

WHY PYTHON PROGRAMMING IN PHARMACEUTICAL SCIENCE?

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DOI: <https://doi.org/10.5281/zenodo.23037327>



How to cite this Article: Dr. Surendra Pardhi^{1*}, Mr. Gajanand Dashahare², Mr. Govind Kirar³, Dr. Vaibhav Solanki⁴ (2026). Why Python Programming In Pharmaceutical Science?. World Journal of Pharmaceutical and Life Sciences, 12(10), 137–144. This work is licensed under Creative Commons Attribution 4.0 International license.

Article Received on 01/09/2026

Article Revised on 23/09/2026

Article Published on 01/10/2026

ABSTRACT

The rapid digital transformation of the pharmaceutical sector has created a growing demand for professionals who can combine pharmaceutical knowledge with computational and data-analytic skills. Python programming has emerged as a valuable educational and professional tool because of its simple syntax, open-source nature, extensive scientific libraries, and applicability in data analysis, visualization, automation, pharmacokinetics, pharmacovigilance, formulation research, clinical studies, bioinformatics, quality control, and artificial intelligence-assisted drug development. The revised B.Pharm curriculum introduced by the Pharmacy Council of India under the NEP 2020 framework recognizes this changing professional environment by including **Basics of Python Programming for Pharmaceutical Sciences** at the undergraduate level. This curricular development represents an important shift from conventional computer literacy toward structured programming, pharmaceutical data handling, scientific visualization, and computational problem-solving. The present review examines the rationale for incorporating Python programming into pharmaceutical education and correlates the revised curriculum with emerging requirements of the pharmaceutical industry. Particular emphasis is placed on the relevance of NumPy, Pandas, Matplotlib, data cleaning, CSV/Excel processing, pharmacokinetic datasets, adverse drug reaction analysis, dissolution-profile visualization, research data management, and introductory pathways toward machine learning and artificial intelligence. The review further discusses the potential contribution of Python competency to pharmaceutical research and development, quality assurance, manufacturing, regulatory science, clinical research, pharmacovigilance, and Pharma 4.0. Challenges related to faculty training, infrastructure, limited instructional hours, data integrity, validation, and responsible use of artificial intelligence are also considered. It is concluded that Python should not be regarded merely as an additional programming subject in the pharmacy curriculum, but as a foundational digital competency capable of improving data literacy, research capability, interdisciplinary collaboration, and industrial readiness among future pharmacy graduates. This article cover subject wisr role of python programming in pharmaceutical industries.

KEYWORDS: Python Programming; Pharmaceutical Sciences; B.Pharm Curriculum; Pharmaceutical Industry; Data Analytics; Artificial Intelligence; Machine Learning; Pharma 4.0; Pharmacy Education; Computational Pharmacy.

1. INTRODUCTION

Pharmaceutical science has traditionally been grounded in chemistry, biology, pharmacology, pharmaceuticals, pharmacognosy, pharmaceutical analysis, quality assurance, and clinical sciences. However, the increasing digitalization of pharmaceutical research and

manufacturing has fundamentally changed the skills expected from pharmaceutical professionals. Modern pharmaceutical organizations generate enormous quantities of data from.

- drug-discovery platforms;
- high-throughput screening;
- molecular modelling;

- analytical instruments;
- formulation-development studies;
- dissolution testing;
- pharmacokinetic studies;
- clinical trials;
- pharmacovigilance systems;
- manufacturing processes;
- environmental monitoring;
- quality-control laboratories; and
- regulatory and quality-management systems.

The ability to generate, organize, analyze, visualize and interpret these datasets has therefore become an important component of contemporary pharmaceutical practice.

Computational methods are particularly important in pharmacometrics and quantitative pharmacology, where machine learning and modelling approaches are increasingly being investigated for handling complex pharmaceutical and biomedical datasets.

Against this background, the Pharmacy Council of India has introduced a major curricular change. The 2026 B.Pharm syllabus as per NEP 2020 places Basics of Python Programming for Pharmaceutical Sciences (BP101T) in Semester I as a core subject carrying 2 credits and 30 instructional hours.

The new curriculum is therefore not simply adding computer literacy; it represents a shift toward computational and data-driven pharmaceutical education.

2. WHY PYTHON?

Python is a high-level, general-purpose programming language widely used for scientific computing, data analysis, automation, visualization and artificial intelligence.

For pharmacy education, Python has several advantages.

- Simple syntax suitable for beginners.
- Large ecosystem of scientific libraries.
- Strong support for numerical and statistical analysis.
- Applications in machine learning and AI.
- Excellent data visualization capabilities.
- Ability to process CSV and Excel datasets.
- Usefulness in research automation.
- Compatibility with notebooks and interactive learning.
- Applicability across multiple pharmaceutical disciplines.
- Transferability of skills to industrial data-analysis environments.

Importantly, Python does not replace pharmaceutical knowledge. Instead, it provides a computational layer through which pharmaceutical knowledge can be applied to real-world data.

3. EVOLUTION OF PHARMACY EDUCATION TOWARD COMPUTATIONAL COMPETENCY

The evolution of pharmacy education can broadly be represented as.

• Traditional Pharmacy Education

Chemistry → Biology → Pharmaceutics → Pharmacology → Pharmaceutical Analysis

↓

• Computer-Aided Pharmacy

Software → Databases → Statistical packages → Instrument software

↓

• Data-Driven Pharmacy

Programming → Data analytics → Visualization → Modelling

↓

• Digital Pharmaceutical Science

AI → Machine learning → Digital laboratories → Automation → Predictive analytics

↓

• Future Pharmaceutical Professional

Pharmaceutical knowledge + computational thinking + data literacy + AI awareness + regulatory understanding

The revised PCI curriculum reflects this transition by introducing Python at the beginning of the B.Pharm programme rather than treating computational skills as an optional or peripheral competency. PCI's 2026 curriculum development process explicitly emphasized competency-based education and alignment with modern clinical practice and industrial technological shifts.

4. PYTHON IN THE REVISED B.PHARM CURRICULUM

The current PCI syllabus identifies BP101T – Basics of Python Programming for Pharmaceutical Sciences as a Semester-I core theory course. It has 2 credits, 30 hours and 50 marks, with 20 marks for sessional assessment and 30 marks for the end-semester examination.

Table 1: Structure of BP101T in the Revised B.Pharm Curriculum.

Parameter	Current requirement
Course code	BP101T
Course title	Basics of Python Programming for Pharmaceutical Sciences
Course type	Core
Semester	I
Credits	2
Instructional hours	30
Weekly theory hours	2
Maximum marks	50
Sessional examination	20
End-semester examination	30
Curriculum framework	NEP 2020
Implementing academic session	2026–27

Source: Pharmacy Council of India, B.Pharm Syllabus 2026.

5. OBJECTIVES OF PYTHON EDUCATION IN PHARMACY

According to the revised syllabus, the course aims to.

- introduce the fundamentals of Python programming for pharmaceutical sciences;
- develop programming skills using control structures, functions and data structures;
- provide knowledge of structured dataset management;

- familiarize students with NumPy and Pandas for healthcare datasets; and
- enable visualization and interpretation of pharmaceutical data.

These objectives demonstrate that the course is designed around application-oriented computational literacy, rather than generic computer programming.

5.1. Unit-Wise Analysis of Python Curriculum

Table 2. Revised Python Curriculum and Its Pharmaceutical Relevance.

Unit	Major contents	Pharmaceutical application
I	Python fundamentals, variables, data types, operators, I/O, strings, libraries	Basic pharmaceutical calculations and data processing
II	Conditional statements, loops, functions	Dosage calculations, BMI and decision-based pharmaceutical calculations
III	Lists, tuples, dictionaries, NumPy, CSV	Pharmaceutical datasets and numerical calculations
IV	Pandas, Series, DataFrames, Excel/CSV, cleaning, filtering, grouping	PK datasets, ADR reports, laboratory and clinical datasets
V	Matplotlib, line, histogram, scatter and box plots	PK curves, ADR trends, dissolution profiles and scientific visualization

The PCI syllabus specifically identifies PK-study datasets, ADR reports, concentration–time curves, ADR reporting rates and dissolution profiles as examples of pharmaceutical data applications.

5.2. Python and Pharmaceutical-Industry Requirements

The pharmaceutical industry is increasingly dependent on digital technologies. Major areas where computational competencies are relevant include.

- Research and Development
- Drug discovery
- Bioinformatics
- Formulation development
- Analytical development
- Quality control
- Quality assurance
- Manufacturing
- Process analytical technology
- Pharmacovigilance
- Clinical research
- Pharmacokinetics
- Pharmacodynamics
- Regulatory affairs
- Medical affairs
- Pharmaceutical supply-chain analytics
- Digital transformation
- AI/ML applications

Table 3. Pharmaceutical Industry Function and Python Application.

Pharmaceutical function	Potential Python application
Drug discovery	Data analysis, molecular-data processing, predictive modelling
Pharmacology	Dose-response analysis
Pharmacokinetics	Concentration–time modelling
Pharmacodynamics	PK/PD data analysis
Formulation	Optimization and experimental-data analysis
Analytical R&D	Instrument-data processing and visualization
Quality Control	Trend analysis and statistical monitoring
Quality Assurance	Quality-data analysis and dashboard development
Manufacturing	Process monitoring and predictive analytics
Pharmacovigilance	ADR data classification and trend analysis
Clinical research	Clinical dataset processing
Biostatistics	Statistical analysis
Regulatory affairs	Structured data preparation and reporting
Pharmacogenomics	Biological and genomic data analysis
Bioinformatics	Sequence and biological-data analysis
Medical affairs	Evidence and literature data analysis
Supply chain	Demand and inventory forecasting

5.3. Python in Drug Discovery and Development

Drug discovery increasingly involves computational approaches capable of processing large chemical, biological and pharmacological datasets.

- Python can support
- molecular-data analysis;
- virtual screening workflows;
- structure–activity relationship analysis;
- molecular-property prediction;
- chemical-data processing;
- target identification;
- drug repurposing;
- machine-learning models;
- ADME/Tox prediction; and
- data visualization.

AI-driven approaches are increasingly being explored across disease prediction, molecular target identification, drug discovery, drug repurposing and pharmacometric modelling. A recent review specifically emphasizes the importance of AI/ML competencies for the next generation of pharmaceutical scientists.

5.4. Python in Pharmacokinetics and Pharmacometrics

Pharmacokinetics is particularly suitable for computational education because students already work with quantitative datasets.

Python can be used for.

- concentration–time data
- C_{max};
- T_{max};
- AUC;
- elimination rate constant;
- half-life;
- clearance;
- volume of distribution;
- compartmental modelling;

- non-compartmental analysis;
- population pharmacokinetics; and
- PK/PD modelling.

For example, students can convert a concentration–time dataset into a graph and use computational approaches to investigate pharmacokinetic parameters.

Machine learning has also been explored as a complementary approach to traditional pharmacometric modelling, particularly for extracting information from complex and large datasets.

5.5. Python in Pharmaceutical Formulation Development

Formulation scientists generate experimental datasets involving

- drug concentration;
 - dissolution;
 - disintegration;
 - hardness;
 - friability;
 - viscosity;
 - particle size;
 - zeta potential;
 - entrapment efficiency;
 - drug-excipient compatibility;
 - stability;
 - formulation composition; and
 - process parameters.
- Python can help students and researchers:

Experimental data → Data cleaning → Statistical analysis → Visualization → Interpretation → Optimization

For example, dissolution data can be imported into Pandas and plotted using Matplotlib to compare different formulations.

5.6. Python in Quality Control

Pharmaceutical quality-control laboratories generate large quantities of analytical data.

Potential applications include:

- assay results;
- dissolution results;
- content uniformity;
- impurity profiles;
- stability data;
- calibration data;
- analytical method validation;
- laboratory trend analysis;
- batch-to-batch comparison; and
- statistical process monitoring.

Python can assist in transforming raw datasets into interpretable tables and graphs.

However, in regulated environments, Python-based calculations or scripts cannot automatically be assumed to be suitable for GMP decision-making. Appropriate validation, access control, version control, documentation, auditability and data-integrity controls are required when software is used in regulated processes.

5.7. Python in Pharmacovigilance

Pharmacovigilance generates extensive adverse-drug-reaction information.

- Python can assist with:
- ADR dataset cleaning;
- duplicate identification;
- classification;
- frequency analysis;
- demographic analysis;
- drug-event association analysis;
- signal-detection research;
- trend visualization; and
- report preparation.

This provides a direct connection with the revised B.Pharm syllabus, which explicitly identifies ADR reports as an example dataset for Pandas-based data handling.

5.8. Python in Clinical Research

Clinical research produces structured datasets containing demographic characteristics;

- treatment groups;
- laboratory parameters;
- adverse events;
- clinical endpoints;
- medication history;
- treatment response; and
- follow-up observations.

Python can provide pharmacy students with basic competency in.

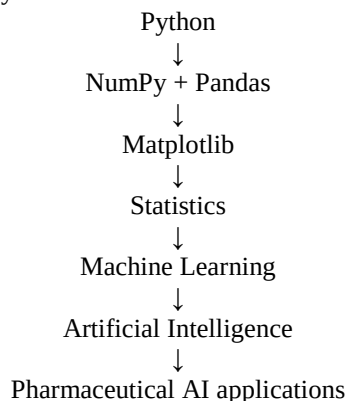
Data import → Data cleaning → Filtering → Grouping → Summary statistics → Visualization

This is particularly valuable because clinical research increasingly depends on data-management and quantitative-analysis capabilities.

5.9. Python, Artificial Intelligence and Machine Learning

Python is closely associated with modern AI and ML workflows.

A pharmacy graduate with Python fundamentals can progressively learn.



This progression is educationally important because students should first understand data structures, data quality, programming logic and visualization before moving toward sophisticated AI applications.

The pharmaceutical sciences are already investigating ML for pharmacometrics and other data-intensive applications, although appropriate model validation and domain expertise remain essential.

5.10. Relationship Between Revised Curriculum and Industry 4.0

Industry 4.0 is characterized by:

- automation;
- Internet of Things;
- cloud computing;
- artificial intelligence;
- machine learning;
- big-data analytics;
- digital twins;
- robotics;
- interconnected systems; and
- real-time decision-making.

The pharmaceutical sector is increasingly incorporating these technologies into manufacturing, quality systems and research.

Python provides an accessible entry point into this ecosystem.

Figure 1. Proposed progression

5.11. Mapping BP101T Learning Outcomes with Industry Competencies

Table 4: Curriculum–Industry Competency Mapping.

BP101T competency	Academic skill	Industrial relevance
Variables and data types	Computational fundamentals	Structured data handling
Operators	Quantitative calculations	Pharmaceutical calculations
Conditional statements	Logical decision-making	Rule-based processing
Functions	Modular programming	Reusable analytical workflows
Lists/dictionaries	Data organization	Dataset management
NumPy	Numerical computing	Scientific calculations
Pandas	Data analytics	QC, clinical and pharmacovigilance data
CSV/Excel handling	Data import/export	Routine industrial datasets
Data cleaning	Data quality	Reliable analysis
Grouping/aggregation	Summary analysis	Batch and trend analysis
Matplotlib	Visualization	Scientific reporting
PK plotting	Pharmaceutical interpretation	Pharmacokinetics
ADR visualization	Safety-data analysis	Pharmacovigilance
Dissolution plotting	Product-performance analysis	Formulation/QC

5.12. Python as an Employability Skill

The revised curriculum creates an opportunity to shift pharmacy education from a predominantly knowledge-based model toward a competency-based model.

- Traditional graduate profile
Pharmaceutical knowledge + laboratory skills

- Emerging graduate profile
Pharmaceutical knowledge + laboratory skills + computational skills + data literacy + communication + interdisciplinary competency

This broader competency profile can potentially support employment in.

- pharmaceutical R&D;
- clinical research organizations;
- pharmacovigilance;
- data-management teams;
- analytical laboratories;
- formulation R&D;
- regulatory operations;
- quality analytics;
- bioinformatics;
- pharmacometrics; and
- digital-health organizations.

5.13. Role of NumPy, Pandas and Matplotlib

The revised curriculum's selection of NumPy, Pandas and Matplotlib is particularly appropriate for an introductory pharmaceutical course.

NumPy

Useful for: numerical arrays; mathematical operations; matrix calculations; numerical datasets.

Pandas

Useful for: tabular data; CSV/Excel files; data cleaning; filtering; grouping; aggregation; missing-value management.

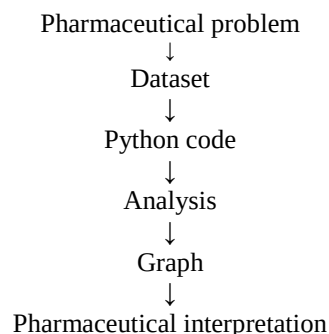
Matplotlib

Useful for: line plots; histograms; scatter plots; box plots; concentration–time curves; dissolution profiles; and ADR trends.

These tools provide a practical pathway from raw pharmaceutical data to scientific interpretation.

5.14. Proposed Industry-Oriented Teaching Model

The implementation of BP101T should preferably avoid teaching Python as a generic computer-science subject. Instead.



For example

Dissolution dataset

→ Pandas

→ Calculate/organize dissolution values

→ Matplotlib

→ Dissolution profile

→ Compare formulations

→ Pharmaceutical conclusion

This approach makes programming meaningful to pharmacy students.

5.15. Suggested Practical Case Studies

Although BP101T is currently a theory course, institutions can strengthen competency through demonstrations and guided exercises.

Table 5. Suggested Pharmaceutical Python Exercises.

Exercise	Python concept
BMI calculator	Variables/functions
Dose calculator	Operators/functions
Dose classification	If–else
Tablet-dissolution dataset	Lists/Pandas
PK dataset	Pandas
Concentration–time graph	Matplotlib
ADR dataset	Pandas
ADR frequency graph	Matplotlib
Assay dataset	DataFrame
Batch-quality comparison	Grouping
Missing-data exercise	Data cleaning
Stability dataset	Visualization
Formulation comparison	Statistical/data analysis
CSV laboratory dataset	File handling

5.16. Data Literacy and Data Integrity

One of the most important benefits of introducing Python is the development of data literacy.

Students should understand that computational analysis is only as reliable as the data being analyzed.

Therefore, Python education should incorporate.

- data provenance;
- correct data entry;
- appropriate data cleaning;
- missing-value identification;
- prevention of inappropriate manipulation;
- reproducibility;
- documentation of analytical workflows;
- version control;
- appropriate interpretation; and distinction between raw data and processed data.

This is particularly relevant to pharmaceutical quality systems, where reliable data are essential for scientifically justified decisions.

6. LIMITATIONS AND CHALLENGES

Despite its advantages, introducing Python into pharmacy education presents several challenges.

- Lack of programming background:-Many pharmacy students enter B.Pharm without prior coding experience.
- Faculty preparedness:- Teachers may have strong pharmaceutical expertise but limited programming experience.
- Infrastructure:- Computer laboratories and suitable software environments are required.
- Curriculum time:- The current BP101T allocation is only 30 hours, requiring careful prioritization.
- Risk of teaching syntax without application:- Teaching Python independently of pharmaceutical examples may reduce student engagement.
- AI dependence:- Students may use generative AI to produce code without understanding the underlying logic.
- Regulatory concerns:- Scripts used for regulated pharmaceutical activities require appropriate validation and governance; educational coding skills should not be equated with validated GMP software capability.

7. CONCLUSIN

The current BP101T course can serve as the foundation for progressively advanced computational education. The 2026 curriculum already includes Applied Biostatistics and Data Analytics for Pharmaceutical Sciences in Semester II, providing a natural progression from introductory Python toward quantitative pharmaceutical data analysis.

The future pharmaceutical workforce is likely to become increasingly interdisciplinary. A pharmaceutical scientist may increasingly need to communicate with: data scientists; software engineers; bioinformaticians.

statisticians; computational chemists; AI specialists; clinical researchers; and regulatory professionals. Therefore, pharmacy graduates do not necessarily need to become professional software engineers. Instead, they should become computationally literate pharmaceutical scientists capable of understanding, applying and critically evaluating computational methods.

This distinction is important.

The objective is not to turn pharmacy students into programmers; it is to turn pharmaceutical professionals into scientifically competent users of computational technology.

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