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# **Intelligent Tutoring System for Python Programming**

## **Introduction**

Programming has become an indispensable skill, especially in the educational curriculum of computer science and also requires the need to demand effective tools for teaching programming languages. The following report focuses on the design and development of an Intelligent Python Tutor, a smart tutoring system specifically designed for fresh beginners into the world of learning Python.(Omankwu et al., 2021)

Python Tutor introduces basic concepts, such as syntax, control structures that use loops and simple data structures, the basic concepts of programming. What makes it different from Python Tutor is its approach: an interactive approach for learners to actively participate in coding exercises as users tackle problems in real-time and get immediate constructive feedback. Learning is reinforced and errors can immediately be corrected while making understanding deepen.

The platform is educational and fun as it integrates practice problem-solving with theory; thus, it is an interesting experience in learning. Python Tutor is more than just a coding tutor; it makes users confident by letting them learn how to be great at their own pace. The system helps people get rid of the intimidation that they face when programming and replaces it with curiosity and enthusiasm. (Yang et al., 2024)

How can an Intelligent Tutoring System leveraging knowledge representation, dynamic feedback, and progress tracking improve the learning effectiveness, engagement, and adaptability of Python programming for beginners compared to existing platforms

What Python Tutor does is innovative through thoughtful design and hands-on methodology towards empowering even the novice programmer. This platform does not just transfer technical skills but makes the journey fulfilling and rewarding. By bridging the gap between theory and procedure, Python Tutor arms the users with deep foundational knowledge and skills with which a user would feel more confident in continuing his programming journey.(M. Wang, W. Wu and Y. Liang)

### **1.1 Research Questions**

* How does an ITS influence the confidence and learning trajectory of beginner programmers compared to traditional teaching methods?
* What is the impact of real-time dynamic feedback on novice programmers' learning outcomes and problem-solving skills?
* How does progress tracking in an Intelligent Tutoring System improve engagement and learning effectiveness in programming education?

## **Project Plan**

### **2.1 Objectives**

* Design a knowledge representation system that facilitates the establishment of relationships between major programming concepts such as syntax, loops, conditional statements and context-aware hint and suggestion generation for learners.
* An Interactive User Interface with Python Libraries allows learners to test the code that gets real-time feedback for errors with explanations. Bui (2019)
* Provide dynamic error detection and feedback mechanisms that examine syntax and logic errors in the code and offer personalized hints and correction suggestions.
* To overcome usability and accessibility challenges, design an intuitive, user-friendly interface that is friendly to beginners and compatible with assistive technologies.
* Test the system's effectiveness through user testing, focusing on learning outcomes, engagement, and error correction capabilities.

### **2.2 Timeline**

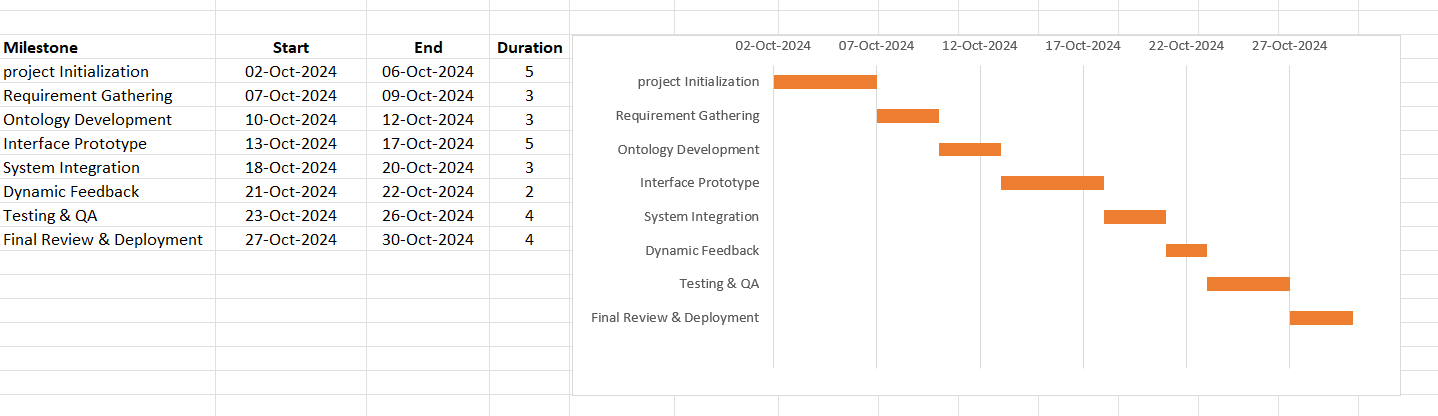


Fig-1 Timeline Gantt chart

## **Literature Review**

(Meng Wang, Wenjun Wu, and Yu Liang,2020) Proposed the concept, structure, and implementation of a novel intelligent tutoring system designed specifically for beginners in C and Python programming. They implemented the system by integrating features such as code classification, program error repair, and personalized knowledge tracing into an existing online programming practice platform. Their approach enhanced the platform's intelligence and significantly improved its ability to support students in learning programming effectively.

Priyanka Sharma and Mayuri Harkishan proposed an Intelligent Tutoring System (ITS) for online programming courses, focusing on user interaction and a subset of computer programming languages. Their design integrates intelligent algorithms, such as optimized ant colony, to enhance formative assessments and provide high-quality feedback. The system aims to offer an immersive learning experience, enabling students, particularly in Pacific regional campuses, to learn programming more effectively and efficiently compared to conventional online methods.

Omankwu Obinnaya Chinecherem, Osodeke Efe Charles, and Onwuzo Chioma Julia proposed the design of an Intelligent Tutoring System (ITS) for teaching Python, aimed at helping students learn the language easily and effectively. The system offers beginner-level lessons and exercises, adapting to individual student needs and progressing gradually from simple to complex concepts. By simulating a one-on-one teaching experience, the ITS saves time, allows students to learn at their own pace, and eliminates the fear of making mistakes. The evaluation of the tutor received excellent feedback from both students and teachers.

Zhiyu Fan and Ashish Dandekar from the National University of Singapore proposed an Intelligent Tutoring System (ITS) designed to provide automated feedback for first-year programming courses. Unlike existing automated grading systems, their ITS focuses on delivering customized error feedback to students. The system was incrementally developed as part of a multi-year Software Engineering course, where third-year students contribute to its improvement each year. This approach not only enhances the tutoring system but also allows its immediate deployment for first-year students, creating a practical and collaborative learning environment for all stakeholders.

### **3.1 Existing Python Intelligence Tutors**

* **Codecademy:** Codecademy provides a comprehensive way to learn Python, teaching things like basic syntax, loops, and Data structures. It has interactive exercises, so you keep practising as you go along. Not ideal is the fact that it doesn't do real-time debugging nor provide explicit ways of troubleshooting particular errors. Still, that's more of a minor annoyance than anything else. Still, it is a great resource for getting familiar with Python.
* **SoloLearn:** SoloLearn is a mobile-friendly learning platform offering gamified lessons for both beginners and experts. While engaging, it only allows limited feedback on predefined examples and doesn't dynamically change based on user mistakes.Chrysafiadi et al. (2022)
* **Python Tutor by Philip Guo:** It is good for exhibiting the execution of a code, visually, showing users how Python programs work line by line. There are no personalized hints; it's not about correcting wrong logical or syntactical errors.

### **3.2 Challenges in Existing System**

The existing systems teaching programming concepts do not possess adaptive features or styles that fit personal or individual learning habits. The mechanisms for feedback in existing platforms are rather general and do not provide provisions for personalization. Error detection typically gets stuck at the surface level without helping users realize where exactly they made a mistake.Chrysafiadi et al. (2022)

### **3.3 Insights for Development**

To address these gaps, Python Tutor (ITS) aims to combine the strengths of existing platforms while introducing features such as Matellio

* **Dynamic Error Feedback:** Analyze the code for syntax and logic errors in submitted user code and provide targeted hints and solutions.
* **Knowledge Representation:** Connect concepts such as loops, conditionals, and data structures so that the system can even offer context-aware advice.
* **Tracking: T**rack performance through exercising and adjust exercises to fit weak areas so that a personalized learning trajectory is ensured.

Python Tutor will bridge the void between stagnant knowledge resources and the demand for real-time, interactive feedback, creating a complete tool for learning Python programming effectively.Chrysafiadi et al. (2022)

## **Development of the Intelligent Tutoring System**

An Intelligent Tutoring System ITS focused on teaching basic programming skills using Python to new programmers emphasizes the following core topics: syntax, loops, conditionals, and data structures. It's focused on the aim of providing a learning experience by giving learners the ability to work through exercises and use dynamic feedback in receiving answers.

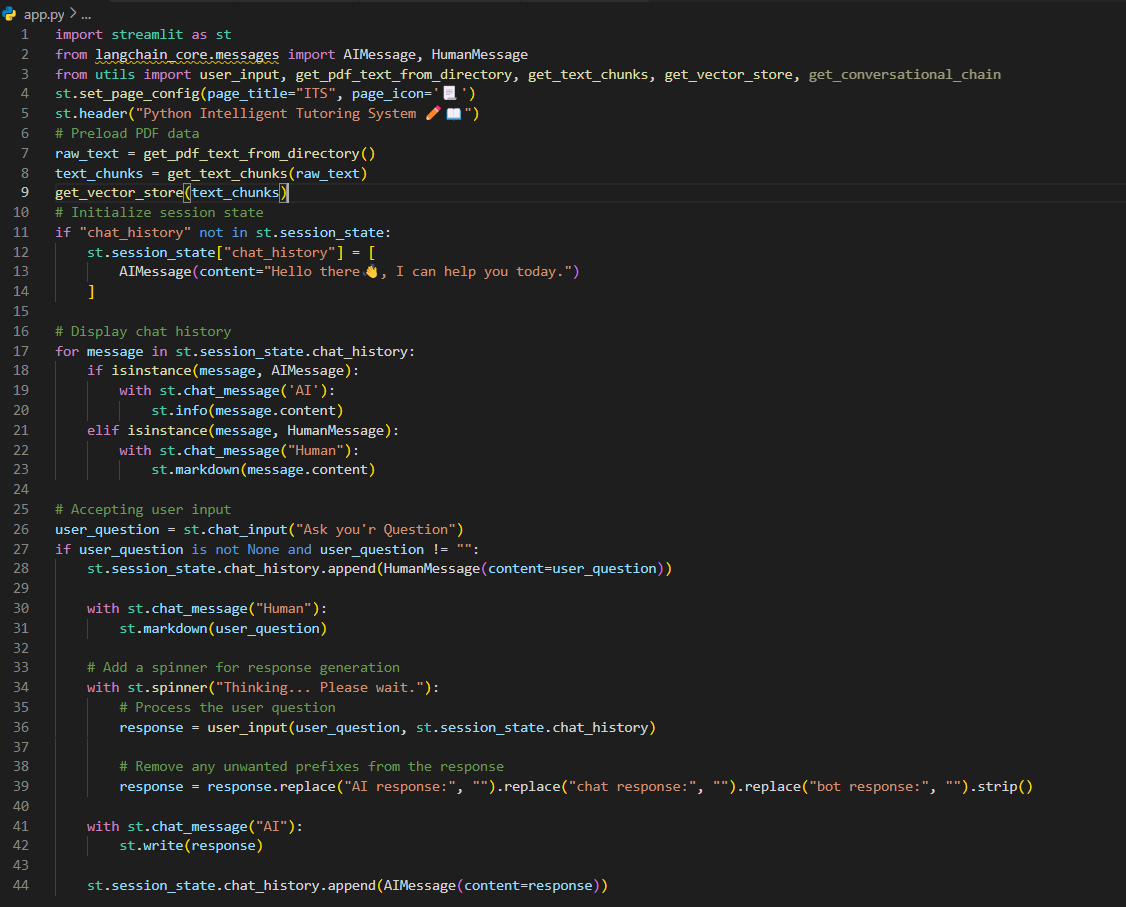


Fig-2 Code of the web UI, Which is developed using Streamlit



Fig-3 Web Application UI

### **4.1 Ontology Design**

**Objective:** Define relationships between programming concepts such as loops, syntax rules

**Process**:

* Built an ontology with classes such as Syntax, Loops, Conditions, and their respective properties.
* Example: The class of Loop has diverse relationships such as Syntax Rules and requirements for the proper structure of a loopAjie (n.d.)

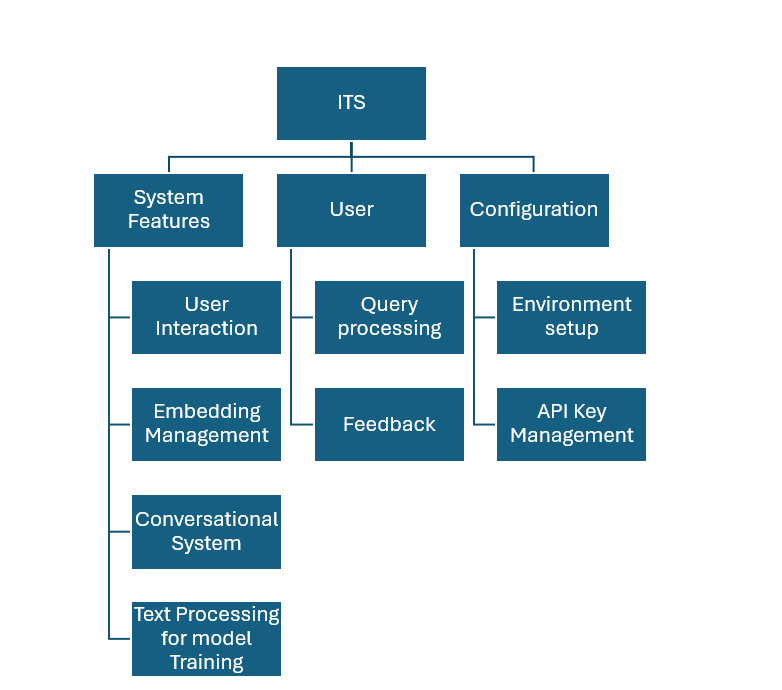


Fig-4 Ontology

### **4.2 Interface Development using Python**

**Objective:** Develop an interactive learning interface where the student inputs their code and receives feedback.

**Process:**

* A graphical interface was designed by making use of the streamlit library of Python.
* Features like real-time code analysis, error detection, and suggestions were designed. For instance, a wrong for loop has been designed as an example. A user is faced with hints pertaining to the Loop class of the ontology. Ajie (n.d.)

## **4.3 Integration and Testing**

* **Integration**: the interface and the ontology are both allied so that the learning content and feedback mechanisms can work there with no hassle.
* **Testing**: Tested with sample exercises to check functionality and error-free working.

## **4.4 Limitations :**

* It only focuses on fundamental concepts of syntax, loops, and conditionals while excluding further advanced subjects like object-oriented programming, recursion, or even the data science library. Basic syntax and simple logic errors will be handled with less success with advanced debugging challenges, for instance, multi-threading problems, and algorithm efficiency issues. as well as providing a near-IDE environment would complete its usability.
* It may take time to process real-time feedback due to the increasing user base or large and complex code submissions.
* Not very adaptable to auditory or kinesthetic learners or special learning preferences. - Highly dependent on accuracy and completeness, which may result in gaps or incorrect feedback if the ontology contains errors.
* Doesn't accommodate collaborative learning activities such as peer code reviews, group projects, or shared exercises.
* Not Python-only: the site restricts learners to Python as a language; there isn't any provision for allowing learners to learn other languages.
* It lacks complete accessibility features for disabled users, such as screen readers or alternative input methods. It is inflexible and not adaptable to unconventional coding styles or non-standard inputs. The structure of foundational lessons is fixed and sometimes becomes repetitive or unchallenging for learners who already have some experience. Exercises are mostly theoretical with limited real-world programming scenarios and are, therefore, less practical.
* It requires an active internet connection, which limits its usability for learners in areas with poor connectivity.
* Dynamic feedback processing requires a lot of computational resources, which slows performance in large-scale or resource-constrained environments.

## **Conclusion**

ITSs are considered transformative educational tools as they can personalize feedback and adaptive learning environments that can improve the learning process. Such systems use technologies like artificial intelligence, natural language processing, and ontology-based knowledge representation to facilitate adaptation of the learning environment to meet individual needs, thereby being effective for all types of learners.

ITSs, therefore, play a major role in guiding users through a step-by-step problem-solving process within programming education. With its emphasis on syntax error, logic error, or errors in the design of a program, it not only corrects the mistakes but explains and gives context-aware solutions, which ensures that not only do learners correct their mistakes but also understand what the concept is.Ijcsis and Koroveshi (2021)

Moreover, ITSs learn dynamically to the pace of each learner's ability and learning style. They can, for example, determine weaknesses, such as issues with loops or conditionals, and provide specific exercises on these topics to improve knowledge of these concepts. Such an adaptive characteristic allows for a constant, continuous progression without being based on the "one-size-fits-all" method applied by traditional teaching approaches.Ijcsis and Koroveshi (2021)

The other significant advantage is that ITSs provide real-time feedback. It is frustrating for a beginner when errors are marked without any explanation. ITSs reduce this by providing immediate, constructive feedback, often accompanied by visualizations or hints, which will help learners correct their mistakes on the spot and improve their confidence in their own abilities.(*AASCIT - Journal - HTML*, n.d.)

ITSs also promote engagement by involving interactive and gamified elements. The existence of features such as tracking, achievements, and rewards facilitates sustained participation, thereby making learning an enjoyable and motivating process. When integrated with user-friendly interfaces and visualization tools, it makes complex topics accessible even to a complete novice.

ITSs also have applications in mathematics, science, and language learning, thus showing their versatility and potential for revolutionizing education. Through the integration of cutting-edge AI technologies with pedagogical principles, ITSs not only enhance knowledge acquisition but also foster critical thinking, problem-solving, and lifelong learning skills.(*AASCIT - Journal - HTML*, n.d.)

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