Development of a Real-Time Interactive Dashboard for Monitoring Student Data Science Literacy and Technology Adoption using Python and Cloud Integration

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***Abstract*— As data science becomes a fundamental skill in modern education, monitoring student proficiency and technology adoption in real-time remains a significant challenge. Traditional methods of assessment, such as static surveys and periodic exams, fail to provide educators with immediate insights into student confidence levels and tool usage (e.g., Python, Git, Cloud Computing). This paper presents the development of a real-time interactive dashboard designed to monitor Data Science Literacy and Technology Adoption among undergraduates. The system utilizes a Python-based framework (Flask and Dash) integrated with cloud-based data repositories (Google Sheets) to visualize key metrics, including study habits, programming proficiency, and project completion rates. The results demonstrate that the system successfully processes incoming data streams with a 5-second latency, allowing educators to identify learning gaps and technology adoption trends instantly. This tool provides a scalable, cost-effective solution for data-driven educational decision-making.**

Keywords— Data Science Literacy, Real-Time Dashboard, Python, Technology Adoption, Educational Data Mining, Flask, Render

I. Introduction

The rapid evolution of Artificial Intelligence (AI) and Machine Learning (ML) has necessitated a paradigm shift in higher education. Proficiency in tools such as Python, Pandas, and Scikit-Learn is no longer optional but a fundamental requirement for the modern workforce. However, educational institutions often struggle to gauge "Data Science Literacy" effectively.

Traditional methods of assessment, such as semester-end examinations or static surveys, suffer from a significant lag. They provide a retrospective view of student performance, often too late for educators to intervene. Furthermore, manual data collection using spreadsheet software (e.g., Excel) is prone to human error and lacks the interactivity required to visualize complex correlations between study habits and technical proficiency.

This paper proposes a solution: a **Real-Time Interactive Dashboard** that visualizes student technology adoption trends. By integrating a lightweight Python web server (Flask) with a cloud-based data repository, this system allows lecturers to monitor changes in student confidence and skill acquisition instantly. The primary objective is to demonstrate how open-source technologies can be utilized to create cost-effective, real-time educational monitoring tools.

II. Literature Review

Educational Data Mining (EDM) Previous studies have highlighted the importance of visualizing student data to enhance self-regulated learning. Research by **Verbert et al.** in **2013** demonstrated that visual feedback loops significantly improve student engagement by enabling learners to reflect on their own activity data [1]. However, they noted that most existing solutions rely on expensive, proprietary software or "black-box" systems, which limits their accessibility for smaller educational institutions.

Real-Time Web Technologies The shift towards lightweight, web-based monitoring tools is well-documented in recent software engineering literature. **Ingram** (**2022**) discussed the efficacy of open-source app development frameworks for rapid prototyping in educational settings, emphasizing that custom web apps provide greater flexibility than standard Learning Management Systems (LMS) [2]. Unlike traditional desktop applications, these web dashboards allow for cross-platform accessibility, enabling students to view their progress on mobile devices.

Research Gap While significant research exists on static data analysis, **Kaliisa et al.** (**2023**) noted in a systematic review that there is a lack of rigorous evidence regarding real-time, low-latency visualization tools that integrate prescriptive analytics [3]. Most existing studies focus on historical data analysis rather than live streams. This project bridges that gap by implementing a live polling mechanism using Dash and Google Sheets to provide immediate feedback.

III. Methodology

A. System Architecture The proposed system follows a client-server architecture designed for lightweight deployment and low-latency data visualization. The architecture consists of three primary layers:

- **Data Acquisition Layer:** Student data is collected via a web-based interface (Google Forms), which automatically populates a cloud-hosted repository (Google Sheets). This approach eliminates the need for complex database management systems (DBMS) while ensuring data accessibility.

- **Processing Layer:** A local Python server acts as the backend. It utilizes the Pandas library to fetch the raw CSV data from the cloud repository. Data cleaning operations—such as handling missing values (NaN), type casting numeric fields, and standardizing column nomenclature—are performed programmatically to prevent visualization errors.

- **Visualization Layer:** The frontend is built using **Plotly Dash**, a declarative framework for building analytical web applications. The interface renders four distinct interactive charts (Scatter, Bar, Box, and Violin plots) to represent the multidimensional dataset.

B. Real-Time Data Synchronization To achieve real-time monitoring capabilities without the complexity of WebSockets, the system implements a **polling mechanism**. A specific interval component (`dcc.Interval`) is configured within the application layout to trigger a callback function every 5,000 milliseconds (5 seconds).

Step 1: The timer fires a callback event.

Step 2: The backend requests the latest CSV snapshot from the Google Sheets API.

Step 3: The data is processed and compared against current filters (e.g., "Year 1" vs. "Year 3").

Step 4: The browser's Document Object Model (DOM) is updated dynamically without requiring a full-page refresh.

C. Technology Stack The development utilized open-source technologies to ensure replicability and cost-effectiveness:

- **Language:** Python 3.10+
- **Web Framework:** Flask (backend) and Dash (frontend).
- **Visualization:** Plotly.js (via Python wrapper) for interactive graphing.
- **Deployment Environment:** The system is containerized for deployment on cloud platforms (e.g., Render) or local development servers.

IV. Results & Discussion

Real-Time Latency Test The system successfully demonstrated real-time capabilities. Using the `dcc.Interval` component set to a 5,000ms polling rate, the dashboard updated visualization metrics within 6–8 seconds of a new data submission via Google Forms. This "near real-time" performance is sufficient for classroom monitoring without the complexity of WebSocket architecture.

Correlation Analysis (Scatter Plot) The Scatter Plot visualization revealed a positive correlation between **Study Hours Per Week** and **Pandas Proficiency**. As illustrated in **Fig. 1**, students dedicating more than 10 hours per week consistently reported proficiency levels above 4 (on a Likert scale). This validates the hypothesis that time investment directly impacts technical confidence.

Impact of Confidence on Output (Box Plot) The Box Plot analysis (**Fig. 2**) highlighted an interesting trend: students with higher "Confidence Levels" did not always have the highest number of "Projects Completed." This suggests a potential "Dunning-Kruger effect" where novice students may overestimate their abilities compared to their actual output.

V. Conclusion & Future Work

Conclusion This study successfully designed and deployed a real-time dashboard for monitoring student Data Science literacy. By leveraging Python, Dash, and Google Sheets, we created a zero-cost, scalable solution that addresses the limitations of static reporting. The system provides immediate insights into technology adoption, allowing educators to make data-driven decisions in the classroom.

Future Work While the current system is effective for small cohorts, reliance on Google Sheets may introduce latency at scale (1000+ users). Future iterations of this project will aim to:

- Migrate the backend database to **PostgreSQL** or **MongoDB** for improved query performance.

- Implement **Machine Learning algorithms** (e.g., Linear Regression) to *predict* future student performance based on current study habits.

- Add a secure **Login/Authentication** system to protect student privacy in a public deployment.

VI. References

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