. Finally, it was discovered that the factors of actual class participation, archived curriculum participation, and hours invested in the material correlated the most with the prediction of the outcome variables. Work presented by Hernandez et al. [228] is focused on predicting the academic performance of students. The authors devised a systematic six-stage ANN-based strategy. Predictors have a varied role in categorizing academic achievement as high or low. The findings imply that it is possible to routinely apply ANNs to identify students' academic performance as good (82%) or low (accuracy of 71%). In assessment measures like recall and F1 score, ANNs beat existing machine-learning methods. Moreover, the authors also address implementation suggestions for ANN as well as numerous concerns for analyzing academic achievement in higher education.

2.9.4 Decision Tree (DT) Model

When thresholds are taken into consideration, decision trees and its variations are regarded as effective models for decision making. This approach not only offers great effectiveness in information assessment but also a workable methodology for many decision support services in many applications. [229]. In 2021, Matzavela and Alepis [230] proposed a categorization of student attributes and a prediction model for improving students' academic performance in smart m-learning settings utilizing the DT Algorithm. This evaluation uses the following specific factors: gender, grades, qualification of a parent, family earnings, if the student is the first child, and whether the student works. When assessments are customized to students' learning skills, they are more successful. By providing individualization, the system produces a smart m-learning environment; it was extensively reviewed by students, and the findings revealed a high approval rate while preserving a high degree of pedagogical affordance. The analysis of the data received from the evaluation factors and then from the prediction method that resulted from the algorithm that the authors developed revealed that there is a link between student achievement and individual qualities. Maji and Arora [231] presented a hybridization strategy that combines DT and ANN classifiers to boost the detection of heart disease. WEKA is used for this. To assess the presented algorithm's efficiency, a tenfold validation testing is conducted on a dataset of patients with heart disease obtained from the UCI repository. It is determined that hybrid DT outperforms the separate techniques for the given dataset. As a result, it encourages improved results for predicting heart disease. Lu and Ma [232] introduced two unique hybrid DT-based machine learning algorithms for obtaining significantly accurate short-term water quality assessment outcomes. The temperature of the water, oxygen level, pH value, conductivity, turbidity, and fluorescent soluble organic are all predicted using these approaches. The authors also examined the model's predicted stability. Based on implementations enhanced results were achieved. In 2018, Alajali et al. [233] introduced a unique technique for reliable junction traffic prediction by including other data sources in the prediction model in addition to road traffic volume data. The authors, in particular, make use of data gathered from reports of traffic accidents and roadwork at junctions. Furthermore, the authors analyze two types of learning schemes: batch learning and online learning.

2.9.5 Quantum Computing based Decision-Modeling

In real-time service contexts, optimization based on Quantum Computing is regarded as one of the most effective decision-making strategies. Consequently, many researchers throughout the world have effectively implemented this method for optimization and computational reasons. Han and Kim [234] suggested an evolutionary computing technique based on Genetic Quantum Computing

(GQA). The linear superposition of solutions along with their relative probability is represented by qubits. In addition, the authors included quantum gates for getting optimum time-sensitive solutions in a wide solution space. Experimental implementations of the knapsack problem were used to evaluate the performance of the provided approach. Based on the results, it was determined that the suggested method was very effective and efficient at getting optimal solutions with minimum delay. In 2017, Bhatia and Sood [113] describe a unique quantum computing-inspired optimization approach for maximizing data accuracy in an IoT application's real-time context. The suggested approach, in particular, integrates the quantum formalization of sensor-specific properties to quantify IoT devices in terms of sensors in proximity and ideal sensor space. The optimization of the provided technique is determined using three main performance indicators: data cost, data availability, and data temporal efficiency. To validate the suggested technique, 90 WiSense nodes, a Raspberry Pi v3, and quantum simulators are used to analyze geographical traffic to address vehicular routing concerns. The acquired results were compared to many cutting-edge optimization techniques. According to the findings, the suggested model improved significantly in terms of statistical characteristics such as accuracy, sensitivity, specificity, and F-measure. Furthermore, increased dependability values represent the suggested approach's best performance. Dai et al. [235] have suggested an interesting work for resource allocation in IoT applications. Authors presented the particle swarm optimization approach inspired by quantum computing for the timely delivery of resources to cloud computing platform users. Based on the experimental implementations of the presented method, it was determined that the suggested mechanism might enhance the computational procedure for resource allocations by reducing iterations during demand analyses. In 2017, Guneysu and Oder [236] suggested a quantum computing-inspired security method for IoT contexts. Several standard encryption techniques, such as Identity-Based Encryption, were applied to provide sensor-level security in the IoT. The authors utilized the provided technique to attain local sensor level and global level security. Based on the results, it was determined that the suggested approach could encrypt and decode big data sets in 103 and 36 milliseconds, respectively.

2.10 State-of-the-Art Research Gaps

After a thorough literature review, some important research gaps are found in the current field of study that needs to be filled.

1. Prior research examined solely Smart Learning Environment (SLE) journal publications from the Internet. In the current study, however, data come from WoS, which is the world's biggest collection of abstracts and citations for peer-reviewed literature. Prior studies intended to provide a summary of SLE study findings in the context of publishing patterns, significant contributors, the most influential articles, and frequently employed keywords [237]. However, the present research focuses on the theme framework, citing trends, and models for decision-making of smart learning. Smart applications necessitate rapid and efficient modeling of decision-making in order to produce time-sensitive, effective results. In addition, this study reveals contemporary decision-making models.

2. Game Theory is extensively explored by various researchers in many applications [238][239]. Several significant works are carried out by researchers in this direction but still there is scope for further improvement in the existing solutions. As per our research, no layered framework is used for the prediction of the performance of student and teacher. The current study proposed an effective multi-layered game-theoretic framework for academic evaluation. The layered structure will specifically divide the entire prediction process into various tiers. It will serve as a benchmark for other research projects.

3. As per the research carried out, there are various technical limitations of conventional systems like, transmission delay issue, time-sensitive analysis of academic data, and limited computations for temporal assessment of academic data. Moreover, the vision of the Performance Index (PI) of students and teachers based on routine performance is also not addressed by researchers. A performance index is a type of performance measurement. It evaluates the success of an organization or of an individual. In context to smart academic evaluation, we can evaluate the performance index of student and teacher. The current research presents the formalization of regularized performance assessments of students and teachers over a temporal scale in terms of PI.

4. For evaluating the effectiveness of proposed model, majority of existing researchers have focused only on improving the accuracy of proposed models, not much effort is done towards improving the other factors such as sensitivity, precision, specificity, etc.

5. The current study concentrated on the efficiency of reliability and stability. Instead of evaluating the proposed model on precision, sensitivity, and accuracy, it is very important to consider stability and reliability. These metrics are only considered in the current study. The ability of a system to carry out and maintain its operations under expected or unanticipated conditions is the reliability [240]. It is crucial to comprehend how reliable the prediction system is. Reliability is a crucial factor to take into account when evaluating models [241]. The degree of consistency between several algorithmic predictions is represented by stability. The effectiveness of the prediction system can be evaluated using this crucial metric. A prediction system is stable if the predictions do not change strongly over a short range of data [242].

2.11 Research Methodology

Based on the identified research gaps, the research methodology is designed to address these gaps and contribute to the field. Here is a proposed research methodology based on the mentioned research gaps:

1. Data Collection and Literature Review: The research will utilize the Web of Science (WoS) database, which contains a vast collection of abstracts and citations for peer-reviewed literature. This will ensure a comprehensive and reliable source of data for the study. The current research conduct an extensive literature review focusing on smart learning environments (SLE) to identify existing studies related to decision-making models and themes. This review will provide a comprehensive understanding of the current state of the field, publishing patterns, significant contributors, and influential articles.

2. Framework Development: Develop a multi-layered game-theoretic framework for academic evaluation that considers the performance of both students and teachers. The presented framework will divide the prediction process into various tiers, enabling more accurate and comprehensive evaluations. The proposed framework will serve as a benchmark for future research projects in the field.

3. Performance Index (PI) Formalization and Evaluation Metrics: Formalize the regularized performance assessments of students and teachers over a temporal scale in terms of a performance index. In addition to accuracy, the research will consider other important evaluation metrics such as sensitivity, precision, specificity, stability, and reliability. The proposed model will be evaluated based on these metrics to assess its effectiveness in academic prediction and decision-making.

4. Results Analysis: Analyze the results of the empirical study to determine the effectiveness and reliability of the proposed models. Compare the outcomes

with existing approaches to highlight the improvements achieved and address the identified research gaps.

5. Discussion and Conclusion: Summarize the findings of the study, discuss the implications of the results, and draw conclusions. Additionally, identify any further research directions and recommendations for future studies to continue filling the research gaps.

2.12 Discussion

In the current chapter, we examined data from the WoS database with extended keywords for an in-depth study, as well as online internet sources [103][91]. The following section discusses a few of the most distinctive characteristics ahead.

1. In earlier studies, only online Smart Learning Environment (SLE) journal articles were evaluated for analysis. In this chapter, data is obtained from WoS, the biggest abstract and citation database for peer-reviewed literature and online sources. Henceforth, the acquired data comprises a variety of sources, including papers, patents, publications, reviews, and meetings.

2. Prior studies intended to provide an overview of SLE research in terms of publishing patterns, major contributors, the most influential publications, and frequently used keywords. The present chapter focuses on smart learning topic structure, educational frameworks, cutting-edge decision making models, and citation patterns. Moreover, this study uncovers contemporary trends and advancements in the smart learning environment. In the framework of scientometric analysis, 4 main topics are formulated: Technological Innovations, Smart Environment, Modes, and Education Levels.

3. The general analysis of the prior study conducted by the researchers is ineffectual compared to the scientometric analysis, which is shown useful

in identifying research topics in a particular subject. In the current study, the VOS Viewer visualization tool is employed to explore the evolution of research subjects in greater depth.

2.13 Inferences

This chapter provides a systematic review that is reinforced by bibliometric research, and it is an important endeavor to provide the most comprehensive perspective on the evolving aspects of smart classrooms. The study aids policymakers, regulators, and academic researchers in understanding the fundamental characteristics of smart classrooms and suggesting relevant research topics for the future. Since a decade ago, there is substantial growth in the number of research publications, and the field is advancing rapidly. This is the first attempt to track the converging tendencies in smart classrooms and map the conceptual connections between the key works of the past quarter-century. According to the findings, the field is not yet evolved. Utilizing bibliometric analysis, evaluations of seminal works on the topic, prolific authors, associated nations, productive journals, keywords used, and interrelationships between works were conducted. In developing nations, smart classroom research is often in its infancy. No references to recent work on the topic is found. Nonetheless, it is evident from substantial research that fresh research on smart classrooms may lead the path to future advancement. In addition, this chapter explored research gaps relevant to existing approaches.

The present survey is an effective stepping stone for future study and makes it simpler for administrators, scientists, and educators to make well-informed suggestions in the field of education. The outcomes of this study might help researchers in developing a smart framework for the education sector by using modern ICT technologies such as IoT, fog computing, and cloud computing.

Chapter 3

A Framework for Academic Evaluation

3.1 Introduction

This chapter gives a brief overview of the layered architecture of the proposed framework. The framework aims to provide an intelligent system for evaluating the performance of students and teachers in an academic environment. The intended users who will benefit from this framework are educational institutions, administrators, monitoring organisations, instructors, and students. The data inputs required for the system, such as information from IoT devices, sensors, and other sources. The expected outputs or outcomes of the system, such as performance metrics, evaluation reports, and decision-making support. The advantages and potential impact of using this framework are improved academic performance, personalized feedback, early intervention, and data-driven decision making. Section 3.2 gives a detailed walkthrough of the various layers of the proposed framework in this thesis.

3.2 Proposed Framework

The presented framework comprises 4 layers, namely: Data Acquisition and Preprocessing (DAP), Data Classification (DC), Data Mining (DM), and Gametic Decision Modeling (GDM). Figure 3.1 depicts the IoT-based structure of the smart academic system for analyzing student and instructor performance. Each layer serves a distinct purpose to achieve the overall model's goals. Data is first collected from various IoT devices implanted in the smart classroom and its surroundings. Data collected is transferred to cloud computing devices for analysis of student and instructor academic achievement. Finally, precise information is transferred to the cloud for decision modeling based on instructor and student performance metrics. Each layer is described ahead in depth.

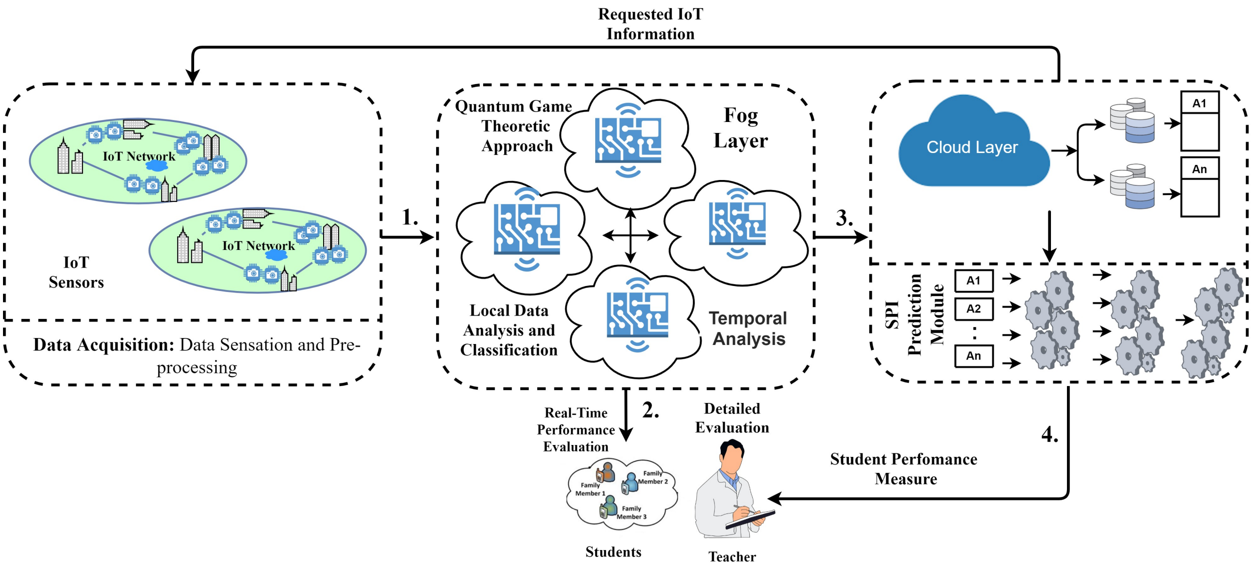


Figure 3.1: Modular Design of the Proposed Framework

3.3 Data Acquisition and Pre-processing (DAP) Layer

DAP is the first layer of the suggested intelligent student and teacher performance evaluation system. This layer collects information on the learning environment, student activities, and staff activities. Numerous IoT devices, including Wireless Sensors, Radio Frequency Identifiers (RFID), GPS sensors, and actuators, are deployed throughout the classroom's ambient environment for this purpose. In addition, sensors are implanted in the body area network and the ambient environment. Many communication protocols, including Wi-Fi, Bluetooth, and Ethernet, are utilized to transport the collected data to the fog layer and cloud storage. Different methods, such as ECC and Secure SSL, are utilized to preserve the security of data transfer to the cloud [243]. In addition, methods such as Credential Mapping and User Authentication are employed to safeguard data at the fog and cloud levels [244].

3.4 Data Classification (DC) Layer: Fog Level

The academic success of students and educators is both directly and indirectly correlated with the data gathered by IoT devices and sensors. In this thesis, two types of datasets—Student Dataset (SD) and Teacher Dataset (TD) are given based on performance evaluation. The SD and TD are further categorized for in-depth assessment of implicit and explicit actions.

1. *Student Dataset (SD)*
   SD consists of the data values linked to the numerous academic activities undertaken by students. Additionally, the actions are divided into two categories: implicit and explicit. Implicit actions are data segments that are directly related to the learner's academic progress. On the other hand,

explicit actions are non-academic data segments that may impact student performance. These are gathered on a monthly or biweekly basis. This information is gathered via IoT sensors and devices placed both inside and outside the classroom.

2. *Teacher Dataset (TD)*

   TD is an extra vital dataset for performance evaluation. Similarly, the dataset is subdivided into two types of actions: implicit and explicit actions. Sensors and IoT devices are used to collect data, which is then sent to fog-cloud storage to be processed further.

Table 3.1 outlines a few of the crucial data segments and associated factors for evaluating the performance of students and teachers. Based on the academic quality evaluation, two categories of data sets are created for this study. These comprise student datasets (SD) and teacher datasets (TD).

Table 3.1: Classification of Data Sets for Performance Evaluation of Student and Teacher along with Procedure for Feature Acquisition

Dataset	Class	Sub-Class	Description	Feature Captured	IoT Technology Utilized
Teacher	**Implicit**	Satisfaction among students	It reveals the proportion of students who were pleased with the lecture's content	Dynamic Signal	Feedback Performa
Teacher	**Implicit**	Lecture	Quality of provided content	Dynamic Signal	Camera Sensor
Teacher	**Implicit**	Assignment	It gives information on how many tasks like research papers, group presentation, or subject related assignments the teacher assigns to the students	Static Signal	Real-Time Communication Tools and time-stamp technology
Teacher	**Explicit**	Presence at the workplace	Describes the teacher's conduct about responsibilities, interaction with students related to subject or other matters	Dynamic Signal	Clock Sensor
Teacher	**Explicit**	Punctuality	Consistency of the lecturer in attending class	Dynamic Signal	Clock Sensors
Student	**Implicit**	Attendance	It discusses how consistently the students attend classes and seminars	Dynamic Signal	ID cards with RFID chips, GPS
Student	**Implicit**	Academic Performance	Based on the grades received in examinations, it analyzes student's performance	Static Signal	Manual Evaluation
Student	**Implicit**	Assignments	Assignments submitted for review by the lecturer	Static Signal	Real-Time communication tools and time-stamp technology
Student	**Explicit**	Attitude or Behavior	Determines a student's attitude towards staff, other students, and equipment utilization	Dynamic Signal	RFIDs and Behavioral Sensors
Student	**Explicit**	Sport Activities	Determines a student's athletic performance	Dynamic Signal	Sensors
Student	**Explicit**	Team-Work	Determines learners' conduct in response to various scenarios like performance of students in group discussion, student participation in sports as a team, group study etc.	Dynamic Signal	RFID Tags and other sensors

3.4.1 Dataset Classification

As stated previously, the primary function of the DC layer is to classify the datasets acquired by the DA layer. In the current scenario, the dataset is classified based on a probabilistic measure known as Probability of Performance (PoP).

Definition 1: Probability of Performance(PoP): *Given an activity a_i at time interval t_i, PoP is based on the likelihood that the activity a_i would improve an individual's academic performance in a student's educational environment.*
The probability measure for measuring the influence of classroom activities on student achievement is provided by the above definition. As seen in Figure 3.2, the Bayesian Belief Network (BBN) model describes two classes based on the PoP metric: Implicit Class (IC) and Explicit Class (EC).

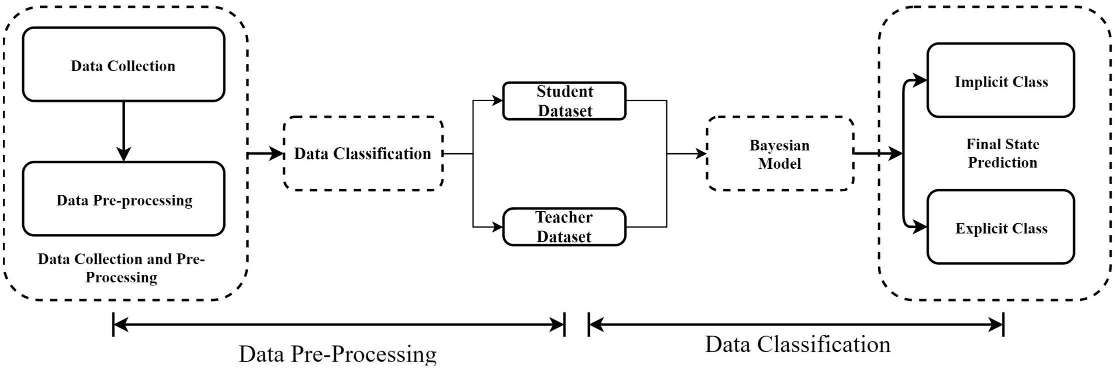


Figure 3.2: Processing and Classification of Data

1. **Implicit Class (IC):-** This class has a direct influence on the student's performance and is characterized by the student's direct engagement in the educational environment. Instances of the implicit class dataset contain information about how often a student goes to class and how well they do in school overall.

2. **Explicit Class (EC):-** This kind of data set includes actions that are indirectly connected to the academic success of students. In other words, it

consists of data events that the learner performs outside of the classroom. The frequency of these data segments may be monthly or weekly. A few instances of explicit class datasets include extracurricular activities such as athletics, art, and craft performances.

3.4.2 Classification based on Bayesian Belief Network (BBN) Model

The BBN Model is utilized to classify datasets into many categories [245]. As indicated previously, two classes are identified based on distinct student characteristics. Let a data instance be represented by the vector $P_i = (P_1, P_2, ... P_n)$ where P_i represents the i^{th} performance parameter, assuming that all performance parameters are independent of one another. $P(\frac{Y_j}{P_1, P_2, ..., P_n})$ represents the conditional probability of student performance instance P_i of class Y_j. When there are several input variables and a particular instance of a performance measure may have a large value, the method mentioned above may result in biases when evaluating the student's performance. The updated BBN is now expressed as follows:

$$P(\frac{Y_j}{P_i}) = \frac{P(Y_j)P(P_i/Y_j)}{P(P_i)}. \tag{3.1}$$

However, the probability of $P(Y_j)P(P_i/Y_j)$ can be improved based on joint probability function as

$=> P(Y_j)P(P_i/Y_j) = P(P_1, P_2, ..., P_n, Y_j)$

$=> P(P_1/P_2, ..., P_n, Y_j)P(P_2, ..., P_n, Y_j)$

$=> P(P_1/P_2, ..., P_n, Y_j)P(P_2/P_3, ..., P_n, Y_j)P(P_3, ..., P_n, Y_j)$

$=> P(P_1/P_2, ..., P_n, Y_j)P(P_2/P_3, ..., P_n Y_j), ..., P(P_{n-1}/P_n, ..., P_n Y_j) * P(P_n/Y_j)P(Y_j)$

Moreover, it is assumed that each feature p_i of the performance variable is not dependent on any other measure p_j i.e. $i \neq j$. Then $P(p_i/p_{i+1}, ..., p_n, Y_j) = P(p_i/Y_j)$

Therefore, the joint probability is described as follows:

$=> P(Y_j) = \Pi_{i=1}^{n} P(Y_j)P(p_i/Y_j)$

=>$P(\frac{Y_j}{p}) = \Pi_{i=1}^{n} P(Y_j)P(p_i/Y_j)/P(p)$

In the equation described above, Y_j depicts the IC and EC categories of variables.

3.5 Data Mining (DM) Layer

The Data Mining (DM) layer is the third layer of the smart academic system's present architecture for evaluating student performance. This layer's fundamental function is to retrieve the data values for IC and EC datasets from the cloud repository. Moreover, one of the most important functions performed by the DM layer is to map each student and instructor performance metric to the temporal dimension for efficient real-time evaluation. The Temporal Mining approach is applied for this purpose. It is a method for collecting the values of data objects over time [246].

3.5.1 Temporal Mining Formulation

It is a method of abstracting data for several factors and aggregating them on a temporal scale. Representing Temporal Mining as: $<s_1,t_1>$, $<s_2,t_2>$,...,$<s_n,t_n>$, where s_i depicts the value of i^{th} individual at given time instance t_i. Several data values are acquired for synchronization. The successful evaluation of student and teacher performance outside and within the smart academic system results from the extraction of factors linked to the scores or performances of students and teachers across a temporal scale. Figure 3.3 illustrates the temporal extraction of these factors on a temporal scale. The proposed paradigm illustrates performance assessment simply in terms of probabilistic estimates of the SPI and TPI.

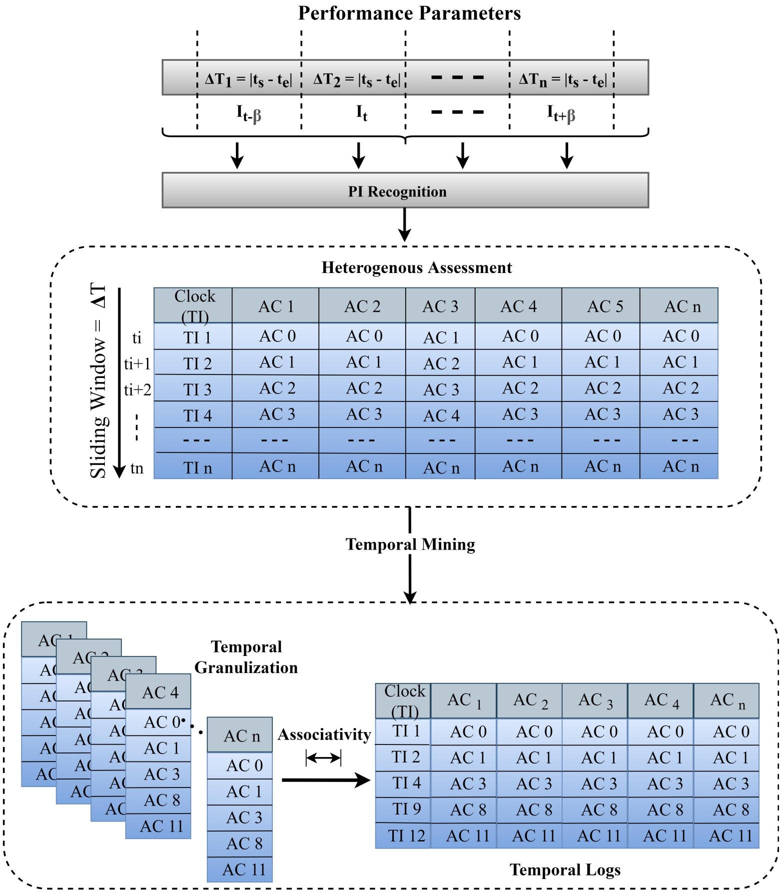


Figure 3.3: Temporal Abstraction

Definition 2: Performance Indicator (PI): *PI is the quantitative indicator for measuring student and instructor performance across temporal granulation* $<s_1,t_1>$, $<s_2,t_2>$,...,$<s_n,t_n>$ *in a particular time interval.*

Definition 2 provides a numerical value for the different performance related characteristics obtained by IoT devices employing the PoP value. In addition, the SPI and TPI are calculated for students and instructors, respectively. The greater the PI value, the better the performance of students and instructors within and outside of the smart academic system. Similarly, the low PI value reflects the poor performance of both students and teachers. It is essential to process data in parallel for computing SPI and TPI. In the current research, Map-Reduce functions are used to achieve parallelism. In addition, technologies like Spark and Apache Hadoop are utilized for extracting and concurrently processing data. SPI and TPI are computed employing Algorithm 1 based on the performance metrics. It provides an overview of SPI and TPI estimation. Initial comparisons are done between parameter values and the threshold values specified by instructors and management authorities. In step 4 of the SPI calculation, $S(A_i)$ is computed, where i is the set of activities accomplished by the student. $Y^x{}_i$ represents the quantum probabilistic value of A_i activity for x days, given that $1 \leq x \leq w$; where w is the number of school working days. In Step 5, the Development Score $DS(S_i)$ is calculated. This indicator indicates that 80% of a student's grade is based on performance related to implicit activities and 20% is based on performance related to specified activities. In the calculation indicated in Step 5, IC and EC represent the number of implicit and explicit actions, respectively. TPI is the quantitative metric for assessing the teacher's overall progress. TPI is calculated mathematically in Step 6 of Algorithm 1 as shown in Table 3.2. In addition, Table 3.3 provides a discussion of each metric used to calculate the performance of a student.

Table 3.2: SPI and TPI Computation Method

Algorithm 1: Steps for Calculating SPI and TPI
Step 1: Enter the IoT data values for m variables as well as the appropriate PoP values.
Step 2: SPI should be initialised at a specified time instance=0.
Step 3: The PoP value of m parameters is compared to a predetermined threshold variable α, which is chosen by the teacher depending on the student's academic performance and activities.
Step 4: If $S(A_i)=\sum^{w}{}_{x=1} Y_i{}^x \backslash W$.
Step 5 : $DS(S_i)= \frac{1}{4}(0.80*\sum^{IC}{}_{i=1} S(A_i)/IC)+0.20*\sum^{EC}{}_{i=1} S(A_i)/EC)) + \frac{3}{4}(\sum^{n}{}_{x=1} M(S_y)/x)$
Step 6 : Overall value of SPI= $\theta * DS(S_i)$ and TPI= $\sum^{n}{}_{j=1} SPI*(S_i/n)$

Table 3.3: Notations for Calculating Student Achievement

S.No.	**Variables**	**Explanation**
1.	A_i	The number of activities that are carried out by the student.
2.	$S(A_i)$	Student Activity Score
3.	Y_i^x	Quantum Probabilistic score of i^{th}activity during x day
4.	$M(S_y)$	Marks obtained by a learner in the monthly report in subject y

3.6 Quantum Gametic Decision Modeling (QGDM)

The suggested system's decision-making layer is the QGDM. Particularly, 2-player quantum game modeling is created based on student and instructor performance to calculate and analyze performance in smart academic environments. In the current situation, a game is played by two individuals, the student, and the instructor. Player-1 (Teacher) may give kids a conducive academic environment that will aid in their overall development. Player 2's (Student) objective is to apply various methods for enhancing their academic performance indicator. The strategy sets used by two players to calculate the SPI and TPI are explored in detail ahead.

3.6.1 Strategy Set

Players choose strategy sets following their distinct roles and behaviors. Progressive Strategy ($S_{\text{Progressive}}$) and Non-Progressive Strategy ($S_{\text{Non-Progressive}}$) comprise the strategy set selected by Player-1 (Teacher). Both of these strategies help the instructor in adopting effective measures that will result in the general advancement of pupils. The notation for strategy set S for the instructor is:
$S_{\text{Teacher}} = S\ (S_{\text{Progressive}}, S_{\text{Non-Progressive}})$.
Contrarily, Player-2 (Student) uses two different sets of strategies: Achieving Strategy ($S_{\text{Achieving}}$) and Non-Achieving Strategy ($S_{\text{Non-Achieving}}$). Both of these strategies are restricted to measuring student achievement concerning their behavior both inside and outside of the smart classroom. Consequently, the notation for the student strategy set S is:
$S_{\text{Student}} = S(S_{\text{Achieving}}, S_{\text{Non-Achieving}})$.

3.6.2 Game Parameters

The game's parameters determine the player's ability to employ a particular strategy. In other words, it allows the player to estimate the profit and loss associated with each strategy. 5 key game factors have been established in the current study. In Table 3.4, the symbolic notation is listed alongside a concise explanation. According to the deployment scenario, the number of parameters may be enhanced or decreased. Nevertheless, this change will not affect the overall methodology. Moreover, these parameters are assessed using quantum probabilistic estimation. In particular, QP(P) determines the QP of student performance for calculating SPI. The QP of students who are not engaging in any of the activities is represented by QP(NP). QP(I) defines the QP as enhancing student performance using a progressive technique. QP(D) signifies the QP of implementing progressive student performance-enhancing methods by instructors. QP(ND) indicates that the instructor does not employ progressive monitoring strategies to enhance student performance.

Table 3.4: Game Metrics

S.No.	**Metrics**	**Meaning**	**Description**
1.	I	Improvement	Performance of students may be enhanced by implementing development initiatives.
2.	D	Development	Teachers may employ a variety of development strategies, such as additional lessons, administering examinations, and assigning homework, to facilitate the student's advancement.
3.	NP	Non-Performing	Those students who do poorly in class may be subject to retaliation.
4.	P	Performing	The performance of students are evaluated based on their test scores, assignments, and involvement in extracurricular activities such as athletics, group discussions, and others.
5.	ND	Non-Development	No development methods have been implemented by the instructor to enhance a student's performance.

3.6.3 Game Utility

The quantum payoff or quantum utility function for the suggested gametic model is developed using the strategy sets employed by 2 players. In the four scenarios listed below, utilities may be developed in accordance with the strategies selected by the learner and instructor.

Scenario 1: Player-1→ $\text{S}_{\text{Progressive}}$, Player-2→ $\text{S}_{\text{Achieving}}$

Using the game characteristics listed in Table 3.4, the quantum utility of each player is determined. In other words, QP of applying developmental initiatives to improve students' performance increases. In such a scenario, the quantum probability of achieving success increases. Now, player-1's utility is

$$[QP(P) + QP(D)] \tag{3.2}$$

Similarly, the QP of not performing drops for Player 2. Nonetheless, self-improvement potential (QP) rises when the students perform well both within and outside the classroom. Consequently, the total utility will equal

$$[-QP(NP) + QP(I)] \tag{3.3}$$

Scenario 2: Player-1→ $\text{S}_{\text{Progressive}}$, Player-2→ $\text{S}_{\text{Non-Achieving}}$

In this strategy set, the QP of the student's performance rating grows when the teacher implements development measures. Therefore, Player-1's utility is calculated to be

$$[QP(P) + QP(D)] \tag{3.4}$$

However, the QP of non-performing rises for Player-2 with a non-performing approach. In addition, the QP for non-development increases, resulting in negative conduct as measured by student performance scores. Consequently, Player-2's overall utility is

$$[QP(NP) + QP(I)] \tag{3.5}$$

Scenario 3: Player-1→ $\text{S}_{\text{Non-Progressive}}$, Player-2→ $\text{S}_{\text{Achieving}}$

In this scenario, despite the teacher not using the development metric, Player-1 has a greater QP of kids performing well in class. The entire utility of Player-1 is thus

$$[QP(P) - QP(D)] \tag{3.6}$$

The QP for non-progressive measurements employed by teachers, on the other hand, lowers the improved student behavior. Henceforth, Player-2's total utility is

$$[-QP(NP) - QP(I)] \tag{3.7}$$

Scenario 4: Player-1→ $\mathrm{S}_{\text{Non-Progressive}}$, Player-2→ $\mathrm{S}_{\text{Non-Achieving}}$
Player 1 selected a non-progressive technique in this instance, resulting in a drop in a student's performance score. Player-1's total utility is

$$[-QP(P) - QP(D)] \tag{3.8}$$

For Player 2, the probability of failure rises. However, the QP of improvement will fall as a result of Player-1's non-progressive approach. Consequently, the total utility will equal

$$[QP(NP) - QP(I)] \tag{3.9}$$

3.6.4 Utility Tree

Based on the aforementioned 4 scenarios, the utility tree is created in Figure 3.4. Additionally, a QP scale is used to compute the strategy set. Let (α) represent the QP for Player-1 to choose the $\mathrm{S}_{\text{Progressive}}$ approach, and let (1− α) represent the QP for Player-1 to adopt the $\mathrm{S}_{\text{Non-Progressive}}$ strategy. Let β be the QP for Player-2 to choose the $\mathrm{S}_{\text{Achieving}}$ strategy, and let (1− β) be the QP for selecting the $\mathrm{S}_{\text{Non-Achieving}}$ strategy.

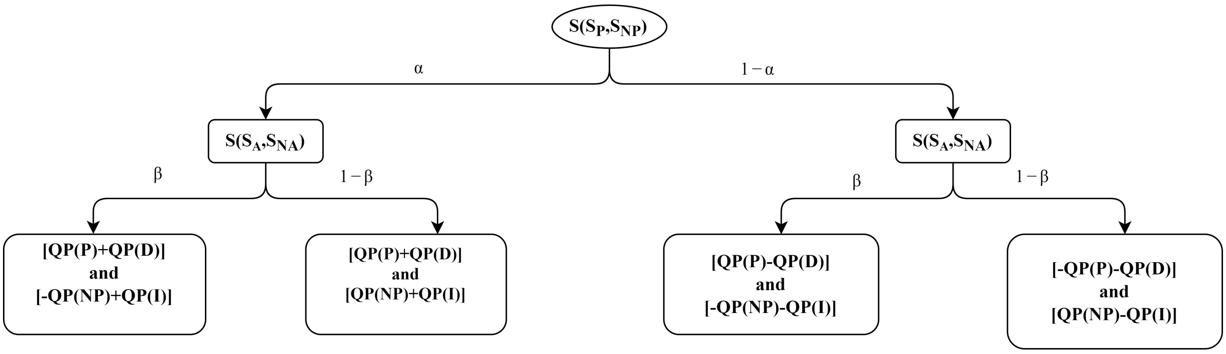


Figure 3.4: Utility Tree

3.6.5 Game Equilibrium

In the suggested system, the Nash equilibrium state is found by utilizing the utility tree to determine the total payoff from the model. Based on the equilibrium approach, 2 cases are analyzed.

Sub-Case 1: Corollary 1(Player-1's Payoff):- *At equilibrium, there is an equal quantum probability for both effective performance and student growth.*

Proof:- The utility tree depicted in Figure 3.4 is used to calculate the quantum payoff for player-1. It is mathematically stated as:

$=> \alpha * [QP(P) + QP(D)] + (1\text{-}\alpha) * [- QP(P) - QP(D)] = \alpha * [QP(P) + QP(D)] + (1\text{-}\alpha) * [- QP(P) - QP(D)]$

$=> \alpha QP(P) + \alpha QP(D) - QP(P) + QP(D) - \alpha QP(P) + \alpha\ QP(D) = \alpha\ QP(P) + \alpha QP(D) + QP(P) - QP(D) - \alpha QP(P) + \alpha QP(D)$

By solving it, we get

$=> QP(P) = QP(D)$

Sub-Case 2: Corollary 2(Player-2's Payoff):- *At equilibrium, the quantum probability of not performing well leads to the destructive conduct of the student.*

Proof:- The utility tree depicted in Figure 3.4 is used to determine the quantum payoff for Player 2. It is mathematically stated as:

$=>\beta*[-QP(NP)+QP(I)]+ (1-\beta)*-[QP(NP)-QP(I)] = \beta * [QP(NP)+ QP(I)]+ (1-\beta)* [QP(NP)-QP(I)]$

$=>- \beta QP(NP)+\beta QP(I)-QP(NP)- QP(I) +\beta QP(NP) +\beta QP(I) = +\beta QP(NP) +\beta QP(I) + QP(NP)- QP(I)- \beta QP(NP) +\beta QP(I)$

By solving it, we get

$=>QP(NP)= -QP(I)$

3.6.6 Algorithmic Description

The suggested framework presents an intelligent academic environment for assessing the progress of students and teachers through the calculation of SPI and TPI. It automates data collection, classification, and decision-making for the student's performance based on a variety of performance factors used while assessing PI. In Table 3.5, the procedural statement is presented in the form of Algorithm 2. As the number of factors used for calculating student performance rises, greater precision is recorded.

Table 3.5: Algorithmic Description

Algorithm 2: Procedure about the Proposed Methodology
Input: P is for Performance Variables for assessing the performance of the student, while S stands for the total number of students. **Output**: Quantum Probability of Student Performance Index (SPI), Quantum Probability of Teacher Performance Index (TPI). **Procedure** **Step 1**: Enter IoT data values for students' performance criteria and save them in the Fog and Cloud nodes for administration. **Step 2** : Based on the PoP threshold value, P is split into 2 sets, namely $P_{Implicit}$, $P_{Explicit}$, so that $P=P_{Implicit} \cup P_{Explicit}$. (*Implicit set of activities (Student) include attendance, assignments, and academic performance, whereas Implicit set of activities (Teacher) include satisfaction among students, quality of lecture, and how many assignments are given by teacher. Similarly, Explicit set of activities (Student) include behavior, sport activities, and team-work, whereas Explicit set of activities (Teacher) include punctuality, teacher's attitude towards students, and sincerity about the responsibilities at the workplace.*) **Step 3** : Temporal Extraction is used to describe the relationship between performance characteristics and time. **Step 4** : Using Algorithm 1, SPI and TPI for $P_{Implicit}$ and $P_{Explicit}$ are determined. Fog Node delivers real-time student and instructor evaluations, whereas Cloud Node gives a full analysis of student and teacher ratings based on the findings. **Step 5** : Use a QGT-based decision-modeling framework to compute the QP for teacher performance, which corresponds to TPI, and the QP for student performance, which corresponds to SPI.

3.7 Mathematical Analysis

ESS stands for Evolutionarily Stable Strategy. In game theory, an ESS is a strategy that, if adopted by a population of players, cannot be invaded by any alternative strategy [247]. It is a concept used to predict the long-term outcomes of strategic interactions among individuals. By computing the ESS, one can identify the points of partial equilibrium in the game represented by the utility tree. These points correspond to specific combinations of α and β values, namely E(0,0), E(0,1), E(1,1), and E(1,0). The Jacobian matrix (J) is analyzed to determine the stability of these equilibrium points. ESS of the game model described has been computed for Players-1 (teacher) and Player-2 (student) in order to assess the efficiency of the suggested QGT framework. To identify the pace as well as direction of the proposed study for game participants, replicator dynamics are calculated for ESS computation. These equations are equated to 0, which is necessary to reach the partial equilibrium. Based on their distinct strategy sets, Player-1 and Player-2's replicator dynamics are analyzed. It is because, in practice, it is the effort made by the teacher to enhance student performance that leads to the performance evaluation of both the student and the teacher. By computing the ESS, the section contributes to validating the whole framework by demonstrating its ability to predict stable outcomes in strategic interactions between the student and the teacher.

Player-1's RE

$=> F_{\text{Player-1}}(1) = \alpha * [QP(P) + QP(D)] + (1-\alpha) * [QP(P) + QP(D)] = \alpha\ QP(D)$

$=> F_{\text{Player-1}}(2) = \alpha * [QP(P) + QP(D)] + (1-\alpha) * [-\ QP(P) + QP(D)] = 2\alpha QP(D)$

$=> F'_{\text{Player-1}}(12) = \beta F_{\text{Player-1}}(1) + (1-\beta) F_{\text{Player-1}}(2)$

$=> F'_{\text{Player-1}}(12) = \beta\alpha QP(D) + (1-\beta)*(2\alpha QP(D))$

$=> F'_{\text{Player-1}}(12) = -\alpha\beta QP(D) + 2\alpha QP(D)$

$=> RE_{\text{Player-1}}(\text{Player-1}) = \beta(F'_{\text{Player-1}}(12) - F_{\text{Player-1}}(1))$

=>$RE_{Player-1}$=$\beta[-\alpha\beta$QP(D)+2αQP(D)-αQP(D)]

=>$RE_{Player-i}$= $\beta\alpha$QP(D)(1-β)

Player-2's RE

=>$F_{Player-2}$(1)= $\beta*$[−QP(NP)+QP(I)]+(1-β)$*$[− QP(NP)−QP(I)]= 2 βQP(I)−QP(NP) − QP(I) −2βP(ND)

=>$F_{Player-2}$(2)= β $*$[QP(NP)+ QP(I)]+(1-β)$*$ [QP(NP)− QP(I)]= 2 βQP(I)+QP(NP)− QP(I)

=>$F'_{Player-2}$(12)=$\alpha F_{Player-2}$(1) + (1-α)$F_{Player-2}$(2)

=>$F'_{Player-2}$(12)=α(2βQP(I)−QP(NP)-QP(I))+ (1-α)(2 βQP(I)+QP(NP)−QP(I))

=>$F'_{Player-2}$(12)=QP(NP)−QP(I)−2(βQP(I)-αQP(NP))

=>$RE_{Player-2}$(Player-2)= β($F'_{Player-2}$(12)−$F_{Player-2}$(1))

=>$RE_{Player-2}$= QP(NP)−QP(I)−2(βQP(I)-αQP(NP))− (2 βQP(I)−QP(NP)− QP(I)) −2βQP(ND)

=>$RE_{Player-2}$=− $\alpha\beta$(QP(I)+QP(NP)+P(ND)+β/α)

Evaluating $RE_{Player-1}$ and $RE_{Player-2}$ over normalization of $\alpha\beta$, we get

$$\beta = \begin{cases} 0,1 \quad if \alpha = 1, QP(D) = 1 \\ anyvalue; otherwise \end{cases}$$

$$\alpha = \begin{cases} 0,1 \quad if \beta = 1, QP(D) = QP(P) \\ anyvalue; otherwise \end{cases}$$

In the mathematical notation, $F_{Player-X}$ and $F'_{Player-X}$ are functions that help estimate replicator equations, and $RE_{Player-X}$ is the replicator equation for Player X. Depending on the values of the equations, a partial equilibrium exists at four points of E(α, β), namely E (0,0), E (0,1), E (1,1), and E (1,0). The Jacobean (J) of a matrix is analyzed as outlined below to determine the most stable technique:

$$J = \begin{bmatrix} \frac{\partial RE_{\text{Player-1}}}{\partial \alpha} & \frac{\partial RE_{\text{Player-1}}}{\partial \beta} \\ \frac{\partial RE_{\text{Player-2}}}{\partial \alpha} & \frac{\partial RE_{\text{Player-2}}}{\partial \beta} \end{bmatrix}$$

$$= \begin{bmatrix} \beta(1-\beta) & \alpha(1-\beta) \\ \beta(-\alpha^2+1) & -\alpha\beta+\beta^2/\alpha \end{bmatrix}$$

The information flow of the quantum game between 2 players, a student and a teacher is depicted below. The final state is computed according to the following equation:

$$|\gamma_{\text{f}}> = \bar{E}\ (P(TPI) \otimes P(SPI))\theta|\gamma_{\text{i}}> \tag{3.10}$$

where $|\gamma_{\text{i}}>=|\ 00>$is the starting state of the qubits, $|\ \gamma_{\text{f}}>$is the final state, θ is an entangling function that entangles the qubits of the players, and P(TPI) and P(SPI) are the PIs of the instructors and learner, respectively. The classical game, which is a subset of the quantum game, uses the classical reward matrix to calculate the payoff whereas $\bar{E}$ denotes a disentangling gate that is used to estimate the final state. The benefit of QGT for instructor and learner may be summarised as follows:

$$<\delta>=\text{QP}_{000}\ |<\gamma_{\text{f}}|000>|^2 + \text{QP}_{001}|<\gamma_{\text{f}}|001>|^2 + \text{QP}_{010}\ |<\gamma_{\text{f}}\ |\ 010>|^2 + \text{QP}_{011}|<\gamma_{\text{f}}|011>|^2$$

where QP_{ij} is the payoff for instructor and learner-related $\text{result}_{\text{ij}}$ of game and i, j ϵ 0. If players follow the quantum approach, entanglement provides the opportunity for their actions to interact. The maximal entangling operator θ for 2∗2 two-player game is described. The level of entanglement is determined by the parameter ψ $\epsilon[0, \frac{\pi}{2}]$. It is possible to write it as follows:

$$\theta = exp(i\frac{\psi}{2}\sigma^{\otimes \text{n}}{}_{\text{x}}) \tag{3.11}$$

3.8 Inferences

In this chapter, a smart system for evaluating student and teacher performance in the academic context is formulated. Data values received via academic monitoring are represented in terms of quantifiable PoP metrics, which is analyzed in terms of SPI and TPI. On the basis of these metrics, the two-player QGT model is presented for analyzing the performance enhancement of the suggested decision making paradigm. Moreover, the current study describes the model's distinct layers. Precisely, the various essential aspects, such as data collection, classification, mining and extraction, prediction and decision-making, are also discussed in this chapter. Furthermore, this chapter discusses the mathematical analysis that is carried out to determine the effectiveness of the proposed system.

Chapter 4

Experimental Simulation

4.1 Introduction

The experimental setup, dataset requirements, motivation for feature selection, missing data management technique, and performance assessment criteria are described in this chapter. The current chapter explains the process of data collection and provides an overview of primary and secondary data collection methods. Exploratory data analysis (EDA) as a key phase in data preprocessing is described in this chapter. It mentions the use of various tools and libraries such as Numpy, Pandas, Seaborn, and Matplotlib for data exploration and visualization. Moreover, the chapter also introduces a specific dataset obtained from the UCI repository and provides a detailed description of its attributes. Overall, comprehensive overview of data collection, EDA, dataset description, data types, and data pre-processing is also described in the current chapter.

4.2 Data Collection

The process of acquiring, measuring, and analyzing diverse sorts of information using a set of validated standard techniques is known as data collection. This task is conducted in order to extract, record, and gather data for analysis. The basic purpose of data collecting is to collect extensive and reliable data and evaluate it in order to make critical choices. Following data acquisition, it goes through a comprehensive data cleansing and processing procedure to guarantee that it is truly usable. The data collection approach is divided into two categories, which are detailed below:

1. *Primary Data Collection Methods*: Primary data, also known as raw data, is information gathered directly from a source through experiments, surveys, or observations. In addition, two types of main data collection methodologies are outlined.

   (a) *Quantitative Data Collection Methods*: It is based on statistical computations and utilizes a number of forms, including closed-ended surveys, correlation analysis, regression analysis approaches, and average, mean, and median metrics. Gathering qualitative data is less costly and more efficient with this strategy.

   (b) *Qualitative Data Collection Methods*: Mathematical computations are not included in any way. This method is closely related to intangible components. Qualitative data collecting methods include interviews, questionnaires, observations, and case studies. The following are some of the several methods for gathering this sort of data:

      - *Observation Method*: The observation technique is employed in behavioral science research. This strategy has been carefully crafted. It is subject to a variety of limitations and inspections.
      - *Interview Method*: This method collects information from verbal or oral responses. It is possible to conduct it in two ways: in person or over the phone.
      - *Questionnaire Method*: This procedure requires mailing a questionnaire to the responder. They are expected to peruse the questionnaire,

fill it out, and return it. The form's questions are arranged in a certain sequence.

2. *Secondary Data Collection Methods*: "Secondary data" refers to information collected by a party other than the original user. It indicates that the data is already accessible and has been extensively evaluated in this situation. Secondary data sources include periodicals, newspapers, books, and journals. It might be data that has already been revealed or data that hasn't yet been published. Government publications, public records, historical and statistical studies, business documents, technical journals, and archives all contain published data.

4.3 Exploratory Data Analysis (EDA)

The exploration of data is a key phase in data analysis. EDA is used to analyze data and extract the key insights. It also comprises the preparation of data sets for analysis by eliminating abnormalities. It is a strategy for evaluating huge data sets in order to extract their important properties, which is typically done visually. Numpy, Pandas, Seaborn, and Matplotlib are employed in the present study for preliminary analysis. Numpy is a Python array processing package. It is a library that makes numerical computations easier. Pandas are data manipulation and analysis tools. Matplotlib and Seaborn are two statistical libraries that are used to visualize data.

4.4 Dataset Description

An extensive dataset provided by the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) was used to evaluate a number of prediction algorithms. In the present study, we used a variety of publicly available data sets obtained from the UCI and Kaggle online data repositories. In this study, the data exploration of one dataset retrieved from the UCI[1] repository is described in detail. The dataset contains student and instructor performance outcomes. It consists of 7029 occurrences. Table 4.1 summarizes the attributes that were included in the dataset.

Table 4.1: Parameters of Dataset

SNo.	**Name of the Attribute**
1.	Instructor ID
2.	Class Code
3.	How often the student is enrolled in this course
4.	Code of the level of attendance
5.	The student's assessment of the course's difficulty
6.	Q1: At the beginning of the semester, the curriculum material, teaching technique, and assessment system were all provided.
7.	Q2: The course's goals and objectives were outlined in detail at the start of the term.
8.	Q3: The number of credits allocated to the course was appropriate.
9.	Q4: The course was covered in accordance with the course outline presented on the very initial day of class.
10.	Q5: The class conversations, homework, applications, and lessons were adequate.
11.	Q6: The textbook and educational materials were adequate and up to date.
12.	Q7: The course included opportunities for fieldwork, applications, laboratory, discussion, and other disciplines.
13.	Q8: The assessments, projects, tasks, and exams aided in the learning process.
14.	Q9: I eagerly participated in lecture discussions because I relished the class so much.
15.	Q10:The course ultimately lived up to my original hopes for it.
16.	Q11: The course was useful and pertinent to my professional progress.
17.	Q12: The education provided me with a fresh perspective on life and the world.
18.	Q13: Appropriate and current knowledge was possessed by the instructor.
19.	Q14:The teacher was well-prepared for class.
20.	Q15: The teacher adhered to the declared lesson plan when delivering instruction.
21.	Q16: The teacher had a strong commitment to the subject and was comprehensible.
22.	Q17: The Instructor arrived to class on time.
23.	Q18: The teacher speaks or delivers material in a clear and understandable manner.
24.	Q19: The Instructor effectively utilized class time.
25.	Q20: The instructor welcomed questions from students and eagerly discussed the subject.
26.	Q21: The Instructor displayed a positive attitude toward the students.
27.	Q22:The Instructor was responsive and considerate of the students' opinions regarding the course.
28.	Q23: The Instructor emphasized the importance of class participation.
29.	Q24: The instructor assigned pertinent homework/projects and assisted/guided students.
30.	Q25: The Instructor answered queries about the course both during and after class.
31.	Q26: Effectively measuring the course objectives, the instructor's evaluation system (midterm and final exams, projects, assignments, etc.) included midterm and final exams, projects, and assignments.
32.	Q27: Exam solutions were delivered and reviewed with students by the instructor.
33.	Q28: The Instructor treated each student with fairness and objectivity.

[1]http://archive.ics.uci.edu/ml/datasets

4.4.1 Datatypes

Depending on the kind of data they store, variables in a dataset can be of different types. It is essential to be aware of the various categories of data that a variable can store, as different methods are necessary for handling different types of data. A variable is a discrete element that stores a value corresponding to a property, quantity, or measurable number. A variable can hold data of several forms, such as numeric, textual, or calendar data. Categorical and numerical data are generically classified as nominal, ordinal, interval, and ratio data. Figure 4.1 depicts the following data categories:

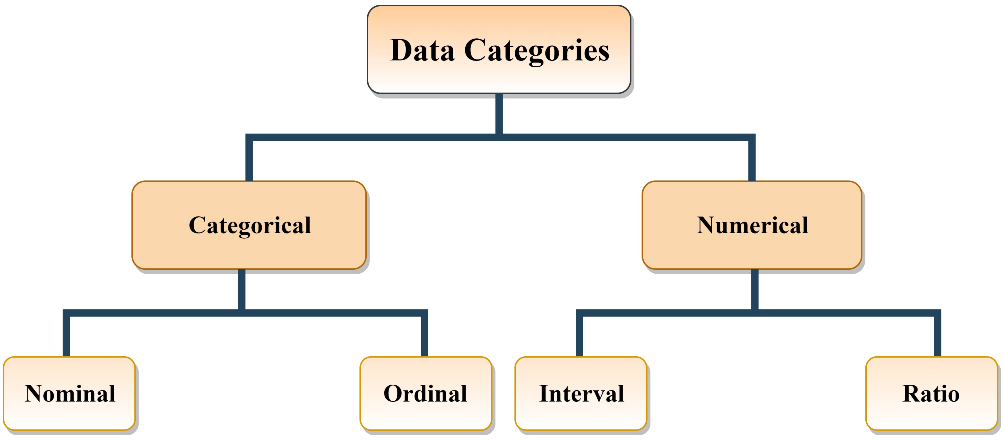


Figure 4.1: Categories of data

1. Categorical data is just information that is categorized rather than expressed numerically, such as gender, sex, or education level. Categorical variables take their values from the predetermined set of values. For instance, the Boolean set: {False, True} is a categorical variable since the values must be retrieved from the set. Another instance is the number of months in a year. Categorical variables are categorized into two types: nominal and ordinal.

   - The term “nominal features” refers to variables that lack any implicit order. There is no effect on the order of the values. For instance, the bike’s color could be red, blue, green, or silver.

- The term "ordinal characteristics" refers to variables that have an implied natural order. For instance, the dress's size is classified as small, large, or extra large.

2. The numerical features are those features whose values are in the integer range. The majority of them are described by numbers and have the attributes of numbers as their primary characteristics. The speed of a car or the number of steps taken while walking are examples of numerical features.

   - Interval: It include the variables whose key attribute is measured in conjunction with continuous data and have a numerical representation. This approach can be used to encode both Fahrenheit and Celsius scales.
   - Ratio: These variables can be scaled to any desired unit of measurement while retaining their meaning and proportionality. For example, length can be described in meters or feet, and money can be stated in a variety of different currencies.

It is essential to pre-process the dataset before applying ML algorithms. Figure 4.2 demonstrates the different dataset attributes and datatypes employed in the current study.

4.5 Data pre-processing

Pre-processing involves cleaning and modifying data so that it may be used as an input for a number of essential data science tasks, such as data visualization, machine learning, deep learning, and data analytics. Feature engineering, feature scaling, outlier detection, missing value handling, categorical variable encoding, and data discretization are some of the most common data preparation operations. Preprocessing data is an essential step in the building of any machine learning prediction model.

```
0  instr        int64
1  class        int64
2  nb.repeat    int64
3  attendance   int64
4  difficulty   int64
5  Q1           int64
6  Q2           int64
7  Q3           int64
8  Q4           int64
9  Q5           int64
10 Q6           int64
11 Q7           int64
12 Q8           int64
13 Q9           int64
14 Q10          int64
15 Q11          int64
16 Q12          int64
17 Q13          int64
18 Q14          int64
19 Q15          int64
20 Q16          int64
21 Q17          int64
22 Q18          int64
23 Q19          int64
24 Q20          int64
25 Q21          int64
26 Q22          int64
27 Q23          int64
28 Q24          int64
29 Q25          int64
30 Q26          int64
31 Q27          int64
32 Q28          int64
dtypes: int64
```

Figure 4.2: Attributes and their Datatypes

Real-world data is typically noisy, has missing values, and may be in an inconvenient format, rendering it unsuitable with machine learning models. Moreover, they frequently contain several inaccuracies. As a result, after the data is acquired, it is converted into a format that the machine learning algorithm can understand.

4.5.1 Missing Values

An observation in the dataset with a missing value is one for which there is no associated value. Due to the fact that missing values may totally change data patterns, it is crucial to comprehend why missing values are present in the dataset and how to resolve them. Missing values in a dataset can be explained in a variety of ways. Several of them are as follows:

1. Humans intentionally neglect to store data frequently, resulting in missing values. Consider creating a dataset using a poll in which customers enter data. Users are not required to fill out all fields. In such cases, you will not receive data for all fields.

2. Another potential reason for the missing value is that the observational data used for feature engineering is unknown. For instance, suppose you want to add a column to a house's area. Multiply the length and width columns to determine the area. The area column will be null if an observation's length or width is absent.

3. Lastly, calculation errors can lead to the absence of quantities. Assume you want to enter a value into a column that is the result of dividing two integers. If the denominator is 0, the result is infinity, which is an undefined value.

Having missing data in your dataset has a number of disadvantages. Some of them are as follows:

1. Many advanced machine learning packages, such as Scikit Learn, fail when your dataset contains missing values. As a result, missing values must be removed from the dataset or modified using missing data imputation techniques.

2. The problem of missing data imputation is that it produces skewed data because it is not a replacement for the original data.

3. Finally, corrupted data may hamper statistical model performance.

4.5.2 Approach for Handling Missing Data

The absence of data values in a dataset can impede model fit. As a consequence of insufficient data analysis, a skewed model may be produced. The variable's behavior and its relationship to other variables cannot be reliably inferred. This can lead to an inaccurate prediction or categorization. Missing values might be caused by data extraction or collection issues. The SimpleImputer pre-processing class in the scikit-learn package can be used to impute missing data in this investigation. It primarily offers the SimpleImputer class, which implements statistical imputation. We can import the SimpleImputer class and then instantiated it with a string argument sent to the strategy parameter. Despite the fact that it is the default and not essential to explicitly mention, we can also put "mean" here for the sake of clarification. The acquired dataset has no missing values. Figure 4.3 depicts that all the attributes have no null values.

4.5.3 Feature selection and Correlation Heatmap

Feature Selection is an essential phase in the preprocessing of data [248]. It is a major tool for dimensionality reduction. The presence of duplicate features in data with a higher dimension may have a detrimental influence on the performance of a model. As a result, identifying the 'primary' characteristics of a dataset and eliminating unnecessary or minor variables that do not significantly contribute to the target/prediction variable is critical. There are several methods for extracting features from a dataset. The target variable is used in these strategies to discover important aspects that increase model accuracy.

```
instr         0
class         0
nb.repeat     0
attendance    0
difficulty    0
Q1            0
Q2            0
Q3            0
Q4            0
Q5            0
Q6            0
Q7            0
Q8            0
Q9            0
Q10           0
Q11           0
Q12           0
Q13           0
Q14           0
Q15           0
Q16           0
Q17           0
Q18           0
Q19           0
Q20           0
Q21           0
Q22           0
Q23           0
Q24           0
Q25           0
Q26           0
Q27           0
Q28           0
dtype: int64
```

Figure 4.3: Data Preprocessing

We used feature selection with Correlation heatmaps in the present study. A Correlation heatmap depicts a two-dimensional correlation matrix between two discrete variables. Colored cells are often used to display data on a monochrome scale. The values of the first dimension are represented as rows in a table, while the values of the second dimension are represented as columns. The cell's color corresponds to the number of measurements linked with the specified dimension.

Correlation heatmaps are useful for data analysis because they illustrate patterns and variations within a single data set. The heat map in Figure 4.4 depicts the relationship between numerous characteristics. The warm color depicts a positive correlation, and the cool color denotes a negative correlation.

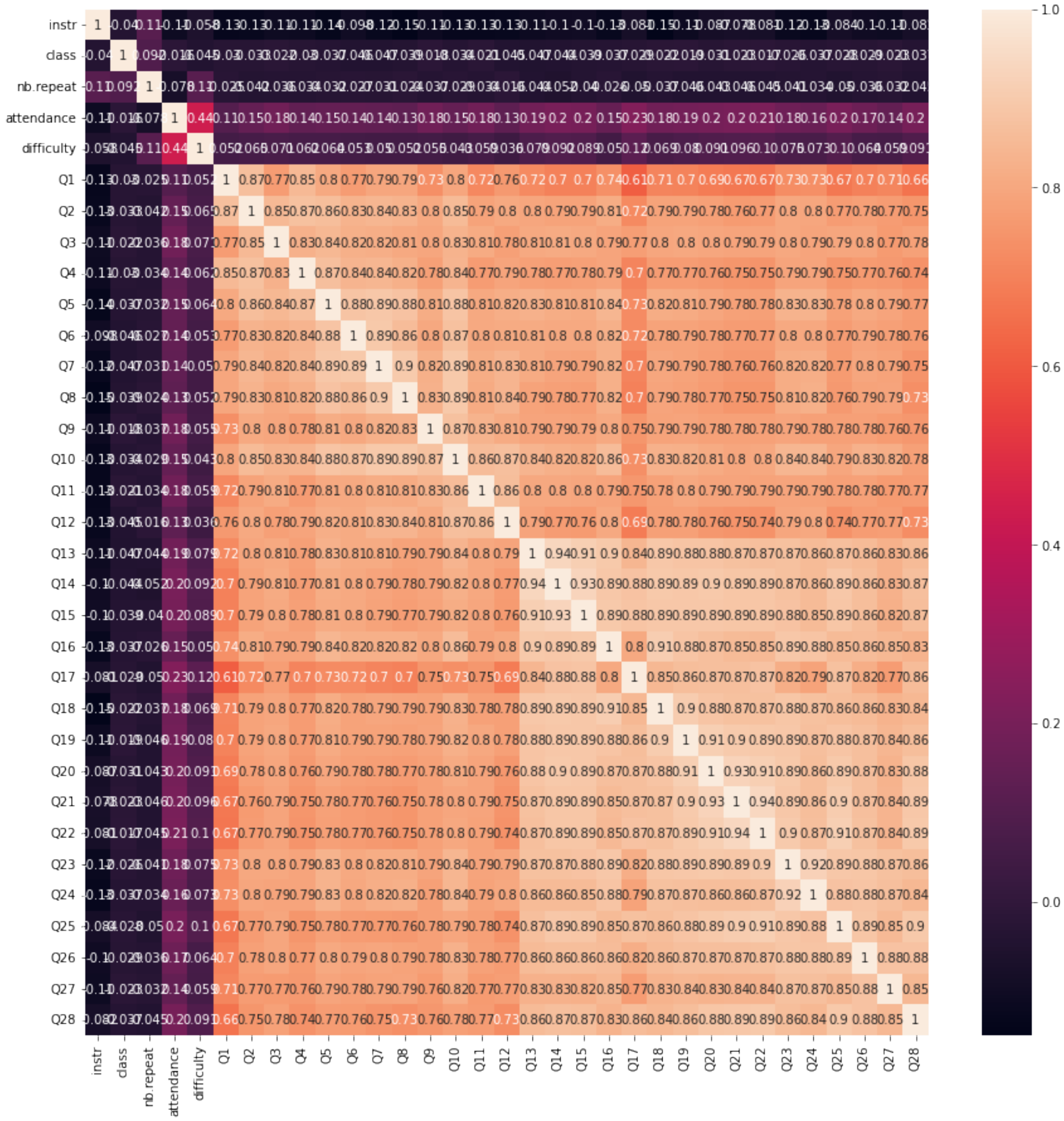


Figure 4.4: Correlation Result of Dataset

4.6 Performance Evaluation Metrics

The predictive modeling approach relies heavily on performance evaluation. By selecting the relevant measures, the efficacy of a predictive model is estimated and compared. It is vital to pick the suitable metrics for a certain prediction model in order to produce an accurate result. Because diverse types of data sets will be used for the same predictive model, it is critical to assess the model's suitability. We assessed our suggested model in this study utilizing a range of indicators. The evaluation metrics are totally determined by the model type and implementation technique. Problems may develop when the model is implemented on unknown data without a sufficient evaluation of the proposed model utilizing several evaluation criteria and relying exclusively on accuracy. The following are a set of performance assessment measures appropriate for the suggested framework evaluation.

Accuracy:- It refers to the proportion of correctly classified examples. It is a more accurate measure as it calculates the number of correctly classified instances on the whole. Mathematically, it can be defined as

$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN} \tag{4.1}$$

Precision:- It computes the percentage difference between the total of correctly classified data. It computes the percentage difference between the sum of correctly categorised data and the entire data. In other words, it is calculated applying the sum of properly categorized data to the total number of classifications evaluated. It may be stated mathematically as

$$Precision = \frac{TP}{TP + FP} \tag{4.2}$$

where TP denotes the total or sum of true positives. (TP+FP) denotes the number of positives, whereas FP is the number of false positives. The higher the precision value, the more accurately identified samples.

Specificity:- Specificity measures ability of model to classify correctly the actual negatives of each of the categories it can predict. It is described as follows:

$$Specificity = \frac{TN}{TN + FP} \tag{4.3}$$

where TN and FP denotes True Negative and False positive respectively.

Sensitivity:- It is also known as recall. It is a ratio of positive events successfully classified by the model. It is denoted by the following formula in mathematics:

$$Sensitivity = \frac{TP}{TP + FN} \tag{4.4}$$

where TP and FN denotes True Positive and False Negative respectively.

Reliability:-It refers to a system's ability to execute and maintain operations in expected and unexpected situations.

Stabilty:-It refers to the changes in the system's output that occur when the training dataset is changed. It is essentially a statistical validation approach used to evaluate the performance of a prediction model. Furthermore, the stability measure is obtained in order to calculate the mean absolute difference, also known as Mean Absolute Shift (MAS). The MAS measure has a value between 0 and 1, with 0 being the least stable and 1 being the most stable.

4.7 Inferences

This chapter discusses exploratory data analysis and the process of utilising visual tools to analyse data. Additionally, the dataset's details, along with its datatypes, missing values, and missing values handling approach are also discussed in this chapter. Moreover, this chapter discusses the correlation heatmap, which depicts the relationship between many variables. Furthermore, the performance metrics criteria employed for evaluating the effectiveness of the proposed model are also detailed in the current chapter.

Chapter 5

Results and Discussion

5.1 Introduction

This chapter outlines the simulation environment and simulation results for implementing the proposed model for evaluation. The 2-player quantum game model proposed consists of many key stages. Initially, performance-based measures are captured in real-time using various IoT devices integrated into the classroom environment. The gathered data is transmitted to a fog node that acts as the interface for data transmission to the cloud repository. Based on the cloud database, a 2-player quantum game model for intelligent decisions based on SPI and TPI values is developed. The suggested model is evaluated using 4 performance parameters. These include:

1. Determining the efficacy of smart device data acquisition in terms of temporal delay in contrast to contemporary decision-making methodologies.

2. Assessing the classification efficacy of the provided data classification system.

3. Estimating the prediction efficacy of the model developed for performance assessment of teachers and students depending on implicit and explicit behaviors.

4. Evaluating the system's reliability and stability throughout a wide range of data instances.

5.2 Implementation Analysis

As previously stated, the presented framework is composed of multiple layers. The primary layer retrieves the dataset from the UCI and Kaggle repositories, which is obtained ubiquitously by utilizing multiple IoT sensors installed in geographically distant regions. The following phase utilizes the BBN approach to categorize the data values as implicit or explicit. Finally, QGT is applied to determine the performance of students and teachers in terms of PoP. The effectiveness of the proposed framework is assessed based on 4 parameters that are discussed in Chapter 4.

5.2.1 Simulation Environment

Four demanding datasets gathered from UCI and Kaggle's online repository are used to simulate the proposed approach. These datasets include SP[1] from UCI which comprises 7029 instances, SAP[2] from UCI which comprises of 3585 instances, SPP[3], and SPA[4] which are comprised of 2120 and 6500 instances respectively. To assess the improved performance of the developed framework, a total of 19,000 observations from all datasets are analyzed. In addition, these databases include student happiness, academic achievement, punctuality, and attendance statistics. The Raspberry Pi v3 is used as a node for fog computing. Game Plan Software is used to analyze the suggested framework's 2-player quantum game model. The experimental simulation was conducted on a computer system with 16 GB of RAM, an Intel i5 processor core, and a clock speed of 3.2 GHz. The comparative

[1]Source:https://archive.ics.uci.edu/ml/datasets
[2]Source:https://archive.ics.uci.edu/ml/datasets/Student +academic+Performance
[3]Source:https://www.kaggle.com/c/datasciencenigeria/data
[4]Source:https://www.kaggle.com/masudur/student-performance-analysis

analysis employs a variety of existing models to ascertain the proposed system's performance enhancement. Additionally, many statistical parameters are analyzed to ascertain the proposed system's overall efficacy.

5.2.2 Temporal Delay

Temporal Delay is the amount of time required to make a quantum gametic decision. In other words, it is the amount of time necessary for assessing the data stored and producing outcomes. If $T_{\text{IoT-assessing}}$ signifies the amount of time consumed by IoT devices for assessing data, $T_{\text{Data-categorization}}$ signifies the amount of time consumed for categorizing the data, and $T_{\text{Decision-modeling}}$ denotes the amount of time consumed for formulating the decision, then the temporal delay can be calculated as follows:

$$\text{Temporal Delay} = T_{\text{IoT-assessing}} + T_{\text{Data-categorization}} + T_{\text{Decision-modeling}}.$$

To conduct a comparative study, the findings are compared to the cutting-edge decision-making approaches of ANN, SVM, and KNN. Detailed findings are presented ahead.

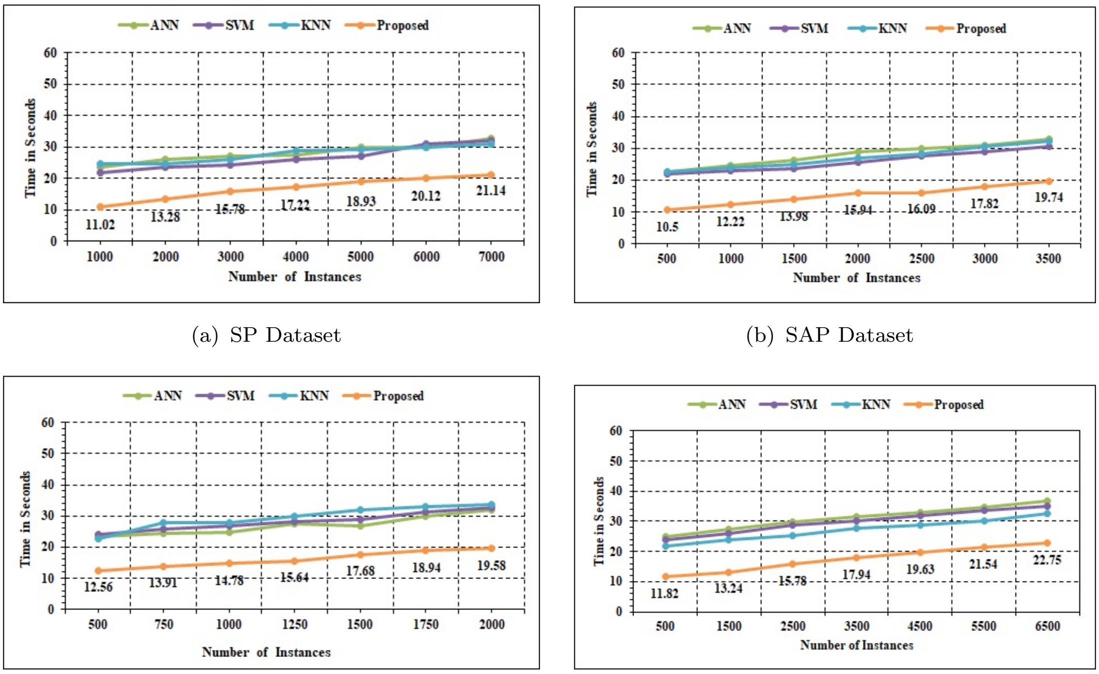
1. Figure 5.1(a) illustrates the findings of the SP Dataset's temporal efficiency. The suggested QGT approach took 19.58 seconds on average to make a decision, compared to 32.74 seconds for ANN, 30.93 seconds for SVM, and 29.24 for KNN.

2. Figure 5.1(b) illustrates that the mean time delay of the SAP Dataset is about 18.71 seconds, which is less than that of the ANN (32.17 seconds), SVM (29.42 seconds), and KNN (28.84 seconds).

3. Figure 5.1(c) demonstrates that the entire execution time for the present paradigm is 20.29 seconds for the SPP Dataset, which is much less than the time required to generate the decision by ANN (30.42 seconds), SVM (31.54 seconds), and KNN (20.13 seconds).

4. The temporal efficacy of the SPA Dataset is illustrated in Figure 5.1(d). It can be seen that the QGT model could make predictions with an average delay of 21.52 seconds, which is much less than ANN (35.84 seconds), SVM (32.02 seconds), and KNN (54.03 seconds).

Based on the recorded findings, it can be demonstrated that the provided method achieves minimal time in automated decision modeling.



(a) SP Dataset (b) SAP Dataset

(c) SPP Dataset (d) SPA Dataset

Figure 5.1: Temporal Delay Efficiency (a) SP Dataset, (b) SAP Dataset, (c) SPP Dataset,(d) SPA Dataset

5.2.3 Classification Efficiency

Classification efficiency is to determine a class for an element in dataset. The assessment of 3 crucial performance indicators, namely Precision (Pr), Specificity (Sp), and Sensitivity (Se), defines the classification effectiveness of the proposed approach. Two classification techniques, namely DT and SVM, are incorporated as a baseline classifier to boost efficiency. However, it is vital to highlight that during implementation, just the classification approach is modified, while the remainder of the framework stays unchanged. In addition, the average of these outcomes for diverse datasets is provided in Table 5.1. The Waikato Environment for Knowledge Analysis (WEKA) is utilized for simulation purposes[5]. WEKA is an open-source performance evaluation tool that is commercially available.

1. It is clearly depicted that the suggested model has an average precision of 94.56% for the obtained data sets. Compared to this, DT achieved a precision value of 92.21%, whilst SVM recorded 91.76%. In the present context, the suggested BBN model is significantly more successful than other classifiers.

2. In terms of specificity analysis, the suggested model has a higher value of 93.45% than DT (91.02%) and SVM (90.22%). Consequently, the provided model is significantly superior.

3. The evaluation of the effectiveness of the suggested model also includes the analysis of sensitivity. In the aforementioned case, it can be noted that the provided model obtains a high value of 94.14% compared to 91.34% by DT and 90.95% by SVM. Based on the estimated findings from the datasets, it is demonstrated that the suggested model is more effective and efficient.

[5]Source:https://www.cs.waikato.ac.nz/ml/weka/

Table 5.1: Classification Efficiency; (Pr Precision, Sp Specificity, Se Sensitivity)

Model	**BBM**			**DT**			**SVM**		
Dataset	**Pr(%)**	**Sp(%)**	**Se(%)**	**Pr(%)**	**Sp(%)**	**Se(%)**	**Pr(%)**	**Sp(%)**	**Se(%)**
1900	**95.35**	**93.14**	**95.12**	**92.72**	**92.27**	**91.87**	**93.72**	**91.14**	**91.21**
3800	**93.69**	**92.89**	**93.12**	**92.64**	**91.68**	**92.88**	**91.35**	**92.63**	**92.32**
5700	**94.57**	**92.75**	**93.42**	**92.82**	**91.13**	**92.08**	**91.09**	**91.55**	**92.81**
7600	**94.75**	**92.84**	**91.12**	**93.73**	**92.05**	**90.87**	**92.72**	**91.51**	**91.72**
9500	**92.94**	**93.75**	**93.64**	**92.82**	**91.22**	**93.09**	**92.63**	**92.35**	**93.89**
11400	**93.58**	**91.89**	**92.34**	**93.21**	**92.14**	**92.07**	**93.09**	**92.06**	**92.86**
13300	**94.72**	**90.93**	**92.21**	**92.23**	**90.81**	**91.14**	**92.14**	**91.89**	**90.16**
15200	**93.62**	**91.54**	**93.62**	**93.12**	**90.45**	**92.15**	**93.04**	**90.19**	**92.34**
17100	**92.52**	**90.30**	**93.42**	**91.34**	**91.10**	**93.04**	**90.18**	**91.42**	**93.14**
19000	**93.42**	**92.01**	**92.42**	**92.22**	**91.89**	**92.10**	**92.24**	**91.04**	**92.40**

5.2.4 Prediction Efficacy

Prediction means to predict a missing or unknown element of a dataset. Prediction Efficacy measures the precision of the proposed approach in a smart academic context. Several statistical indicators are recorded to determine prediction efficacy. These include sensitivity, precision, and accuracy. The suggested model is contrasted with three cutting-edge models, namely K-NN, ANN, and SVM, to ascertain the overall values of the statistical parameters.

1. Figure 5.2 (a, b, c, and d) demonstrates that the suggested model attains an average precision of 96.76%. SVM was able to achieve 91.21% precision, whereas K-NN claimed 92.26%. In addition, ANN acquired average precision of 92.17%.

2. In Figure 5.2 (e, f, g, and h), the suggested model registered a better accuracy value of 97.34% than SVM (90.12%), K-NN (92.32%), and ANN (91.43%). It demonstrates the superiority of the proposed approach.

3. Figure 5.2 (i, j, k, and l) illustrates the outcomes of the sensitivity analysis of several prediction models. The suggested model's sensitivity value is 94.07%. Similarly, the results for the other models were 93.18% (K-NN), 92.62% (cANN), and 93.64% (SVM). From these results, it's clear that the model given is much better than other models.

   As a result, the gametic model of decision modeling outperforms other standard prediction models.

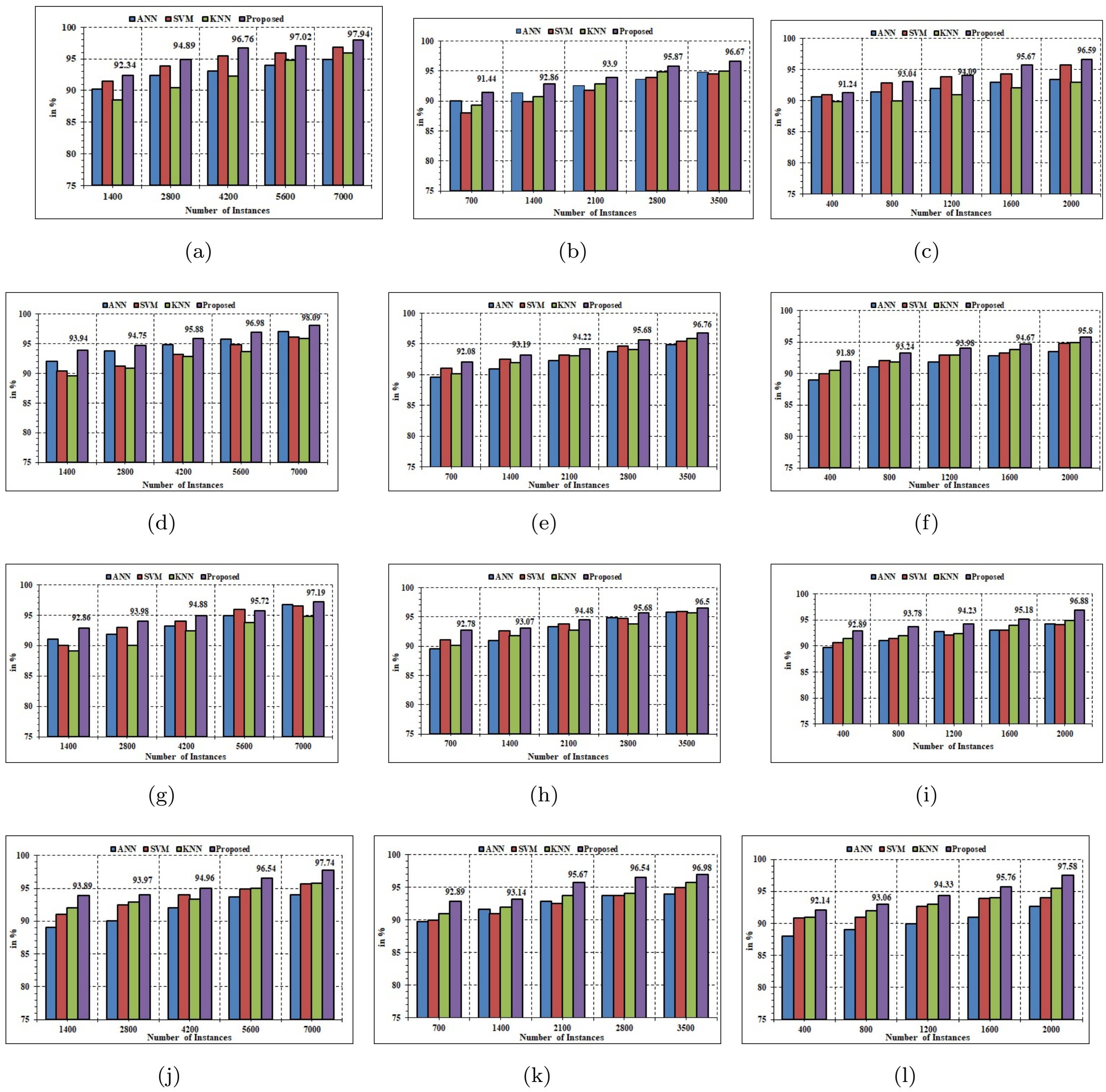


Figure 5.2: Prediction Efficacy (a,b,c,d):- Precision of Dataset SP, SAP, SPP, and SPA (e,f,g,h):- Accuracy of Dataset SP, SAP, SPP, and SPA (i,j,k,l):- Sensitivity of Dataset SP, SAP, SPP, and SPA

In addition, RMSE, MAE, RAE, and RRSE are computed for error rates in prediction. As demonstrated in Table 5.2, the suggested framework achieves the lowest error rates in terms of RMSE (2.78±.0.10%), MAE (4.17±0.11%), RAE (6.03±0.42%), and RRSE (2.39±0.33%). Moreover, Table 5.3 is depicting the results of various performance metrics of different datasets.

Table 5.2: Error Rates

Types of Error	**SVM**	**K-NN**	**ANN**	**Proposed**
RAE	5.64±0.28%	6.88±0.19%	6.47±0.29%	6.03±0.42%
RMSE	4.22±0.05%	5.12±0.10%	4.05±0.38%	2.78±0.10%
MAE	6.04±0.10%	9.24±0.45%	8.78±0.18%	4.17±0.18%
RRSE	7.54±0.15%	7.11±0.04%	7.32±0.72%	2.39±0.33%

Table 5.3: Results of Various Performance Metrics

Performance Metrics	**Methods**	**SP**	**SAP**	**SPP**	**SPA**
Temporal Delay (in sec)	ANN	32.74	32.17	30.42	35.84
	SVM	30.93	29.42	31.54	32.02
	KNN	29.24	28.84	29.13	54.03
	Proposed	**19.58**	**18.71**	**20.29**	**21.52**
Precision (in %)	ANN	91.7	92.48	92.19	92.04
	SVM	92.18	91.63	90.04	91.75
	KNN	92.58	92.53	92.07	91.89
	Proposed	**95.93**	**94.14**	**96.24**	**96.02**
Accuracy (in %)	ANN	92.65	92.30	92.14	90.05
	SVM	92.9	91.40	90.3	91.42
	KNN	92.04	93.04	91.92	90.54
	Proposed	**96.92**	**95.98**	**97.84**	**98.04**
Sensitivity (in %)	ANN	91.74	92.90	92.07	92.10
	SVM	93.59	93.14	92.91	93.02
	KNN	93.81	92.84	93.02	92.91
	Proposed	**95.42**	**94.50**	**94.67**	**94.04**

5.2.5 Reliability Analysis

One of the crucial aspects of a high-quality software solution is reliability. This is in accordance with ISO 25000 SQUARE requirements for assessing software product quality. Ensuring the model's reliability will boost the models' credibility and, as a result, their acceptance by end users. In general, reliability is a system's ability to execute and maintain activities under expected and unforeseen circumstances. There are numerous methods for estimating reliability, including model-independent and model-dependent estimation [249]. By varying the learning set, the model's independent reliability is calculated. The model-independent reliability estimates for particular predictions, which are implemented as estimations of either accuracy or prediction error as a positive or negative performance indicator [250]. These estimations are defined as metrics, with higher values representing more model accuracy and vice versa. The high reliability assessment indicates that the prediction model adheres to accuracy [251]. It is essential for evaluating the overall effectiveness of the proposed approach. The findings are compared to cutting-edge prediction models to assess the validity of the proposed model. The level of accuracy is determined by the variation in reliability patterns of 4 prediction models. With a rise in the number of data instances for experimental simulation, the proposed model's reliability is enhanced. Figure 5.3 illustrates the outcomes of the simulation. From this, it can be inferred that the proposed model has the greatest value of average reliability, i.e. 96.16%, compared to K-NN(91.25%), ANN(94.34%), and SVM(93.46%). Furthermore, the suggested quantum gametic decision-making has a constantly higher pattern, making it a suitable strategy for decision-making in the smart educational environment for student performance assessment.

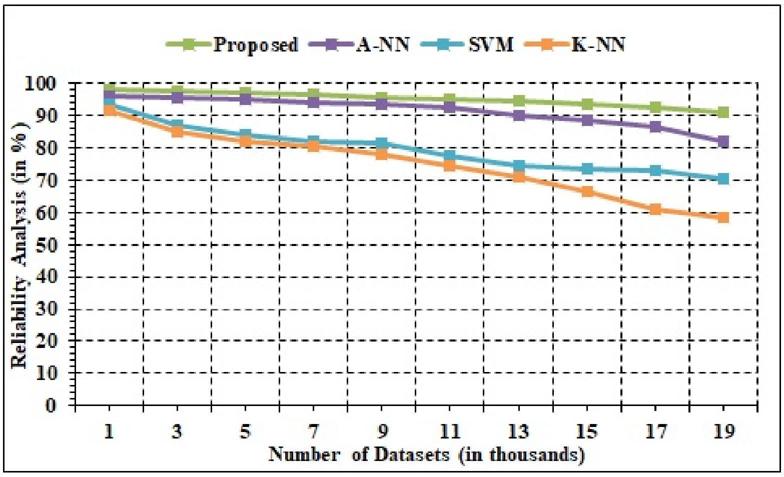


Figure 5.3: Reliability Analysis

5.2.6 Stability Analysis

System stability is a widely-used metric for evaluating the overall efficacy of a system [252]. In particular, the stability of a learning algorithm refers to how the system's output alters when the training dataset is modified. A learning algorithm is considered stable if the learned model is not significantly affected by changes to the training dataset. The predictability of the system influences user trust in the system. Furthermore, a prediction system is stable if its forecasts do not fluctuate greatly within a narrow range of data. When applied to a big dataset, it evaluates and anticipates the model's total stability [253]. Mean Absolute Shift (MAS) is utilized to evaluate the system's stability. The MAS value varies from 0 to 1, where 0 represents the least stable system and 1 represents the most stable system. Figure 5.4 demonstrates that the MAS has the lowest value of 0.54 and the highest value of 0.85, with an average value of 0.70. It is determined that the proposed methodology presented for analyzing student and teacher performance is extremely effective and useful.

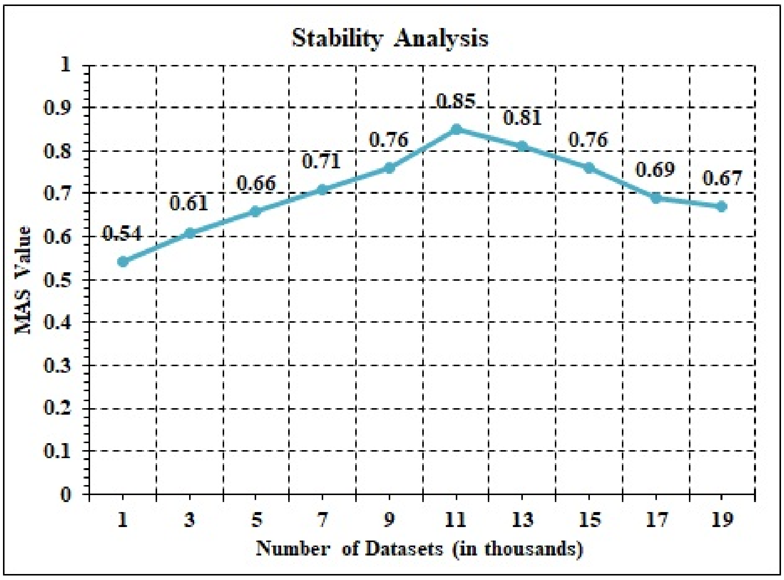


Figure 5.4: Stability Analysis

5.2.7 Discussion

Numerous factors, such as temporal efficiency, prediction efficiency, classification efficiency, reliability analysis, and stability analysis are examined for the proposed system. Notably, several key points are discussed ahead.

1. Using the SP, SAP, SPP, and SPA datasets, the proposed model is able to acquire temporal delay averaging to 19.58 seconds, 18.71 seconds, 20.29 seconds, and 21.52 seconds, respectively. It is relevant in light of the present research domain.

2. The prediction efficiency is expressed in terms of precision, accuracy, and sensitivity. Using the SP, SAP, SPP, and SPA datasets, the current technique achieved an average precision value of 96.32%, 95.16%, 97.9%, and 96.74%, respectively. Based on these findings, it can be said that the presented system achieves a greater value of precision than the other existing models. Moreover, the provided model achieved accuracy numerating to 96.8%, 97.4%, 95.7%, and 96.9% utilizing the SP, SAP, SPP, and SPA datasets, respectively. Furthermore, the presented model has a sensitivity value numerating to 95.04%, 94.5%, 97.18%, and 94.02% for the acquired datasets.

3. The classification efficiency for the acquired datasets is expressed in terms of precision, specificity, and sensitivity. The current technique achieved an average precision value of 94.56%. Based on these findings, it can be said that the presented system achieves a greater value of precision than the other existing models. Moreover, the provided model achieved specificity numerating to 93.45%. Furthermore, the presented model has a sensitivity value numerating to 94.14%.

4. The presented model has a reliability value of 96.16 %, which is significantly greater than the reliability score of other strategies. The reliability score

increases in proportion to the size of the dataset, making it well-suited for handling large data sets.

5. The proposed system has a high degree of stability and is well suited for evaluating large datasets in the context of predicting the performance of students and teachers. The Mean Absolute Shift (MAS) measure used in stability analysis has an average value of 70%. The results indicate that the presented system has the lowest MAS value of 54% and a highest MAS value of 85%.

5.3 Inferences

Machine Learning is an important area of research in today's world since it executes jobs without being programmed in advance. Machine learning approaches are generically classified as supervised, unsupervised, semi-supervised, and reinforcement learning. When historical data is available, supervised learning is used to extract future occurrences from training datasets. The most common and efficient supervised learning algorithms are SVM, DT, and KNN. Unsupervised learning uncovers hidden patterns by using unlabeled input data. The most prevalent unsupervised learning techniques include K-mean clustering, K-nearest neighbor, Hierarchical clustering, and Principal component analysis. Semi-supervised learning is a kind of machine learning that involves training models using more unlabeled data than labeled data. It is a combination of unsupervised learning (without labeled data) and supervised learning (with labeled data). ANN is a subfield of machine learning that deals with procedures influenced by the function or structure of the brain. The research conducted in the context of this chapter included a thorough examination of the use of machine learning algorithms mentioned above, for evaluating the performance of students and teachers. Experiments showed that the constantly higher pattern of the proposed quantum gametic decision-making enables it an effective technique for decision-making in the smart educational environment for the examination of student and teacher performance based on temporal efficiency, prediction efficiency, classification efficiency, reliability, and stability.

Chapter 6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

This study presents a comprehensive game-theoretic framework for academic evaluation to predict the performance of students. The proposed system for academic evaluation is composed of 4 layers: the Data Acquisition and Preprocessing (DAP) layer, the Data Classification (DC) layer, the Data Mining (DM) layer, and the Gametic Decision-Modeling (GDM) layer. To summarise, the proposed research work is divided into three major components: data acquisition, data cleaning, and the deployment of Bayesian belief networks to classify the data into implicit and explicit class events. To validate the model, a large number of simulations are carried out, and the results are compared to current prediction models. Several statistical criteria like, temporal delay, classification efficiency, prediction efficiency, reliability, and stability are used to determine that the effectiveness of proposed system. The validation of the model proposed was carried out on the challenging datasets. To assess the improved performance of the developed framework, a total of 19,000 observations from all datasets are analyzed. Using the SP, SAP, SPP, and SPA datasets, the proposed model is able to acquire temporal delays averaging 19.58 seconds, 18.71 seconds, 20.29 seconds, and 21.52 seconds, respectively. It is significant in terms of the current research domain. Accuracy, Precision, and Sensitivity are used to quantify prediction efficiency. The current approach achieved an average accuracy of 96.8%, 97.4%, 95.7%, and 96.9%, respectively. Based on these findings, it can be concluded that the presented model outperforms other state-of-the-art models in terms of accuracy. Additionally, the provided model achieved the highest value of precision and sensitivity. The presented system has a reliability score of 96.16%, which is greater than that of other methodologies. The reliability score improves as the dataset increases in size, making it suited for large datasets. The Mean Absolute Shift (MAS) metric, which is employed in stability analysis, has an average value of 70%. The findings show that the offered system has a minimum MAS value of 54% and a maximum MAS value of 85%. Additionally, the findings indicate that the existing prediction approach is capable of evaluating the performance of students effectively and efficiently. Moreover, mathematical analysis has also been carried out to depict the performance of the proposed framework.

6.2 Future Directions

Research is an evolutionary process, and the completion of one research problem is the beginning of many upcoming works. The outcomes of the thesis pave the way for future research and simplify things for administrators, researchers, and educators to make well-informed suggestions in the field of smart education. The following section discusses the various main future research directions:

1. Traditional education has led to greater dropout rates and an inadequate online learning environment for students. Future research should focus on applying the notion of Game Theory to educational institution ratings and online education.

2. In the coming years, there will be a lot of studies on online or hybrid learning in education. Work to discover broader topics of concern to researchers, the impact of research in many domains, the patterns and growth of online and hybrid learning methodologies, and the viability of cross-disciplinary theories for online and hybrid learning will help to determine the future of research in this discipline.

3. The convergence between online and hybrid classroom educational environments and job competencies will also be addressed. Measures that show how academic knowledge is used in the workplace must be backed up by classroom evaluation indicators, such as student-reported progress or credits earned in online or hybrid programs.

4. There are no technological tools for assessing the quality of education. In a broader sense, advance software solutions for providing students with access to a great education can be designed.

5. Personal information extraction from students, teachers, and even management personnel is pervasive in smart classroom environments. Thus, there is a need for more research on the ethical consequences of data collection, such as privacy and data security.

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