1. Questions

Q1: Does the model perform as accurately as expected on your smartphone? List a few methods to improve the model's accuracy.

Answer:

- **Model Performance on Smartphone:**
  Yes, the model performed accurately on the smartphone. The model detected keywords Hello World reliably under normal conditions, but struggled in noisy environments.
- **Methods to Improve Accuracy:**
  1. **Increase Dataset Diversity:** Use a more diverse dataset, including variations in accents, background noise, and speaker demographics.
  2. **Data Augmentation:** Introduce techniques like pitch shifting, adding synthetic noise, and time-stretching to enhance robustness.
  3. **Hyperparameter Tuning:** Optimize parameters like the learning rate, batch size, and the number of epochs during training.
  4. **Model Architecture Improvement:** Experiment with advanced architectures or pre-trained models suitable for TinyML.

Q2: When building a model for resource-limited hardware, how do you balance fast inference times with acceptable model accuracy? What trade-offs did you encounter?

Answer:

- **Balancing Inference Time and Accuracy:**
  To balance inference speed with accuracy, I opted for INT8 quantization, which reduces the model's size and computational demands while slightly sacrificing precision.
- **Trade-offs Encountered:**
  1. **Reduced Accuracy:** Quantization and smaller model sizes led to a slight decrease in accuracy, especially for harder-to-detect keywords.
  2. **Increased Latency in Debugging:** Optimized models require careful tuning to ensure functionality without loss of key features.
  3. **Hardware Constraints:** The limited computational power and memory of the Arduino Nano 33 BLE Sense meant I had to simplify the model architecture.

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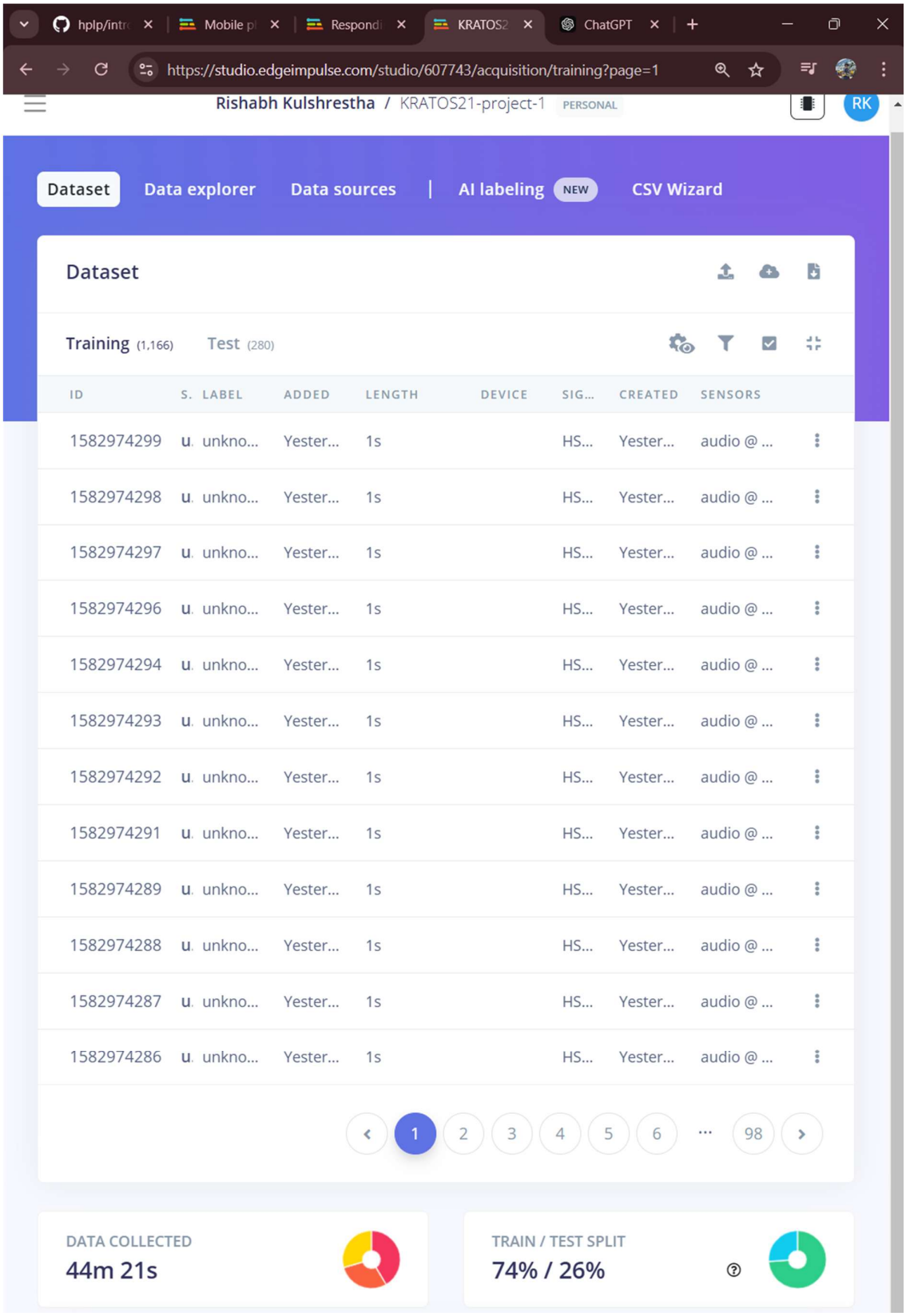
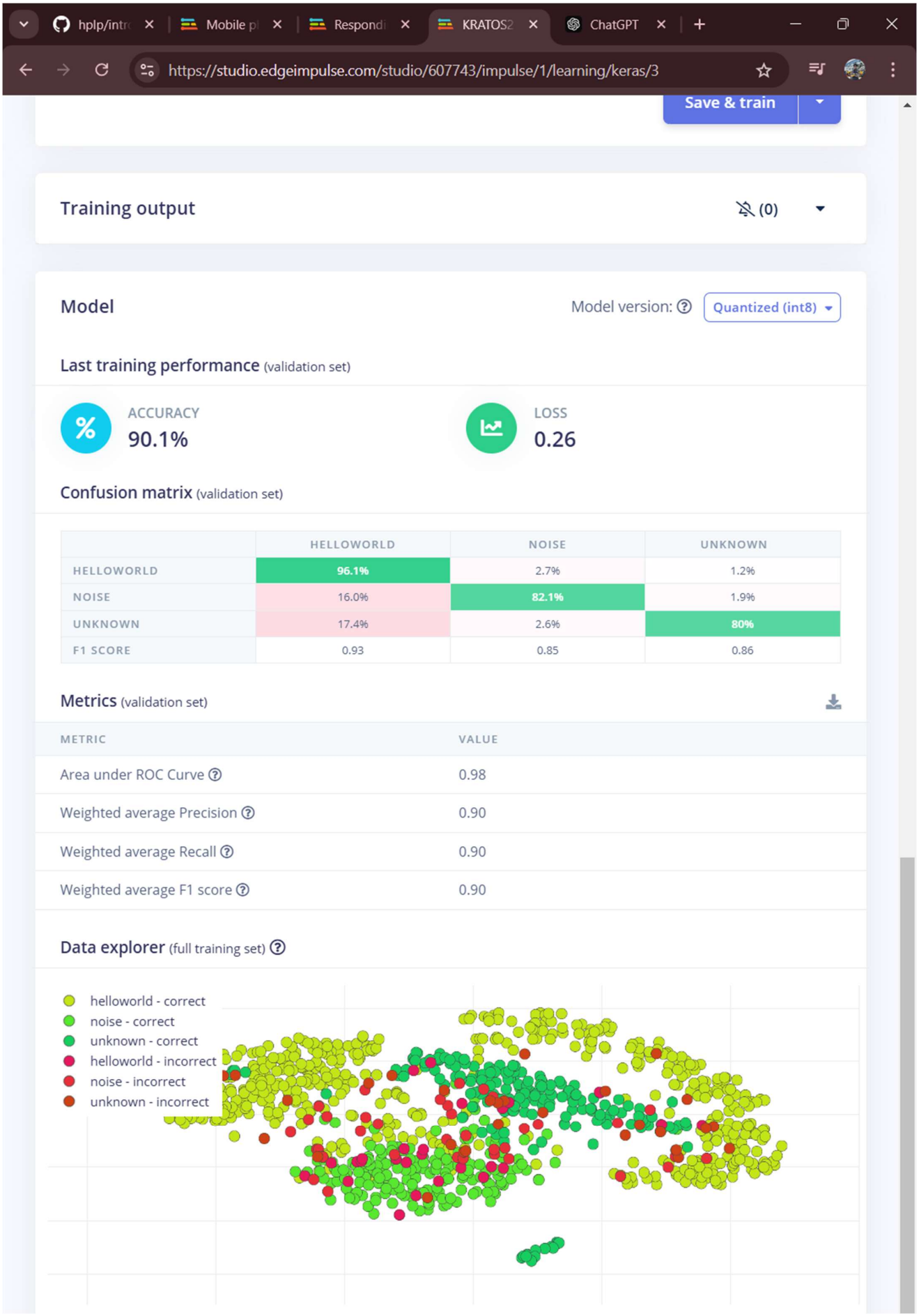
2. Screenshots of Training Performance

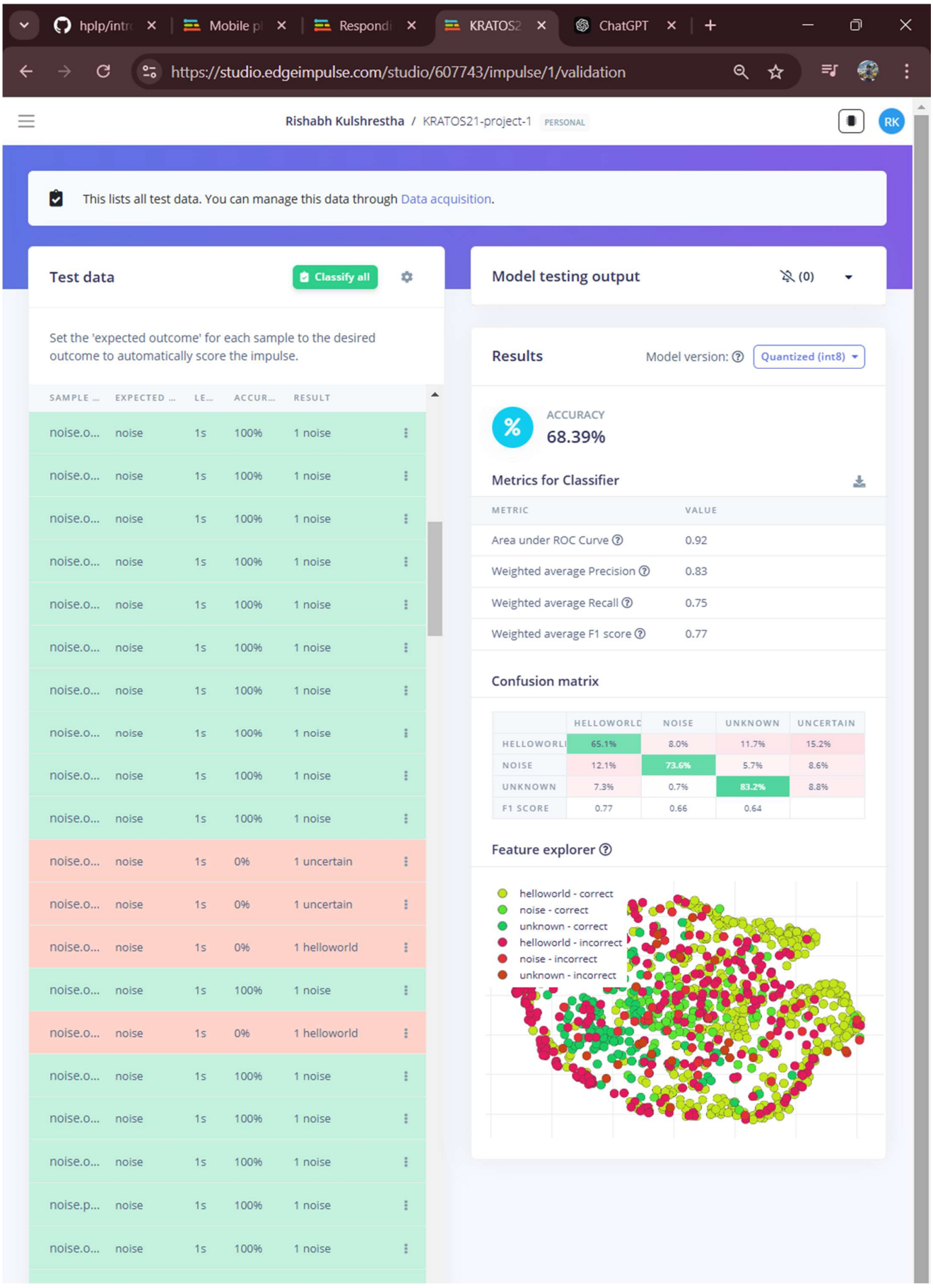
- **Screenshot 1:** Training data summary



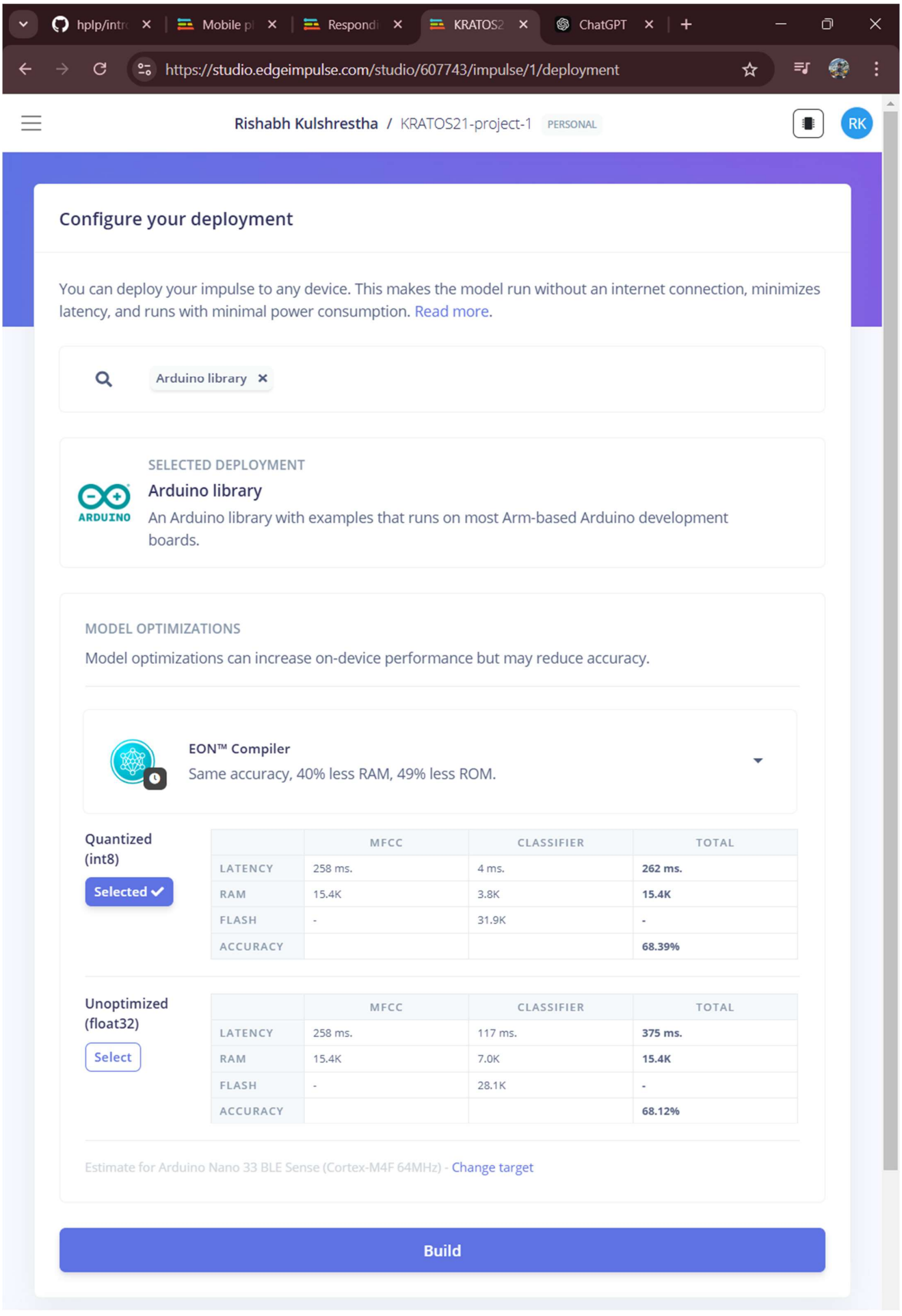
- **Screenshot 2:** Model accuracy and loss curves after training completion.



- **Screenshot 3:** Model evaluation performance.



- **Screenshot 4:** Edge Impulse Deployment page showing the selection of INT8 quantization.



3. Videos

Links to Videos:

1. **Keyword-Spotting Model on Smartphone:**
   Screenshot of mobile device connected to the edgeplus model and video showing the model running on the smartphone and correctly identifying spoken keywords.

   Link: Keyword-Spotting Model on Smartphone
   https://drive.google.com/drive/folders/18rZ7eRGpJRK9KCaFSCYXKz5Gzo9ya-Bi?usp=sharing

2. **Keyword-Spotting Model on Arduino Nano 33 BLE Sense:**
   Video demonstrating the model deployed on the Arduino board, showing the serial monitor output or LED control via voice commands.

   Link: Keyword-Spotting Model on Arduino Nano 33 BLE Sense
   https://drive.google.com/drive/folders/18rZ7eRGpJRK9KCaFSCYXKz5Gzo9ya-Bi?usp=sharing

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4. Reflections

- **Experience Deploying to Smartphone:**
  "The deployment to the smartphone was straightforward, as Edge Impulse provides clear instructions. The mobile microphone captured high-quality inputs, which contributed to better keyword detection."
- **Experience Deploying to Arduino:**
  "Deploying the model to the Arduino Nano 33 BLE Sense was a rewarding challenge. First-time compilation took longer than expected (~20 minutes), and I faced difficulties loading the ZIP library into Arduino IDE initially. Adjusting the model's memory allocation and debugging issues related to the serial monitor were the most time-consuming tasks."
- **Technical Difficulties and Observations:**
  1. The need to re-enter the Arduino IDE after adding the library was a surprising step.
  2. The model's response time on Arduino was slightly slower than on the smartphone due to hardware limitations.
  3. Noisy environments significantly impacted the detection quality on both platforms.