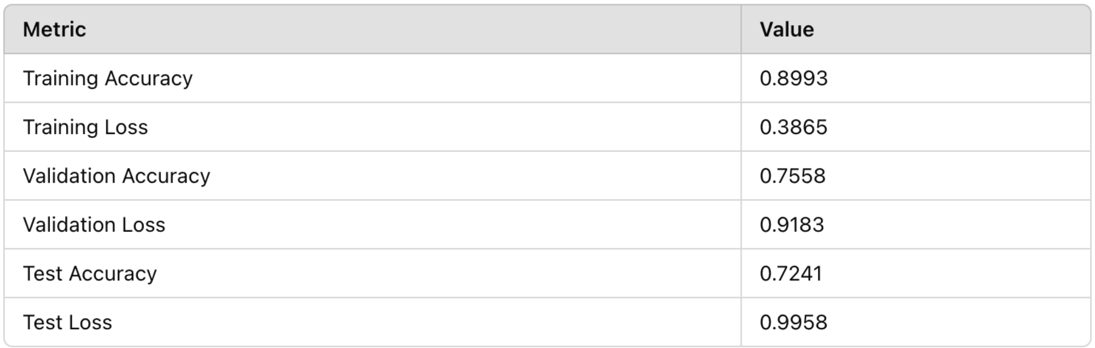
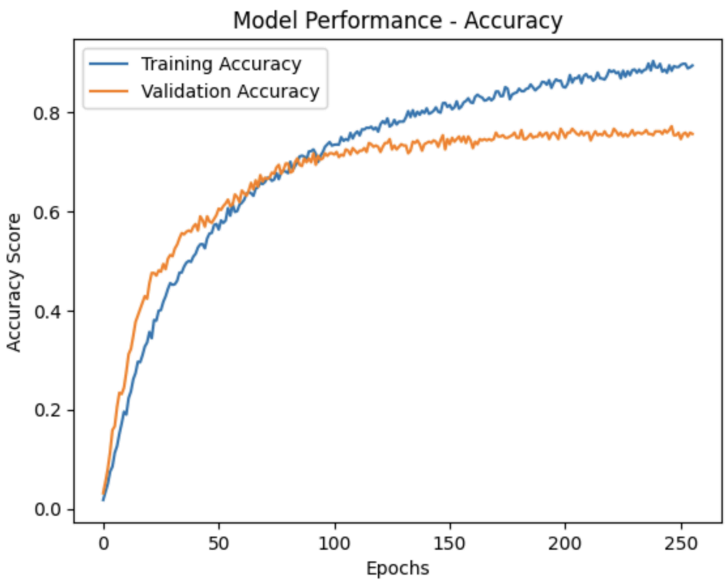
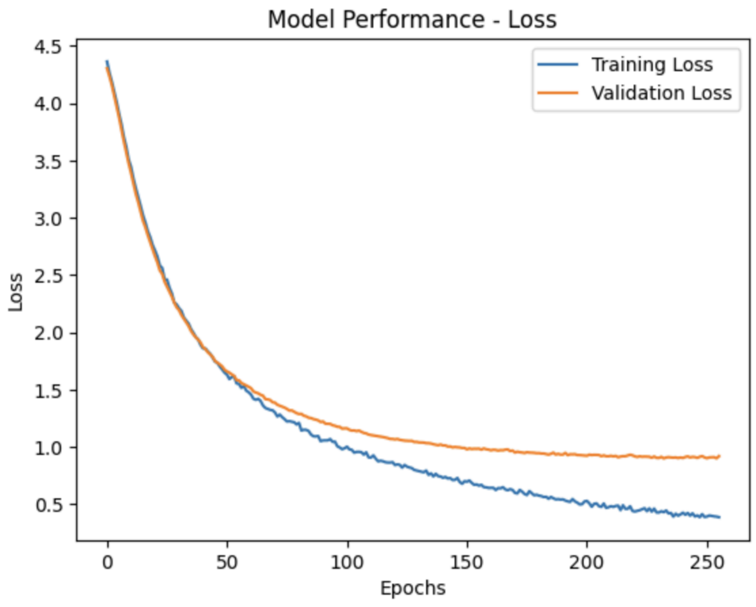
## 1) Training with minimum number of samples for each class: approx. 26%

- The validation set of 385 samples (5 samples each for all 77 classes) are drawn..
- Due to class imbalances, I first trained the models on the minimum number of samples (n_samples = 34) for each class from the training dataset.
    - The size of the training set = 2618
- The test sample set of 1/3rd of the testing set is also drawn from the testing set.
- The training and testing sets are both balanced.
- Then I trained a neural network model with an input layer of 64 neurons, a dropout layer of 0.3, and an output layer with softmax as an activation function for a multiclass classification task for num_class = 77 classes.
- The model's performance is shown below:

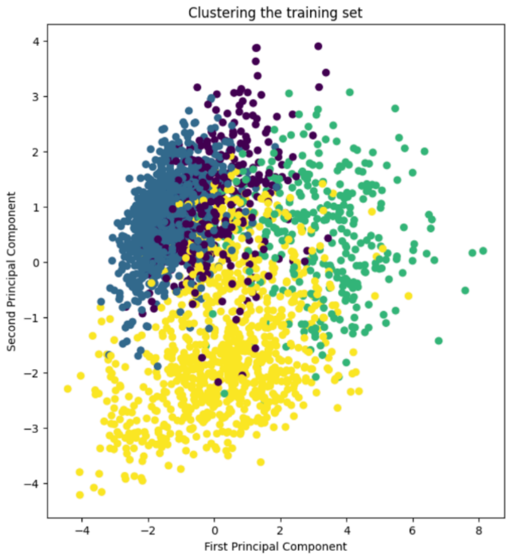


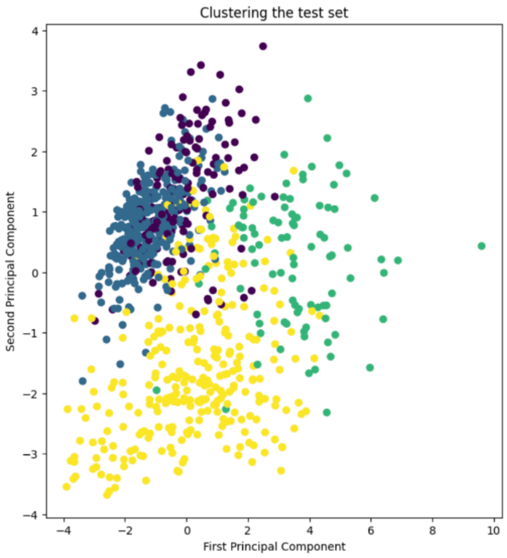
| Metric | Value |
|---|---|
| Training Accuracy | 0.8993 |
| Training Loss | 0.3865 |
| Validation Accuracy | 0.7558 |
| Validation Loss | 0.9183 |
| Test Accuracy | 0.7241 |
| Test Loss | 0.9958 |

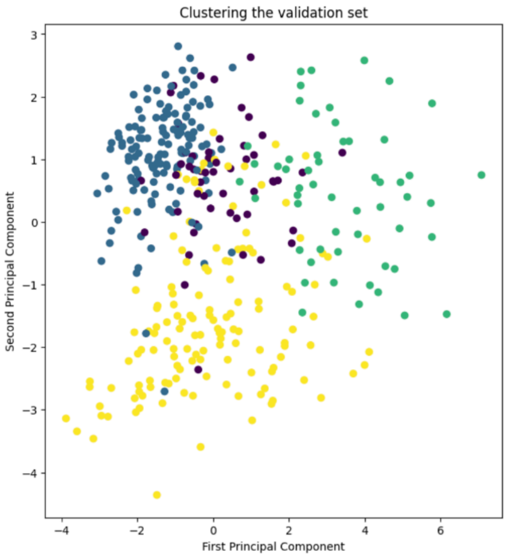




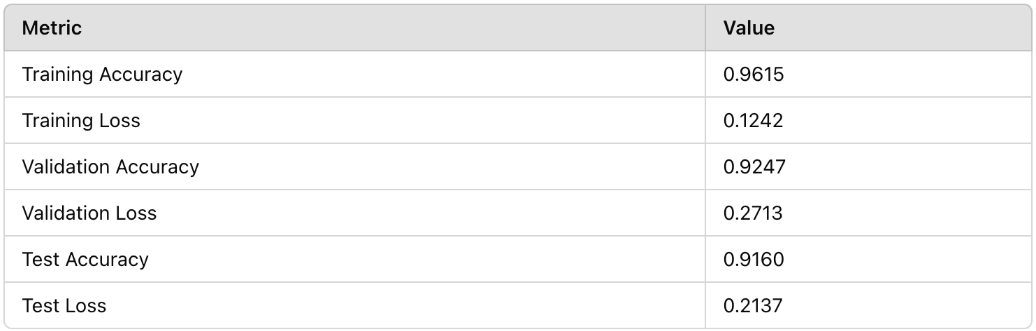
- Then I use hierarchical clustering (ward method) to form 4 clusters of the datasets. The clusters can be visualized as below along their first two principal components.



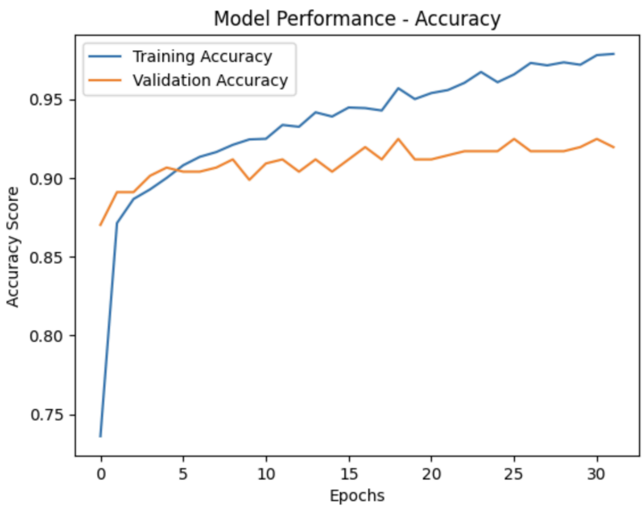


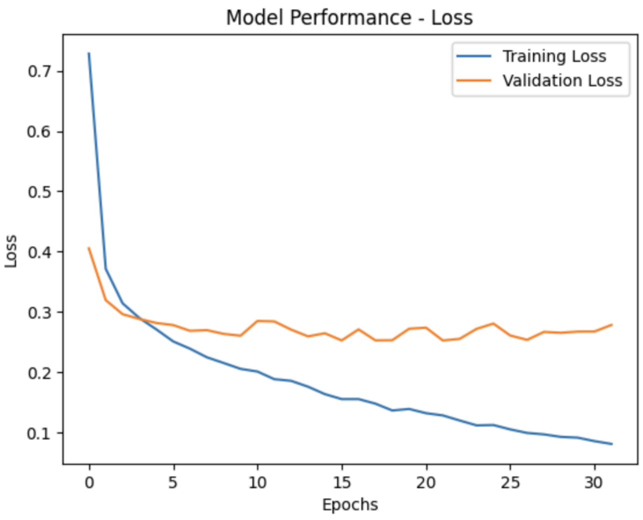


- Then I trained a neural network model with an input layer of 16 neurons and an output layer with softmax as an activation function for a multiclass classification task for num_class = 4 classes, for classifying the data into 4 distinct clusters.
- The model's performance is shown below:

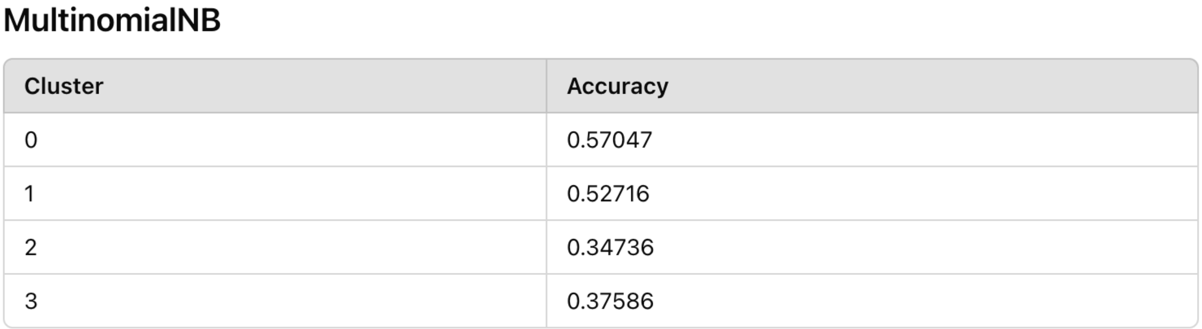


| Metric | Value |
|---|---|
| Training Accuracy | 0.9615 |
| Training Loss | 0.1242 |
| Validation Accuracy | 0.9247 |
| Validation Loss | 0.2713 |
| Test Accuracy | 0.9160 |
| Test Loss | 0.2137 |



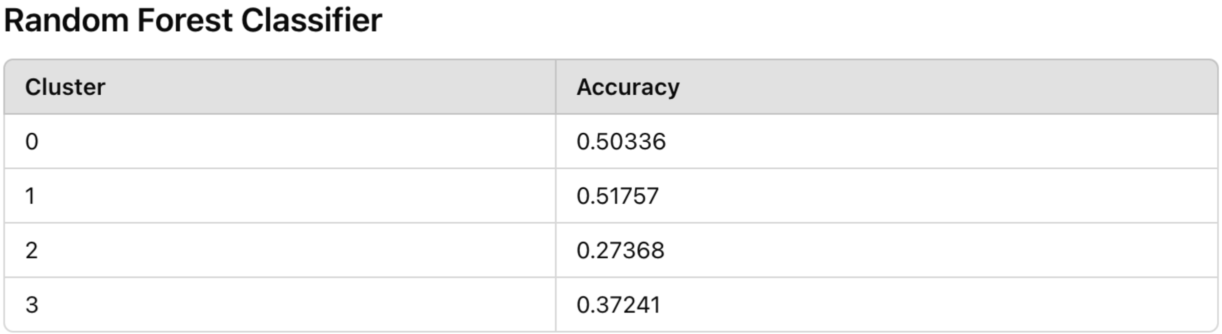


- Then I attempted classification of the labels within each individual cluster using MultiNomialNB and Random Forest Classifier:
- The initial performance of the models are shown below:



### MultinomialNB

| Cluster | Accuracy |
|---|---|
| 0 | 0.57047 |
| 1 | 0.52716 |
| 2 | 0.34736 |
| 3 | 0.37586 |



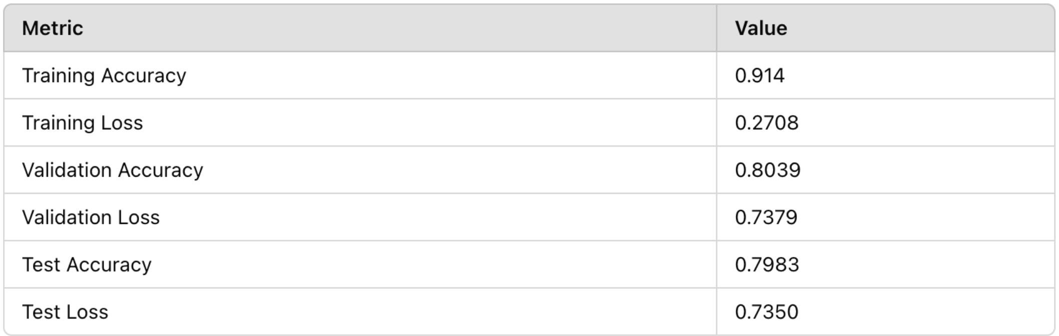
### Random Forest Classifier

| Cluster | Accuracy |
|---|---|
| 0 | 0.50336 |
| 1 | 0.51757 |
| 2 | 0.27368 |
| 3 | 0.37241 |

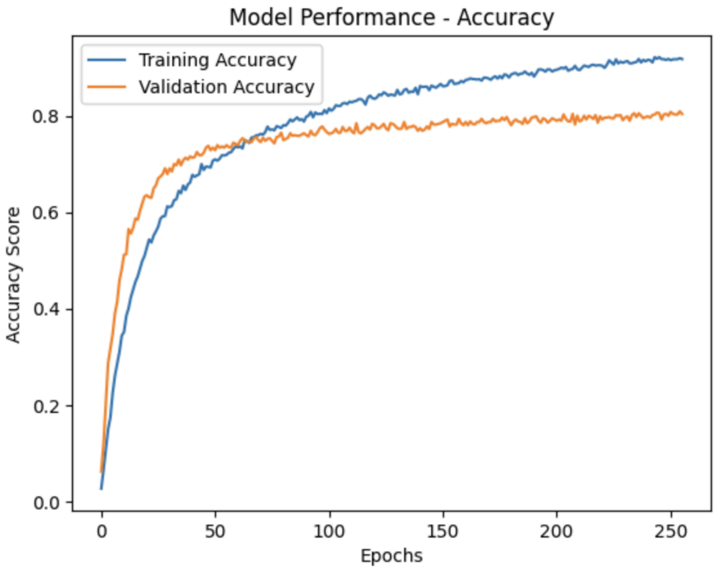
- The model accuracy in the classification of the 77 labels within each of the 4 clusters is not well. I hypothesize that this is due to the homogeneity of the data within each cluster and lack of enough training samples.

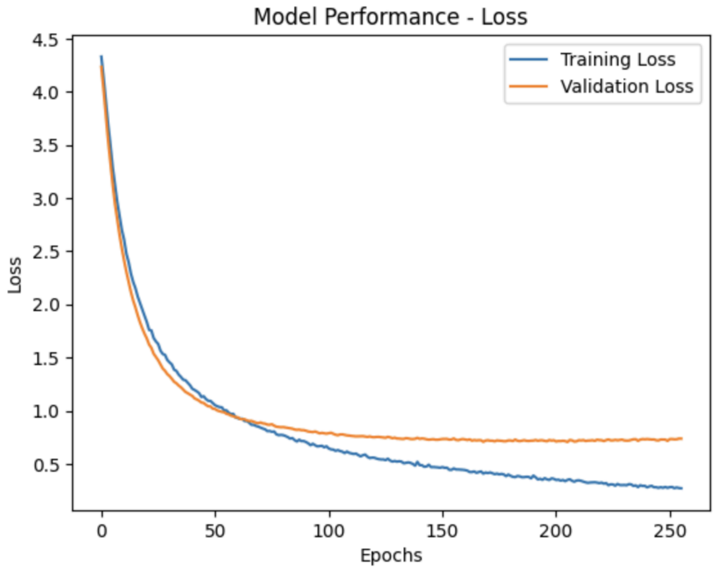
## 2) Increasing the training samples from 2618 to 5540: approx. 60%

- I increased the number of training samples to 4089, and the performance of different models on the earlier classification tasks are shown below:
- Model’s performance on the classification of 77 classes increased for training, validation, and testing sets, as shown below:

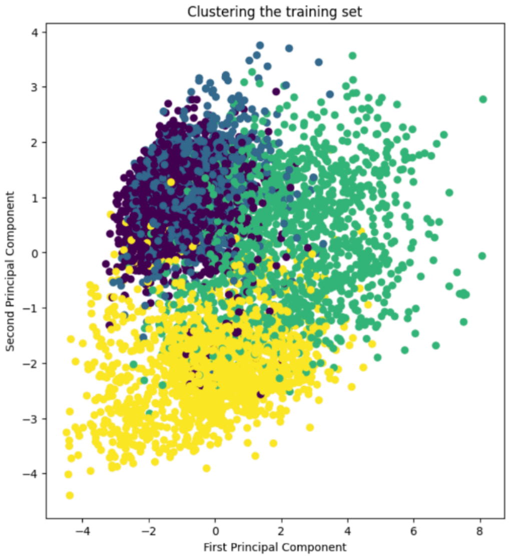


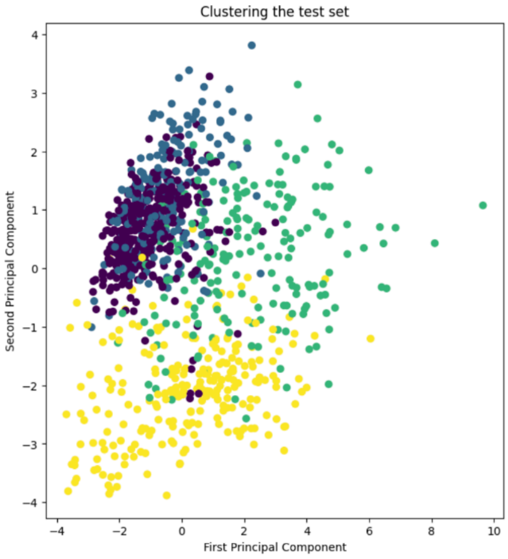
| Metric | Value |
|---|---|
| Training Accuracy | 0.914 |
| Training Loss | 0.2708 |
| Validation Accuracy | 0.8039 |
| Validation Loss | 0.7379 |
| Test Accuracy | 0.7983 |
| Test Loss | 0.7350 |

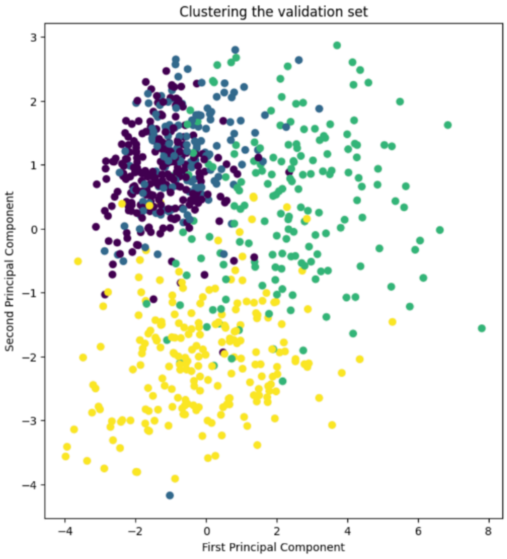


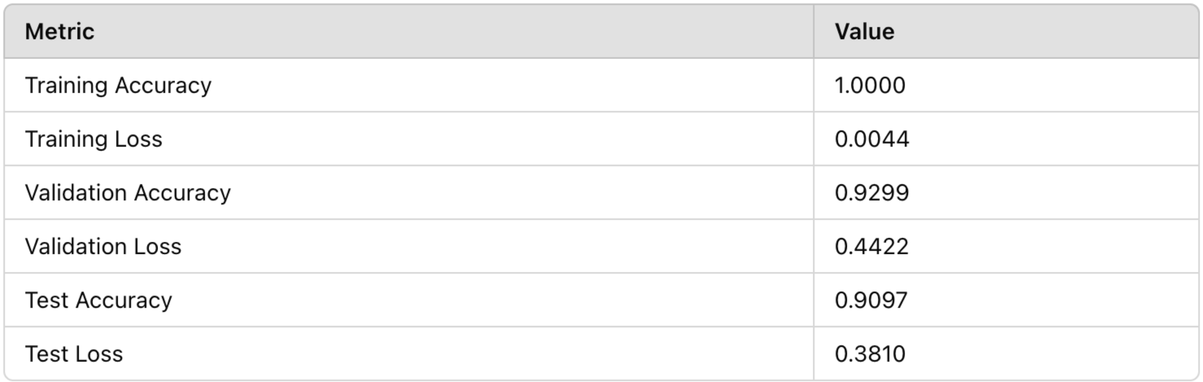


- Then I use hierarchical clustering (ward method) to form 4 clusters of the datasets. The clusters can be visualized as below along their first two principal components.



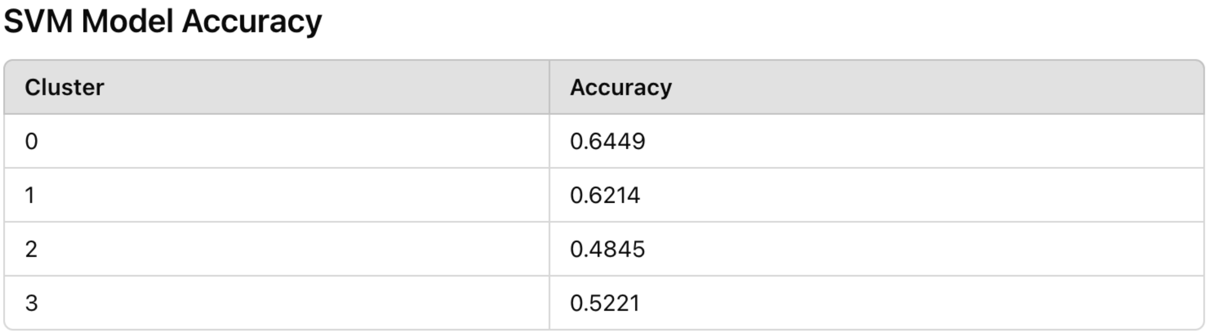






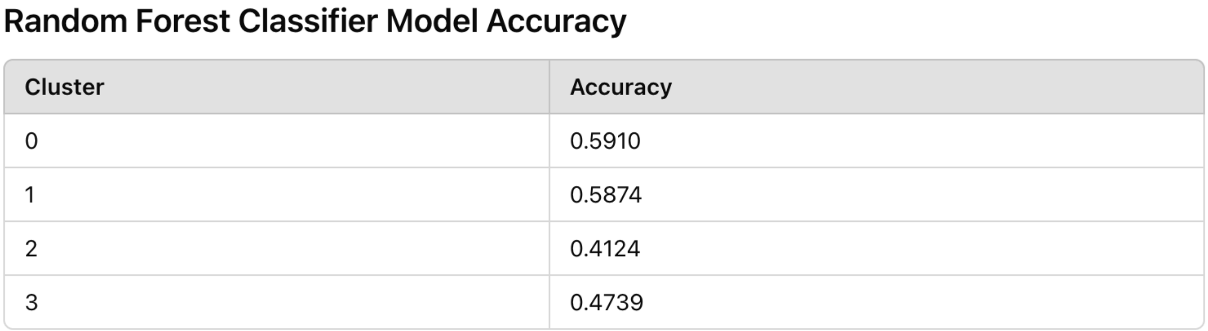
| Metric | Value |
|---|---|
| Training Accuracy | 1.0000 |
| Training Loss | 0.0044 |
| Validation Accuracy | 0.9299 |
| Validation Loss | 0.4422 |
| Test Accuracy | 0.9097 |
| Test Loss | 0.3810 |

- The performance of classification of the labels within the clusters didn't increase significantly. I alternatively also used SVM that resulted in slightly better performance.



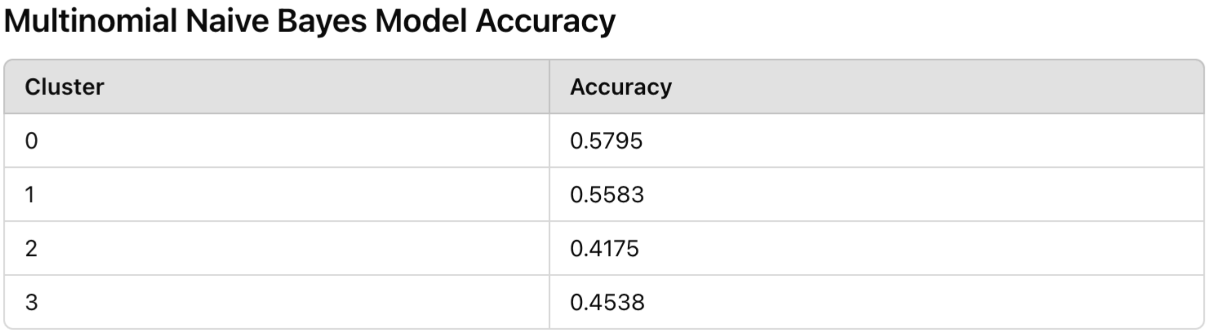
### SVM Model Accuracy

| Cluster | Accuracy |
|---|---|
| 0 | 0.6449 |
| 1 | 0.6214 |
| 2 | 0.4845 |
| 3 | 0.5221 |



### Random Forest Classifier Model Accuracy

| Cluster | Accuracy |
|---|---|
| 0 | 0.5910 |
| 1 | 0.5874 |
| 2 | 0.4124 |
| 3 | 0.4739 |

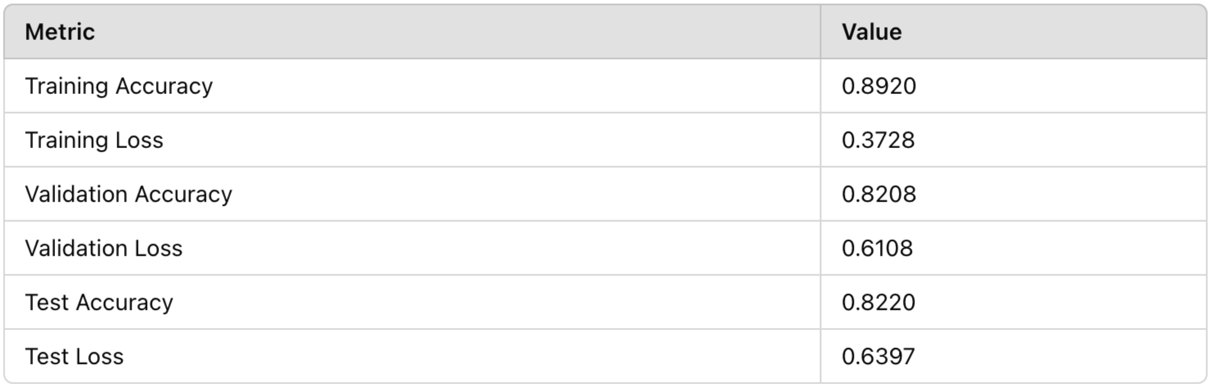


### Multinomial Naive Bayes Model Accuracy

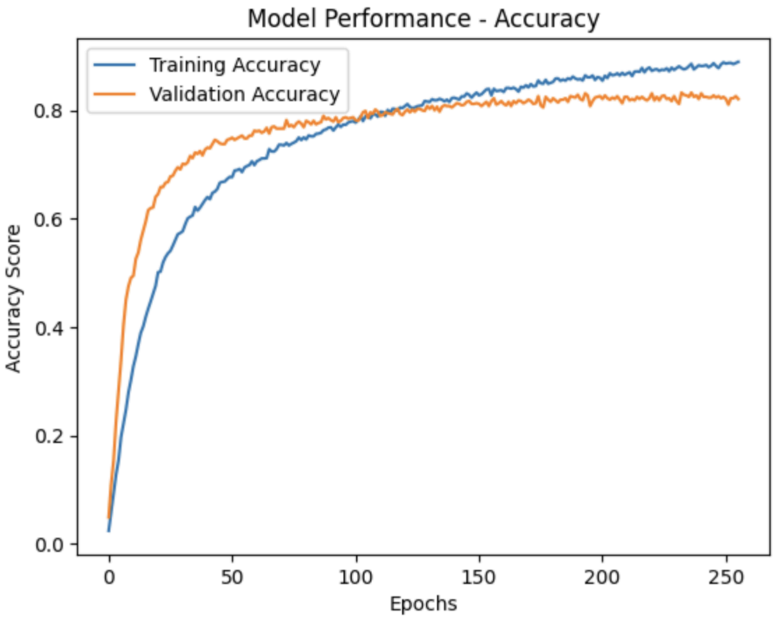
| Cluster | Accuracy |
|---|---|
| 0 | 0.5795 |
| 1 | 0.5583 |
| 2 | 0.4175 |
| 3 | 0.4538 |

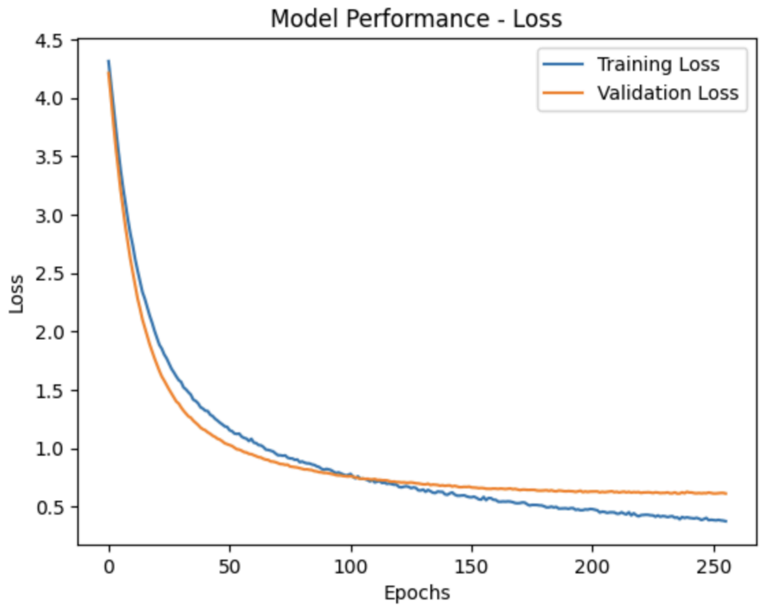
## 3) Increasing the training samples from 5540 to 7385: approx. 80%

- I increased the number of training samples to 7385, and the performance of different models on the earlier classification tasks are shown below:
- Model's performance on the classification of 77 classes increased for training, validation, and testing sets, as shown below:

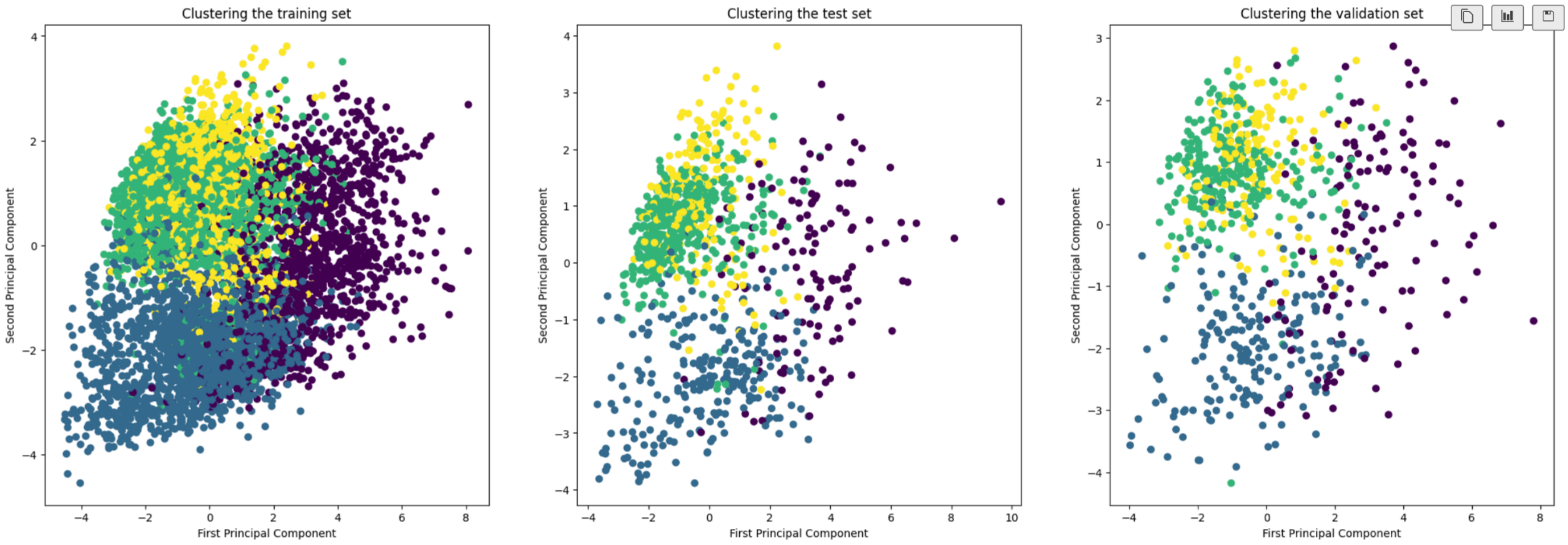


| Metric | Value |
|---|---|
| Training Accuracy | 0.8920 |
| Training Loss | 0.3728 |
| Validation Accuracy | 0.8208 |
| Validation Loss | 0.6108 |
| Test Accuracy | 0.8220 |
| Test Loss | 0.6397 |





- The clusters can be visualized as below along their first two principal components.



- The performance of classification of the labels within the clusters is also shown below:

### Multinomial Naive Bayes

| Cluster | Accuracy |
|---|---|
| 0 | 0.41935 |
| 1 | 0.41036 |
| 2 | 0.53580 |
| 3 | 0.58823 |

### Random Forest Classifier

| Cluster | Accuracy |
|---|---|
| 0 | 0.37097 |
| 1 | 0.42231 |
| 2 | 0.59753 |
| 3 | 0.65158 |

### Support Vector Machine (SVM) using RBF kernel

| Cluster | Accuracy |
|---|---|
| 0 | 0.53225 |
| 1 | 0.54980 |
| 2 | 0.67160 |
| 3 | 0.68778 |