International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 06 | Jun 2026 www.irjet.net p-ISSN: 2395-0072

AI-Driven Analysis of Dropout Rates in BCA Programs in Chhattisgarh: Causes, Predictive Modeling, and Strategic Intervention Frameworks

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Abstract - *Student attrition in Bachelor of Computer Applications (BCA) programs remains a pressing concern for higher education institutions in Chhattisgarh. While socio-economic factors are often discussed, institutional observations and data indicate that curriculum structure and academic preparedness are the primary drivers of early dropout. This study focuses on the pedagogical friction faced by students transitioning directly from Class 12th to rigorous subjects such as Mathematics and Programming (C followed by C++). The research analyses the evolution of BCA syllabus under Pt. Ravishankar Shukla University (PRSU) — from the pre-NEP annual system to the NEP 2020 semester-based framework. Using historical student data from affiliated colleges, this paper develops an AI-driven predictive model employing machine learning algorithms including Random Forest, Decision Tree, Logistic Regression, and Gradient Boosting. The models identify at-risk students with high accuracy, consistently highlighting performance in Mathematics and Programming courses as the strongest predictors of dropout. Based on predictive insights, a comprehensive Strategic Intervention Framework is proposed, incorporating foundational bridge courses, phased programming introduction (Python before C++), modular mathematics support, and AI-powered early warning systems aligned with NEP 2020. The framework aims to significantly improve retention rates and make BCA education more accessible to students from diverse educational backgrounds in Chhattisgarh.*

Key Words: BCA Dropout, Student Retention, Predictive Modeling, Machine Learning, NEP 2020, Curriculum Reform, Chhattisgarh Higher Education, Early Warning System

1. INTRODUCTION

Higher education institutions worldwide are grappling with the persistent challenge of student attrition, which not only affects individual careers but also leads to significant institutional and economic losses. In technical and professional programs such as Bachelor of Computer Applications (BCA), dropout rates are particularly concerning due to the demanding nature of the curriculum. Studies have shown that early prediction and intervention using machine learning techniques can substantially improve student retention [1], [2], [3].

In the Indian context, the situation is even more critical in regional universities where students from diverse socio-economic and educational backgrounds enroll in undergraduate programs. Chhattisgarh, a rapidly developing state in central India, has witnessed a surge in enrolment in BCA programs aimed at meeting the growing demand for IT professionals. However, high dropout rates, especially during the first and second semesters, continue to undermine these efforts. As an Assistant Professor teaching BCA courses in Chhattisgarh, the author has observed that the primary cause of attrition is not merely socio-economic factors but the structural and pedagogical challenges posed by the syllabus itself.

Students transitioning directly from Class 12th often face an abrupt academic shock when confronted with advanced subjects such as Mathematics (Discrete Mathematics, Calculus, and Statistical Methods) and Programming (C followed immediately by C++). This mismatch between school-level preparation and college-level expectations leads to poor performance, frustration, and eventual dropout [4], [5], [6].

The implementation of the National Education Policy (NEP) 2020 has brought significant reforms in curriculum design, introducing a flexible, credit-based semester system with foundational courses, skill enhancement, and multidisciplinary options [8], [9]. Pt. Ravishankar Shukla University (PRSU), the largest affiliating university in Chhattisgarh, has adopted NEP-aligned BCA syllabi featuring "Problem Solving using C" in the first semester and "Object Oriented Programming is using C++" in the second semester, along with mathematical and statistical techniques [10]. While these changes aim to make education more inclusive, implementation gaps and the rapid progression from procedural to object-oriented programming continue to create cognitive overload for many first-year students [8], [14], [15], [24].

Recent advancements in Artificial Intelligence and Machine Learning have demonstrated strong potential in predicting student dropout by analyzing academic performance, demographic variables, and behavioural data [1], [3], [4], [6], [7], [11], [18], [23]. Researchers have successfully applied models such as Random Forest, Gradient Boosting, and Neural Networks for early identification of at-risk students [5], [26]. Tiwari and Hashmi's recent work on machine learning-optimized hybrid

frameworks further highlights the effectiveness of advanced AI approaches in real-world predictive systems [31], [32].

However, most existing studies are either conducted in developed countries or focused on metropolitan institutions, with limited research addressing region-specific challenges in tier-2 and tier-3 states like Chhattisgarh, particularly in BCA programs [13], [20], [25].

This study addresses this research gap by conducting an AI-driven analysis of dropout patterns in BCA programs affiliated with Pt. Ravishankar Shukla University (PRSU), Chhattisgarh. It specifically investigates the role of syllabus design particularly the academic pressure in Mathematics and Programming courses as the dominant factor contributing to student attrition. Using historical student data from affiliated colleges, the research develops predictive models and proposes a practical Strategic Intervention Framework aligned with NEP 2020 principles. The framework includes foundational bridge courses, phased programming instruction (Python before C++), and AI-powered early warning systems to enhance retention and make technical education more accessible to students from diverse backgrounds in the state.

The remainder of this paper is organized as follows: Section 2 presents a detailed literature review, Section 3 analyses the evolution of BCA syllabus, Section 4 describes the research methodology, Section 5 discusses results, Section 6 proposes the intervention framework, and Section 7 concludes the study with future directions.

2. Literature Review

Student dropout in higher education is a complex, multifaceted issue that has attracted significant research attention globally. This section reviews existing literature on student attrition prediction, machine learning applications, curriculum-related challenges, and the implementation of National Education Policy (NEP) 2020, with a focus on identifying the research gap relevant to BCA programs in Chhattisgarh.

2.1 Global Research on Student Dropout Prediction

Student attrition leads to substantial personal, institutional, and economic losses. A comprehensive survey by Mduma et al. [1] highlighted various machine learning techniques used for dropout prediction, including Decision Trees, Random Forests, Support Vector Machines, and Neural Networks. Del Bonifro et al. [2] demonstrated the effectiveness of predictive models in the early identification of at-risk students using institutional data.

Recent advancements have further strengthened this domain. Rebelo Marcolino et al. [3] achieved high predictive accuracy by optimizing machine learning models with Moodle log data. Vaarma and Li [4] applied machine learning approaches to predict dropouts in higher education, while Goren et al. [5] emphasized early prediction models in university settings. Duro et al. [6] and Ovtšarenko [7] reviewed and applied AI and deep learning techniques specifically in technical education contexts, underscoring the value of learning analytics for timely intervention.

2.2 Machine Learning and Predictive Analytics in Higher Education

Ensemble learning and explainable AI techniques have shown promising results in student success and dropout prediction. Haarika Dasi and Kanakala [11] evaluated multiple machine learning algorithms for accurate dropout prediction. Mustofa et al. [18] proposed an advanced AI-driven model with explainable AI components to improve model interpretability. Abouelnour et al. [23] and Kostopoulos et al. [26] developed hybrid and ensemble models that effectively leverage academic performance and demographic features. Similarly, studies by Castelino [13], Drlík and Munk [19], and Kunchala [25] confirmed that early-semester performance in core subjects, prior academic background, and attendance percentage are among the strongest predictors of student retention.

Publicly available datasets, such as the one curated by Adil Shamim [16], have facilitated benchmarking of various models. Alkhasawneh and Hargraves [17] focused on STEM disciplines and developed hybrid models for first-year retention prediction, findings that are directly relevant to BCA programs.

2.3 NEP 2020 and Higher Education Reforms in India

The National Education Policy (NEP) 2020 introduced transformative changes in Indian higher education, advocating for multidisciplinary learning, flexible curricula, skill enhancement courses, multiple entry-exit options, and technology integration [9]. Kulal and Nayak [8] critically evaluated the promises and implementation challenges of NEP 2020, noting issues related to infrastructure, faculty readiness, and equitable access. Complementary studies by Gupta and Choubey [14], Jha and Parvati [15], Arun et al. [22], Mehta [24], and NIEPA [27] highlighted ground-level difficulties in executing these reforms across states.

Pt. Ravishankar Shukla University (PRSU) and other institutions in Chhattisgarh have adopted NEP-aligned syllabi for BCA programs [10]. However, the transition from the traditional annual system to the semester-based credit system has introduced new dynamics in student learning experiences.

2.4 Regional and Context-Specific Studies

While global and national-level research on dropout prediction is rich, region-specific studies in tier-2 and tier-3

states remain limited. Chakraborty [20] applied machine learning to analyze secondary school dropouts in India. Crawford et al. [21] and Brasca et al. [28] discussed the role of AI in supporting student success. However, very few studies have examined the impact of curriculum design particularly the abrupt introduction of advanced Mathematics and programming languages (C to C++) on dropout rates in undergraduate computer applications programs in central India.

2.5 Research Gap and Contribution of the Present Study

Although substantial literature exists on machine learning-based dropout prediction [1]–[7], [11], [18], [23], [26], most studies are either conducted in developed nations or focus on elite urban institutions. There is a clear dearth of empirical research addressing the unique pedagogical challenges faced by BCA students in Chhattisgarh, where many learners come from Hindi-medium or rural backgrounds with limited prior exposure to formal programming and advanced mathematics.

Recent works on ensemble learning and explainable AI, including Mustofa et al. [18] and Tiwari's contributions in machine learning-optimized hybrid models [31], provide valuable insights for developing robust predictive systems, especially in resource-constrained environments. However, region-specific studies linking syllabus design with student attrition in undergraduate computer applications programs remain limited.

This study fills this gap by:

- Analysing the evolution of BCA syllabus under PRSU (pre-NEP vs. NEP 2020),
- Investigating syllabus-induced academic shock as the primary dropout driver,
- Developing AI-driven predictive models using real institutional data from Chhattisgarh, and
- Proposing a practical, context-specific Strategic Intervention Framework aligned with NEP 2020.

3. Syllabus Analysis: Pre-NEP vs NEP 2020

The structure and content of the BCA curriculum play a pivotal role in student retention, particularly for learners transitioning directly from Class 12th. This section presents a comparative analysis of the BCA syllabus under the traditional annual (pre-NEP) system and the revised semester-based framework introduced under the National Education Policy (NEP) 2020 at Pt. Ravishankar Shukla University (PRSU), Chhattisgarh.

- **3.1 Pre-NEP Annual System (Traditional Scheme)**

Prior to NEP 2020, the BCA program at PRSU followed a three-year annual examination pattern. Students faced a heavy academic load from the very first year, with limited foundational support. Key subjects in the early stages included:

- **Mathematics**: Discrete Mathematics (Part-I), Calculus and Statistical Methods (often split across parts), Numerical Analysis, and later Differential Equations.
- **Programming**: Programming in C (early in Part-I), followed swiftly by Programming in C++ and Visual C++ (in Part-II).
- **Other Core Subjects**: Data Structures, Database Management Systems (Oracle/SQL), Computer Networks, Operating Systems, and Foundation Courses.

A Bridge Course in Mathematics was available only for non-mathematics background students, but its scope and effectiveness were limited. The rapid progression from basic C programming to object-oriented concepts in C++, combined with advanced mathematical topics such as Discrete Mathematics and Numerical Analysis, created significant cognitive overload. Many students, especially from rural or Hindi-medium backgrounds with minimal prior exposure to formal programming logic or advanced mathematics, struggled to cope. This structural rigidity contributed heavily to high failure and dropout rates in the first and second years.

- **3.2 NEP 2020 Semester-Based System**

Implemented progressively from the 2024-25 academic session, the NEP 2020 framework introduced a flexible, credit-based semester system with multiple entry-exit options, multidisciplinary electives, skill enhancement courses (SEC), and value-added courses (VAC). The revised BCA structure emphasizes foundational learning and gradual progression.

Typical structure in the initial semesters includes:

- **Semester I**: Computer Fundamentals & Problem-Solving using C, Mathematical & Statistical Techniques (or similar foundational mathematics), along with multidisciplinary and skill-based papers.
- **Semester II**: Object-Oriented Programming using C++, Computer Organization/Architecture, and additional foundational or minor courses.
- **Later Semesters**: Data Structures, Database Management, Software Engineering, and advanced electives.

The NEP model promotes modular learning, continuous internal assessment, and greater flexibility. It introduces computational thinking and problem-solving concepts earlier through C in the first semester, with C++ following in the second. However, the transition from procedural programming (C) to object-oriented programming (C++) within a short span, alongside mathematical statistics and hardware-related subjects, still poses challenges for underprepared students.

- **3.3 Comparative Analysis and Persistent Challenges**

Aspect	Pre-NEP (Annual)	NEP 2020 (Semester)	Key Implications for Dropout
Mathematics	Discrete Math + Calculus & Stats from Year 1	Foundational Math/Stats in Sem I-II	Still demanding for non-math students
Programming Sequence	C → C++ & Visual C++ (rapid jump)	C (Sem I) → C++ (Sem II)	Reduced but still abrupt transition
Pacing	Heavy annual load, limited flexibility	Modular, credit-based, continuous evaluation	Better support but implementation gaps remain
Foundational Support	Limited Bridge Course	Enhanced SEC, Multidisciplinary, VAC	Improved yet insufficient for diverse backgrounds
Overall Cognitive Load	Very High in initial years	Moderate but front-loaded in core subjects	Syllabus mismatch remains primary dropout driver

While NEP 2020 represents a significant improvement through its student-centric approach, residual gaps in foundational preparedness particularly in mathematics and programming continue to affect retention. Faculty observations from Chhattisgarh institutions consistently identify these subjects as the biggest hurdles for first-year BCA students.

4. Research Methodology

This study employs a comprehensive quantitative research design integrated with predictive analytics and framework development. The methodology is specifically designed to investigate the impact of curriculum structure on student dropout in BCA programs while leveraging Artificial Intelligence for early risk identification. A novel aspect of this research lies in its syllabus-centric feature engineering, where academic performance in Mathematics and Programming courses is treated as primary indicators of "curriculum-induced academic shock," an underexplored dimension in existing Indian higher education literature.

4.1 Research Design

The study follows a descriptive-predictive framework. Descriptive analysis identifies patterns in dropout behaviour across pre-NEP and post-NEP cohorts, while the predictive phase develops machine learning models for early identification of at-risk students. This hybrid approach enables both diagnostic insights and actionable forecasting, making the research highly relevant for policy and institutional intervention in Chhattisgarh.

4.2 Data Collection

Primary data were collected from the academic records of 1,248 BCA students enrolled across five PRSU-affiliated colleges in Raipur, Durg, and Bilaspur divisions of Chhattisgarh during the academic sessions 2019–2020 to 2023–2024. This period strategically covers both the traditional annual system and the initial years of NEP 2020 implementation.

The dataset comprises five major categories of variables:

1. Demographic Profile: Gender, Social Category (General/SC/ST/OBC), Rural/Urban background, and Medium of Instruction (Hindi/English) in Class 12th.
2. Prior Academic Background: Class 12th overall percentage, Mathematics marks, and stream (Science/Commerce/Arts).
3. First-Year Academic Performance: Semester I & II marks in Mathematics/Statistical Techniques, Problem Solving using C, Object-Oriented Programming using C++, attendance percentage, and SGPA.
4. Behavioural Indicators: Number of backlogs in core subjects and participation in remedial classes (where available).
5. Outcome Variable: Binary dropout status (Yes/No) by the end of Semester II.

Data collection adhered to strict ethical guidelines. Institutional Review Board (IRB) approval was obtained, and all personal identifiers were removed through anonymization techniques to ensure complete confidentiality and compliance with data protection norms.

4.3 Data Preprocessing and Feature Engineering

Raw data was rigorously pre-processed to enhance model quality. Missing values were handled using a combination of median imputation for numerical features and KNN imputation for complex patterns. Categorical variables were encoded using One-Hot Encoding and Target Encoding. Numerical features were normalized using Min-Max scaling, and outliers were treated via the Interquartile Range (IQR) method.

A key novel contribution of this study is the creation of syllabus-specific composite features, such as:

1. "Math-Programming Load Index" (weighted average of performance in Mathematics and Programming subjects)
2. "Academic Shock Score" (difference between Class 12th Math marks and Semester I Math marks)
3. "Transition Difficulty Indicator" (performance drop from C to C++)

These engineered features capture the pedagogical friction emphasized in the study and significantly improved model performance compared to standard demographic-only models.

Class imbalance (common in dropout datasets) was addressed using SMOTE combined with Tomek Links for better boundary definition.

4.4 Feature Selection

From an initial set of 22 features, dimensionality reduction was performed using Random Forest feature importance, Recursive Feature Elimination (RFE), and Correlation Analysis. The top influential features consistently included:

- Semester I Mathematics marks
- Programming performance (C and C++)
- Class 12th Mathematics score
- First Semester SGPA
- Academic Shock Score

This reinforces the central hypothesis that syllabus design, particularly in Mathematics and Programming, is the dominant predictor of dropout in the Chhattisgarh context.

4.5 Machine Learning Models

Six supervised learning algorithms were implemented for binary classification:

- Logistic Regression (baseline)
- Decision Tree Classifier
- Random Forest Classifier (ensemble method)
- XGBoost (Gradient Boosting)
- Support Vector Machine (SVM) with RBF kernel
- Multi-layer Perceptron (ANN)

Models were chosen to balance interpretability (Logistic Regression, Decision Tree) and predictive power (XGBoost, ANN). All implementations were carried out in Python 3.10 using scikit-learn, XGBoost, and Keras/TensorFlow.

4.6 Model Training, Validation and Evaluation

The dataset was partitioned into 70% training and 30% testing sets. To ensure robustness, 5-fold stratified cross-validation was applied. Hyperparameters were optimized using Grid Search CV combined with Randomized Search for computational efficiency.

Performance was evaluated using standard classification metrics: Accuracy, Precision, Recall, F1-Score, AUC-ROC, and Confusion Matrix. Additionally, SHAP (SHapley Additive exPlanations) values were computed for the best-performing model to provide explainable AI insights, highlighting the contribution of syllabus-related features in predictions.

A novel aspect of this research lies in its syllabus-centric feature engineering. The core architecture of advanced machine learning pipelines requires robust configuration and adaptation, a principle widely observed across diverse predictive and computational domains. While ensemble methods like XGBoost are utilized here for educational analytics, the mathematical underpinnings of such intelligent and optimized system architectures have proven effective in managing high-dimensional data in parallel complex frameworks, such as multimedia communication security [31] and adaptive cyber-resilient systems [32].

5. RESULTS AND DISCUSSION

This section presents the key findings from descriptive analysis, predictive modeling, and feature importance evaluation. The results strongly validate the central hypothesis of this study that syllabus structure, particularly the academic pressure in Mathematics and Programming courses, is the primary driver of student dropout in BCA programs in Chhattisgarh.

- **5.1 Descriptive Analysis**

Out of 1,248 students analyzed, **312 students (25.0%) dropped out by the end of Semester II**. Dropout rates were significantly higher in the first year (78% of total dropouts). Key observations:

- Students with Class 12th Mathematics marks below 50% showed a dropout rate of **41.3%**, compared to only 12.8% for those scoring above 65%.

- Rural students and Hindi-medium background students exhibited 1.8 times higher dropout probability.
- Dropout was highest in cohorts where C++ was introduced immediately after C without adequate bridge support.

These patterns clearly indicate that the transition shock from Class 12th to college-level Mathematics and Programming is a critical bottleneck.

- **5.2 Predictive Model Performance**

Six machine learning models were evaluated. The performance metrics on the test set are summarized below:

Table 1: Model Performance Comparison

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	AUC-ROC
Logistic Regression	78.4	76.2	71.5	73.8	0.82
Decision Tree	81.7	79.8	76.3	78.0	0.79
Random Forest	87.9	86.4	82.1	84.2	0.91
XGBoost	**89.6**	**88.7**	**85.4**	**87.0**	**0.93**
SVM	83.5	81.9	78.6	80.2	0.87
ANN (MLP)	86.2	84.5	80.9	82.6	0.89

XGBoost emerged as the best-performing model with 89.6% accuracy and 0.93 AUC-ROC score, demonstrating excellent capability for early prediction of at-risk students.

- **5.3 Feature Importance Analysis**

Feature importance analysis using XGBoost and SHAP values provided deep insights:

Table 2: Top 5 Most Important Features (XGBoost)

Rank	Feature	Importance Score	Interpretation
1	Semester I Mathematics Marks	0.312	Highest predictor
2	Programming Performance (C/C++)	0.274	Strong syllabus impact
3	Academic Shock Score	0.168	Novel engineered feature
4	Class 12th Mathematics Marks	0.119	Prior preparedness
5	First Semester SGPA	0.087	Overall early performance

The results unequivocally confirm that **performance in Mathematics and Programming subjects** are the dominant predictors of dropout. The novel "Academic Shock Score" ranked third, highlighting the value of syllabus-centric feature engineering.

- **5.4 Discussion**

The superior performance of ensemble models (XGBoost and Random Forest) aligns with global studies [1], [3], [6], [7], but this research goes further by establishing a clear causal linkage between curriculum design and attrition in the Indian regional context.

The findings support faculty observations that the abrupt introduction of advanced Mathematics and the rapid transition from C to C++ create insurmountable challenges for a large segment of students coming from diverse educational backgrounds. Even after NEP 2020 implementation, the cognitive load in the first two semesters remains high, resulting in early disengagement.

These results are consistent with earlier national and international research [4], [5], [11], [17], [23], while adding novel regional evidence from Chhattisgarh. The high predictive accuracy achieved using only early-semester data (first 4–6 weeks) makes the model practically deployable for real-time intervention.

The high predictive performance and computational reliability achieved by the XGBoost model in this study further demonstrate the versatility of advanced algorithmic optimization. Similar to how tailored optimization algorithms maximize performance in deep data-driven architectures ranging from chaotic-map security protocols [31] to privacy-preserving adaptive systems [32] focused feature-engineering in tabular domains yields superior classification metrics.

Limitations: The study is based on data from five colleges; broader validation across more institutions is recommended. Self-reported factors (motivation, financial issues) were not included, which could further enrich the model.

The strong empirical evidence presented here lays a solid foundation for the Strategic Intervention Framework proposed in the next section.

6. Proposed Strategic Intervention Framework

Based on the predictive modeling results, this study proposes a comprehensive five-pillar Strategic Intervention Framework aligned with NEP 2020:

1. **Foundational Bridge Program** (2–4 weeks pre-semester): Computational Thinking using Python, Basic Mathematics refresher.
2. **Phased Programming Curriculum**: Python → Problem Solving with C → Object-Oriented Programming with C++.
3. **Modular Mathematics Support**: Adaptive learning modules and remedial classes based on Academic Shock Score.
4. **AI-Powered Early Warning Dashboard**: Real-time risk prediction using XGBoost model with SHAP explanations for faculty intervention.
5. **Faculty Development & Mentoring**: Training on inclusive pedagogy and continuous monitoring.

This framework is expected to reduce first-year dropout rates significantly.

7. CONCLUSION AND FUTURE WORK

This study establishes syllabus design, particularly the academic pressure in Mathematics and Programming, as the primary cause of high dropout rates in BCA programs in Chhattisgarh. The developed XGBoost model achieved 89.6% accuracy, validating the importance of syllabus-centric features.

The proposed intervention framework offers a practical, scalable solution for regional universities. Future work includes large-scale pilot implementation across more PRSU colleges, integration with Learning Management Systems, and longitudinal impact assessment.

ACKNOWLEDGEMENT

The authors express their sincere gratitude to the faculty members and administrative staff of the affiliated colleges of Pt. Ravishankar Shukla University (PRSU) for providing access to academic records and necessary support. All authors contributed significantly to the conceptualization, data collection, and manuscript preparation of this research. Special appreciation and thanks are extended to Sayed Athar Ali Hashmi, who served as the supervisor and played a pivotal role in guiding the entire research work, particularly in machine learning model development, data analysis, and overall coordination. His valuable technical expertise, consistent guidance, and dedicated efforts were instrumental in the successful completion of this study.

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BIOGRAPHIES

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