PART II. CLASSIFICATION (CLASMODL):

JOAQUIN MOLTO (PID: 6119985)

In [ ]:
```
# IMPORT STATEMENTS
import sklearn as sk
from sklearn.metrics import r2_score
import numpy as np
import pandas as pd
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense
from tensorflow.keras.optimizers import RMSprop
from tensorflow.keras.callbacks import ModelCheckpoint, EarlyStopping
import matplotlib.pyplot as plt
import matplotlib.style as style
# style.use('C:/Users/jmolt/.matplotlib/stylelib/rose-pine.mplstyle')
```

In [ ]:
```
XtrainDF = pd.read_csv('TR.csv')
XvalDF = pd.read_csv('TT.csv')
XtstDF = pd.read_csv('TS.csv')

y_trainDF = pd.read_csv('TR_CLS_TARGET_OH.csv')
y_valDF = pd.read_csv('TT_CLS_TARGET_OH.csv')
y_tstDF = pd.read_csv('TS_CLS_TARGET_OH.csv')
```

In [ ]:
```
Xtrain = XtrainDF.to_numpy()
Xval = XvalDF.to_numpy()
Xtst = XtstDF.to_numpy()

y_train = y_trainDF.to_numpy()
y_val = y_valDF.to_numpy()
y_tst = y_tstDF.to_numpy()
```

In [ ]:
```
Xtrain.shape, Xval.shape, Xtst.shape, y_train.shape, y_val.shape, y_tst.shape
```

Out[ ]:
```
((4872, 12), (1615, 12), (10, 12), (4872, 4), (1615, 4), (10, 4))
```

In [ ]:
```
print(Xtrain.shape[0],Xtrain.shape[1])
```

```
4872 12
```

In [ ]:
```
XtrainDF_STD = pd.read_csv('TR_STANDARDIZED.csv')
XvalDF_STD = pd.read_csv('TT_STANDARDIZED.csv')
XtstDF_STD = pd.read_csv('TS_STANDARDIZED.csv')
```

In [ ]:
```
Xtrain_STD = XtrainDF_STD.to_numpy()
Xval_STD = XvalDF_STD.to_numpy()
Xtst_STD = XtstDF_STD.to_numpy()
```

In [ ]:
```
Xtrain_STD.shape, Xval_STD.shape, Xtst_STD.shape, y_train.shape, y_val.shape, y_tst
```

Out[ ]:
```
((4872, 12), (1615, 12), (10, 12), (4872, 4), (1615, 4), (10, 4))
```

In [ ]:
```
print(Xtrain_STD.shape[0],Xtrain_STD.shape[1])
```

```
4872 12
```

CLASMODL01

In [ ]:
```
# DEFINE MODEL ARCHITECTURE
clasmodl01 = Sequential([
    Dense(8, activation='relu', input_shape=(Xtrain.shape[1],)),
    Dense(4, activation='softmax')
])
```

In [ ]:
```
# COMPILE THE MODEL
clasmodl01.compile(
    optimizer=RMSprop(),
    loss="categorical_crossentropy",
    metrics=['accuracy'])
```

In [ ]:
```
# TRAIN THE MODEL
history = clasmodl01.fit(
    Xtrain,
    y_train,
    epochs = 100,
    validation_data=(Xval,y_val)
)
```

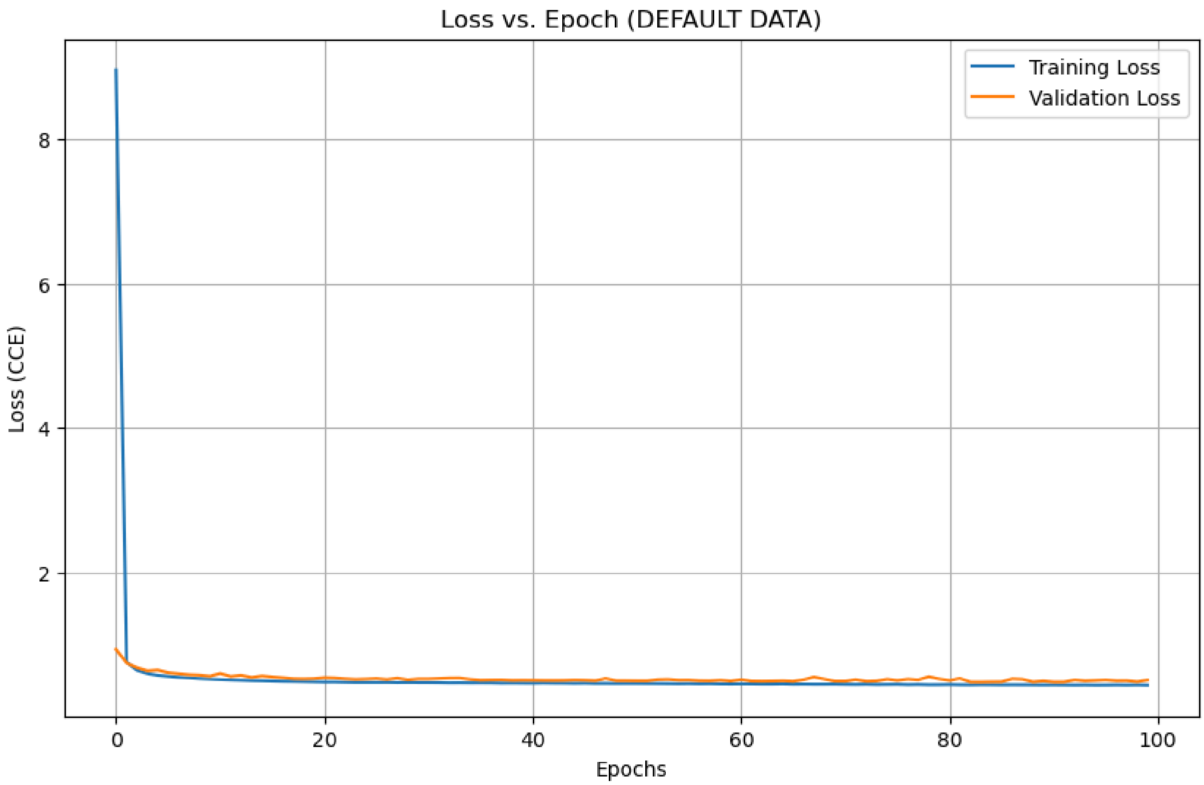
In [ ]:
```
# EXTRACT HISTORY FOR LOSS AND MAE ON THE TRAINING AND VALIDATION SET
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

# REPORT THE FINAL LOSS AND MAE ON THE TRAINING AND VALIDATION SET
final_loss_train = loss[-1]
final_acc_train = acc[-1]
final_loss_val = val_loss[-1]
final_acc_val = val_acc[-1]
```

In [ ]:
```
print(f'Final Loss (Training): {final_loss_train}, Final Accuracy (Training): {fina
print(f'Final Loss (Validation): {final_loss_val}, Final Accuracy (Validation): {fi
```

```
Final Loss (Training): 0.43704554438591003, Final Accuracy (Training): 0.80541872978
21045
Final Loss (Validation): 0.5075479745864868, Final Accuracy (Validation): 0.77708977
46086121
```

In [ ]:
```
plt.figure(figsize=(10, 6))
plt.plot(loss, label='Training Loss')
plt.plot(val_loss, label='Validation Loss')
plt.title('Loss vs. Epoch (DEFAULT DATA)')
```

```
plt.xlabel('Epochs')
plt.ylabel('Loss (CCE)')
plt.legend()
plt.grid(True)
plt.show()
```



In [ ]:
```
# COMPILE THE MODEL
clasmodl01.compile(
    optimizer=RMSprop(),
    loss="categorical_crossentropy",
    metrics=['accuracy'])
```

In [ ]:
```
# TRAIN THE MODEL
history = clasmodl01.fit(
    Xtrain_STD,
    y_train,
    epochs = 100,
    validation_data=(Xval_STD,y_val)
)
```

In [ ]:

```
# EXTRACT HISTORY FOR LOSS AND MAE ON THE TRAINING AND VALIDATION SET
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

# REPORT THE FINAL LOSS AND MAE ON THE TRAINING AND VALIDATION SET
final_loss_train = loss[-1]
final_acc_train = acc[-1]
final_loss_val = val_loss[-1]
final_acc_val = val_acc[-1]
```

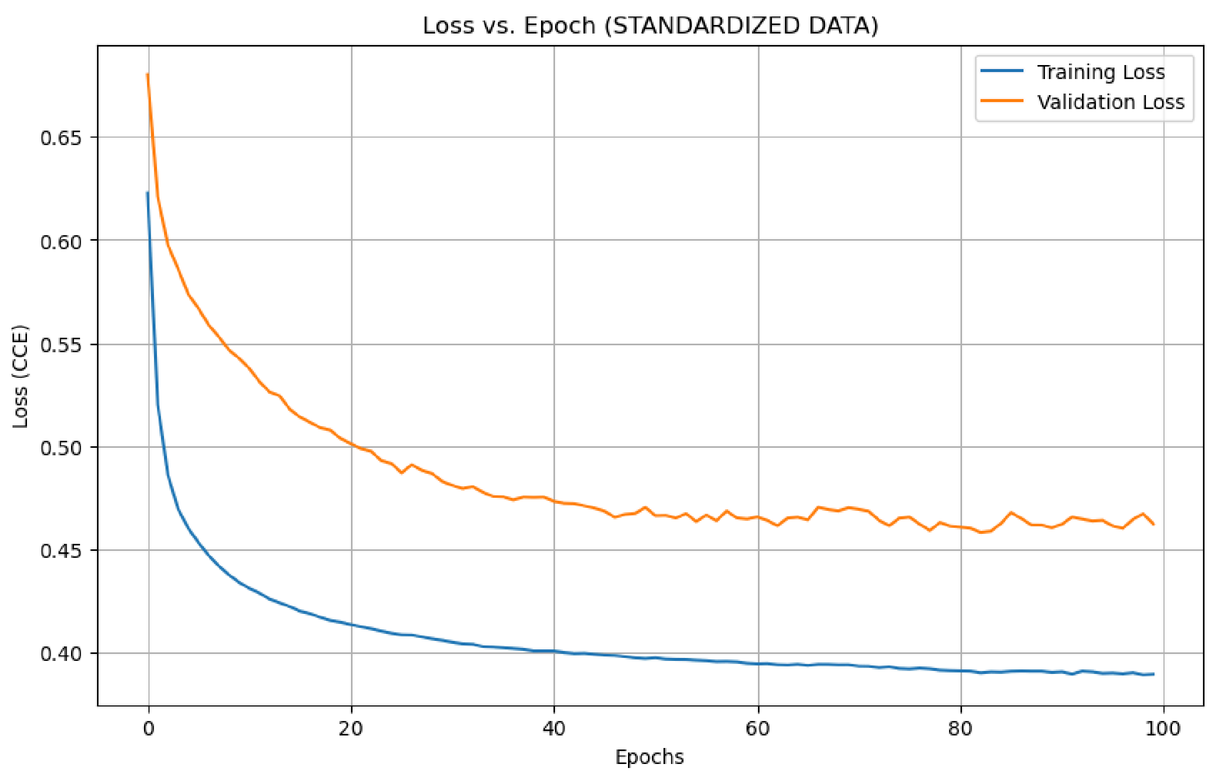
In [ ]:

```
print(f'Final Loss (Training): {final_loss_train}, Final Accuracy (Training): {fina
print(f'Final Loss (Validation): {final_loss_val}, Final Accuracy (Validation): {fi
```

```
Final Loss (Training): 0.38961753249168396, Final Accuracy (Training): 0.82717567682
26624
Final Loss (Validation): 0.4623268246650696, Final Accuracy (Validation): 0.82043343
78242493
```

In [ ]:

```
plt.figure(figsize=(10, 6))
plt.plot(loss, label='Training Loss')
plt.plot(val_loss, label='Validation Loss')
plt.title('Loss vs. Epoch (STANDARDIZED DATA)')
plt.xlabel('Epochs')
plt.ylabel('Loss (CCE)')
plt.legend()
plt.grid(True)
plt.show()
```



__CLASMODL02__

In [ ]:
```
# DEFINE MODEL ARCHITECTURE
clasmodl02 = Sequential([
    Dense(16, activation='relu', input_shape=(Xtrain.shape[1],)),
    Dense(8, activation='relu'),
    Dense(4, activation='softmax')
])
```

In [ ]:
```
# COMPILE THE MODEL
clasmodl02.compile(
    optimizer=RMSprop(),
    loss="categorical_crossentropy",
    metrics=['accuracy'])
```

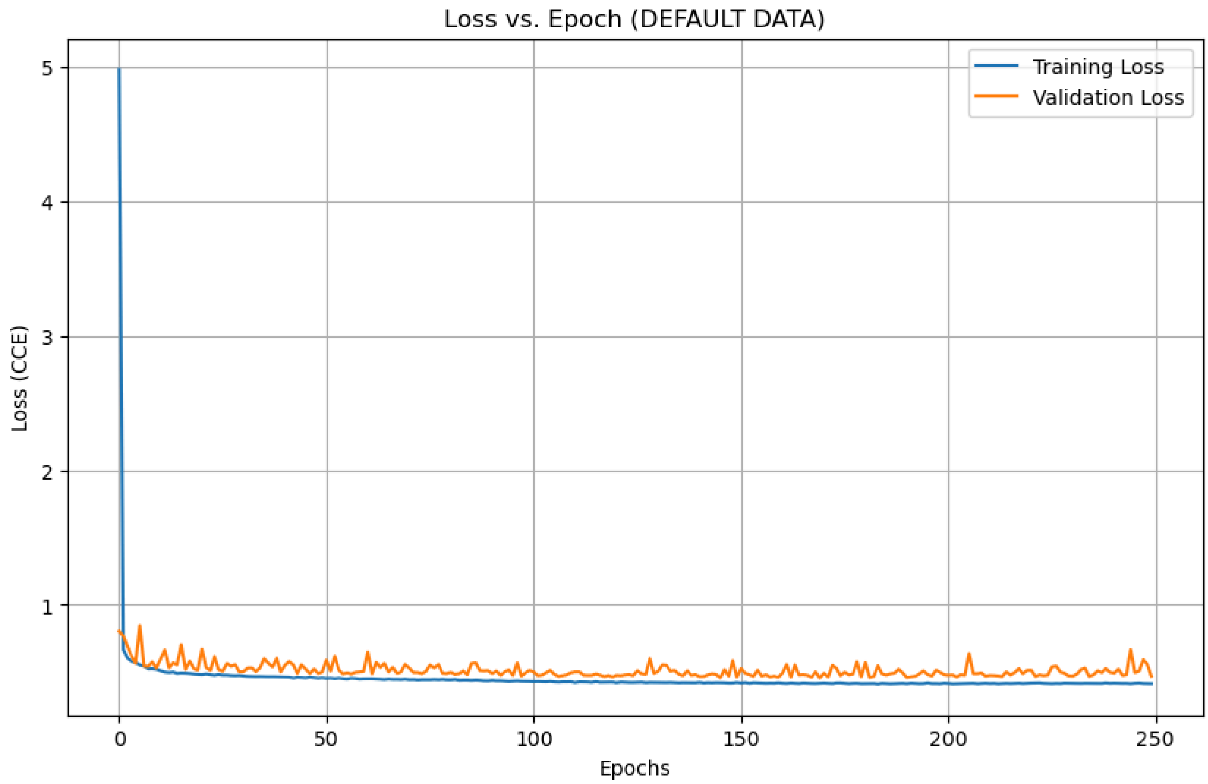
In [ ]:
```
# TRAIN THE MODEL
history = clasmodl02.fit(
    Xtrain,
    y_train,
    epochs = 250,
    validation_data=(Xval,y_val)
)
```

In [ ]:
```
# EXTRACT HISTORY FOR LOSS AND MAE ON THE TRAINING AND VALIDATION SET
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

# REPORT THE FINAL LOSS AND MAE ON THE TRAINING AND VALIDATION SET
final_loss_train = loss[-1]
final_acc_train = acc[-1]
final_loss_val = val_loss[-1]
final_acc_val = val_acc[-1]
```

In [ ]:
```
print(f'Final Loss (Training): {final_loss_train}, Final Accuracy (Training): {fina
print(f'Final Loss (Validation): {final_loss_val}, Final Accuracy (Validation): {fi
```

```
Final Loss (Training): 0.41282349824905396, Final Accuracy (Training): 0.81588667631
14929
Final Loss (Validation): 0.46927961707115173, Final Accuracy (Validation): 0.8105263
113975525
```

In [ ]:
```
plt.figure(figsize=(10, 6))
plt.plot(loss, label='Training Loss')
plt.plot(val_loss, label='Validation Loss')
plt.title('Loss vs. Epoch (DEFAULT DATA)')
plt.xlabel('Epochs')
plt.ylabel('Loss (CCE)')
plt.legend()
plt.grid(True)
plt.show()
```



In [ ]:
```
# COMPILE THE MODEL
clasmodl02.compile(
    optimizer=RMSprop(),
    loss="categorical_crossentropy",
    metrics=['accuracy'])
```

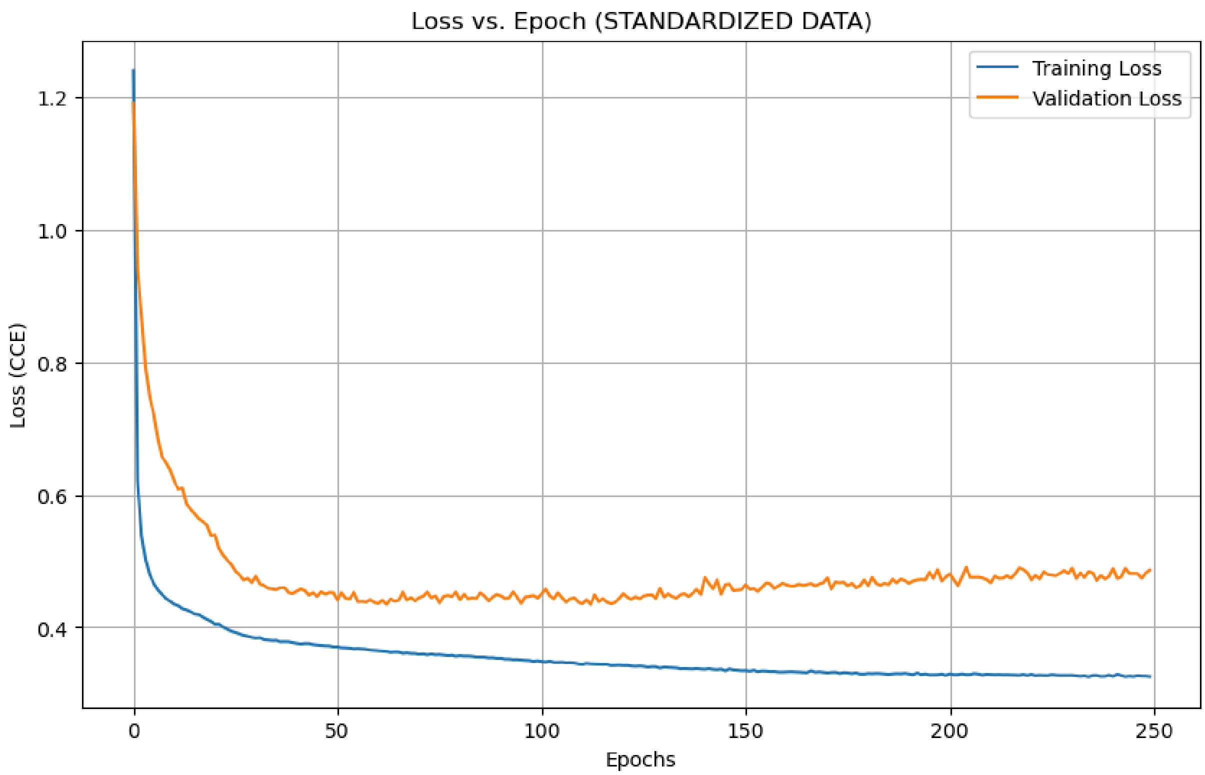
In [ ]:
```
# TRAIN THE MODEL
history = clasmodl02.fit(
    Xtrain_STD,
    y_train,
    epochs = 250,
    validation_data=(Xval_STD,y_val)
)
```

In [ ]:
```
# EXTRACT HISTORY FOR LOSS AND MAE ON THE TRAINING AND VALIDATION SET
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

# REPORT THE FINAL LOSS AND MAE ON THE TRAINING AND VALIDATION SET
final_loss_train = loss[-1]
final_acc_train = acc[-1]
final_loss_val = val_loss[-1]
final_acc_val = val_acc[-1]
```

In [ ]:
```
print(f'Final Loss (Training): {final_loss_train}, Final Accuracy (Training): {fina
print(f'Final Loss (Validation): {final_loss_val}, Final Accuracy (Validation): {fi
```

```
Final Loss (Training): 0.32588276267051697, Final Accuracy (Training): 0.86247944831
84814
Final Loss (Validation): 0.48632386326789856, Final Accuracy (Validation): 0.8173374
533653259
```

In [ ]:
```python
plt.figure(figsize=(10, 6))
plt.plot(loss, label='Training Loss')
plt.plot(val_loss, label='Validation Loss')
plt.title('Loss vs. Epoch (STANDARDIZED DATA)')
plt.xlabel('Epochs')
plt.ylabel('Loss (CCE)')
plt.legend()
plt.grid(True)
plt.show()
```



__CLASMODL03__

In [ ]:
```python
model_checkpoint_callback = ModelCheckpoint(
    filepath="clasmodl03.keras",
    save_best_only=True,
    monitor='val_loss',
    mode='min'
)
early_stopping_callback = EarlyStopping(
    monitor='val_loss',
    mode='min',
    patience=500,
    verbose=1,
    restore_best_weights=True
)
```

```
In [ ]: # DEFINE MODEL ARCHITECTURE
        clasmodl02 = Sequential([
            Dense(32, activation='relu', input_shape=(Xtrain.shape[1],)),
            Dense(16, activation='relu'),
            Dense(4, activation='softmax')
        ])
```

```
In [ ]: # COMPILE THE MODEL
        clasmodl02.compile(
            optimizer=RMSprop(),
            loss="categorical_crossentropy",
            metrics=['accuracy'])
```

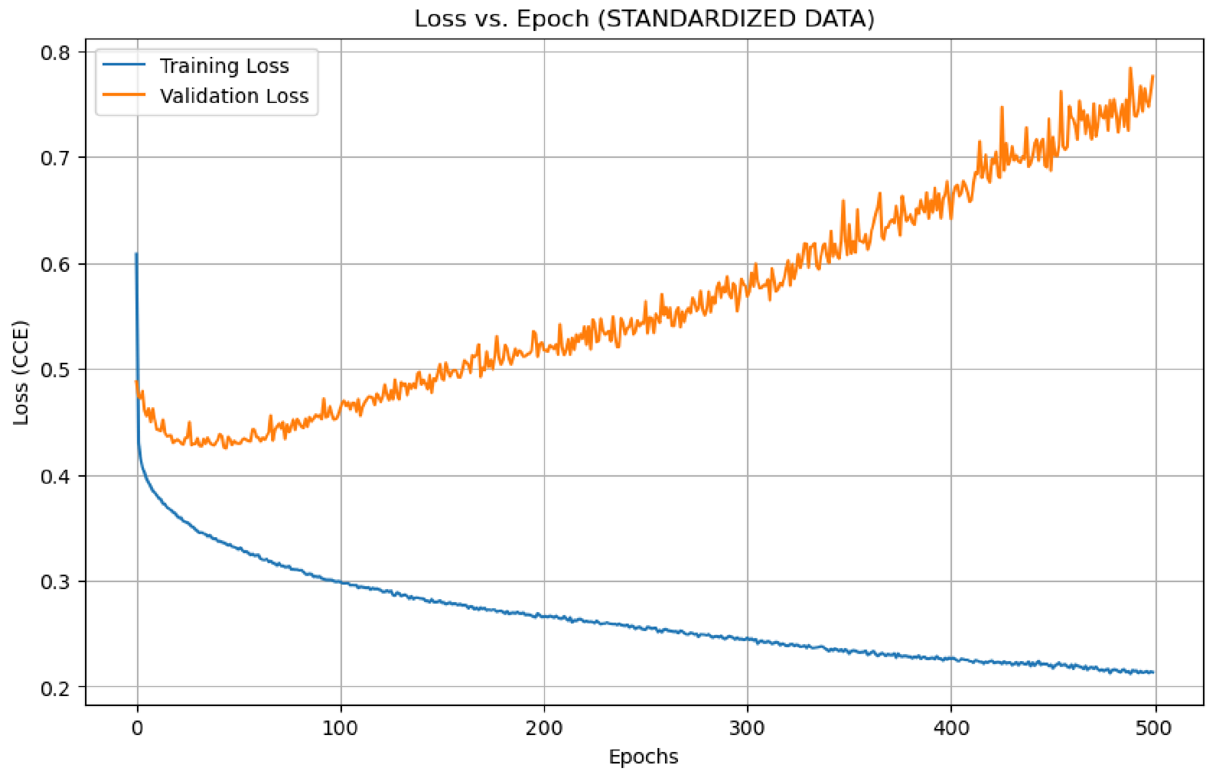
```
In [ ]: # TRAIN THE MODEL
        history = clasmodl02.fit(
            Xtrain_STD,
            y_train,
            epochs = 500,
            validation_data=(Xval_STD,y_val),
            callbacks=[model_checkpoint_callback,early_stopping_callback]
        )
```

```
In [ ]: # EXTRACT HISTORY FOR LOSS AND MAE ON THE TRAINING AND VALIDATION SET
        loss = history.history['loss']
        val_loss = history.history['val_loss']
        acc = history.history['accuracy']
        val_acc = history.history['val_accuracy']

        # REPORT THE FINAL LOSS AND MAE ON THE TRAINING AND VALIDATION SET
        final_loss_train = loss[-1]
        final_acc_train = acc[-1]
        final_loss_val = val_loss[-1]
        final_acc_val = val_acc[-1]
```

```
In [ ]: print(f'Final Loss (Training): {final_loss_train}, Final Accuracy (Training): {fina
        print(f'Final Loss (Validation): {final_loss_val}, Final Accuracy (Validation): {fi
```

```
Final Loss (Training): 0.21356301009655, Final Accuracy (Training): 0.91153532266616
82
Final Loss (Validation): 0.7759798765182495, Final Accuracy (Validation): 0.83034056
4250946
```

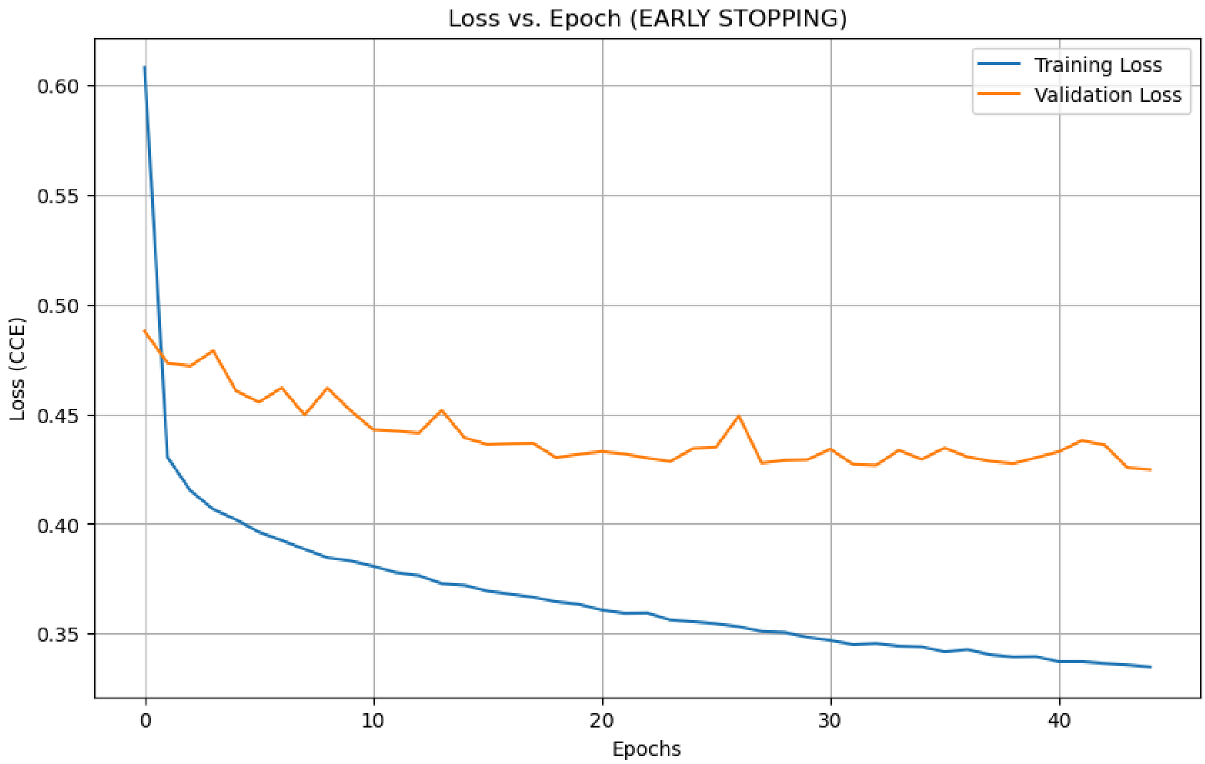
```
In [ ]: plt.figure(figsize=(10, 6))
        plt.plot(loss, label='Training Loss')
        plt.plot(val_loss, label='Validation Loss')
        plt.title('Loss vs. Epoch (STANDARDIZED DATA)')
        plt.xlabel('Epochs')
        plt.ylabel('Loss (CCE)')
        plt.legend()
        plt.grid(True)
        plt.show()
```



In [ ]:
```
# Assuming 'val_loss' is being monitored
val_loss_history = history.history['val_loss']

# Find the epoch number with the lowest validation MAE
best_epoch = val_loss_history.index(min(val_loss_history)) + 1  # adding 1 because
best_val_loss = min(val_loss_history)

print(f"The lowest validation loss was: {best_val_loss}")
print(f"At epoch: {best_epoch}")
```

```
The lowest validation loss was: 0.4247453510761261
At epoch: 45
```

In [ ]:
```
loss = history.history['loss'][:best_epoch]
val_loss = history.history['val_loss'][:best_epoch]

plt.figure(figsize=(10, 6))
plt.plot(loss, label='Training Loss')
plt.plot(val_loss, label='Validation Loss')
plt.title('Loss vs. Epoch (EARLY STOPPING)')
plt.xlabel('Epochs')
plt.ylabel('Loss (CCE)')
plt.legend()
plt.grid(True)
plt.show()
```



In [ ]:
```
from tensorflow.keras.models import load_model

clasmodl03 = load_model('clasmodl03.keras')
y_pred = clasmodl03.predict(Xtst_STD)
```

```
1/1 [==============================] - 0s 96ms/step
1/1 [==============================] - 0s 96ms/step
```

In [ ]:
```
y_tst
```

Out[ ]:
```
array([[0., 1., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 1., 0., 0.],
       [0., 1., 0., 0.],
       [0., 1., 0., 0.],
       [0., 1., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 1., 0., 0.]])
```

In [ ]:
```
y_tst_argmax = np.argmax(y_tst, axis=1)
```

In [ ]:
```
y_tst_argmax
```

Out[ ]:
```
array([1, 1, 2, 1, 1, 1, 1, 1, 2, 1], dtype=int64)
```

In [ ]:
```
y_pred
```

```
Out[ ]: array([[1.3998745e-01, 8.2713997e-01, 3.2865651e-02, 6.9142520e-06],
               [3.0806675e-04, 9.1591090e-01, 8.3780818e-02, 2.4190538e-07],
               [1.9920767e-04, 9.0744448e-01, 9.2353180e-02, 3.1403667e-06],
               [2.4322237e-04, 9.6053547e-01, 3.9221343e-02, 2.2080545e-08],
               [3.0347140e-04, 8.2655603e-01, 1.7313604e-01, 4.3929358e-06],
               [1.4552487e-02, 9.4477135e-01, 4.0663201e-02, 1.2927101e-05],
               [1.1321844e-04, 3.7643611e-01, 6.2343681e-01, 1.3908181e-05],
               [1.1809849e-05, 7.9043764e-01, 2.0955044e-01, 5.0718256e-08],
               [1.3860335e-04, 9.7240394e-01, 2.7457401e-02, 2.1441380e-08],
               [6.4478215e-04, 7.1244025e-01, 2.8690794e-01, 6.9616053e-06]],
              dtype=float32)
```

```
In [ ]: y_pred_argmax = np.argmax(y_pred, axis=1)
```

```
In [ ]: y_pred_argmax
```

```
Out[ ]: array([1, 1, 1, 1, 1, 1, 2, 1, 1, 1], dtype=int64)
```

```
In [ ]: # Assuming y_pred are the probabilities from the model's softmax layer
        # Convert probabilities to predicted class labels
        y_pred_labels = np.argmax(y_pred, axis=1)

        # Assuming y_test are the actual targets in one-hot encoded format
        # Convert one-hot encoded targets back to class labels
        y_test_labels = np.argmax(y_tst, axis=1)

        # Iterate through all predictions and actual targets
        for i in range(len(y_pred_labels)):
            prediction_label = y_pred_labels[i]
            actual_label = y_test_labels[i]
            # Compare predicted class label with actual class label
            hit = "1" if prediction_label == actual_label else "0"
            print(f"Prediction: {prediction_label}, Actual: {actual_label}, Hit: {hit}")
```

```
Prediction: 1, Actual: 1, Hit: 1
Prediction: 1, Actual: 1, Hit: 1
Prediction: 1, Actual: 2, Hit: 0
Prediction: 1, Actual: 1, Hit: 1
Prediction: 1, Actual: 1, Hit: 1
Prediction: 1, Actual: 1, Hit: 1
Prediction: 2, Actual: 1, Hit: 0
Prediction: 1, Actual: 1, Hit: 1
Prediction: 1, Actual: 2, Hit: 0
Prediction: 1, Actual: 1, Hit: 1
```

RANDOM CLASSIFIER

```
In [ ]: y_test_labels
```

```
Out[ ]: array([1, 1, 2, 1, 1, 1, 1, 1, 2, 1], dtype=int64)
```

```
In [ ]: import copy
        test_labels_copy = copy.copy(y_test_labels)
        np.random.shuffle(test_labels_copy)
```

In [ ]:

```
hits_array = np.array(y_test_labels) == np.array(test_labels_copy)
random_accuracy = hits_array.mean()

print(f"Random Classifier ACC: {random_accuracy}")
```

```
Random Classifier ACC: 0.6
```