

```

import pandas as pd
import numpy as np
import torch
import torch.nn as nn
import torch.optim as optim
from torch.utils.data import DataLoader, TensorDataset
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score, confusion_matrix,
precision_recall_fscore_support
import time
import matplotlib.pyplot as plt
from imblearn.over_sampling import SMOTE
from sklearn.metrics import mean_absolute_error, mean_squared_error,
r2_score, mean_absolute_percentage_error
from sklearn.metrics import ConfusionMatrixDisplay
from IPython.display import display
from sklearn.preprocessing import StandardScaler

column_names = [f"col_{i}" for i in range(16)]
train_data = pd.read_csv('train_1_to_3iz.dat', sep='\t', header=None,
names=column_names)
test_data = pd.read_csv('test_1_to_3iz.dat', sep='\t', header=None,
names=column_names)

print(train_data.shape)
print(test_data.shape)

(8921, 16)
(6121, 16)

print(train_data.columns)
print(test_data.columns)

Index(['col_0', 'col_1', 'col_2', 'col_3', 'col_4', 'col_5', 'col_6',
'col_7',
       'col_8', 'col_9', 'col_10', 'col_11', 'col_12', 'col_13',
'col_14',
       'col_15'],
      dtype='object')
Index(['col_0', 'col_1', 'col_2', 'col_3', 'col_4', 'col_5', 'col_6',
'col_7',
       'col_8', 'col_9', 'col_10', 'col_11', 'col_12', 'col_13',
'col_14',
       'col_15'],
      dtype='object')

train_data.head(n=5)

    col_0      col_1      col_2      col_3      col_4      col_5      col_6
col_7 \
0      1 -0.912718  0.666102 -0.303196 -0.112648  0.508833      0 -

```

```
0.408591
1      1 -0.908576  0.651015 -0.274404 -0.152392  0.551327     0 -
0.417720
2      1 -0.904296  0.635498 -0.245047 -0.192319  0.592876     0 -
0.426905
3      1 -0.899876  0.619548 -0.215145 -0.232353  0.633324     0 -
0.436145
4      1 -0.895314  0.603167 -0.184720 -0.272414  0.672512     0 -
0.445436
```

	col_8	col_9	col_10	col_11	col_12	col_13	col_14
col_15							
0	0.745861	-0.952928	0.993635	-0.860865	-60.00000	99.0	99
1	0.759065	-0.961614	0.988320	-0.834289	-59.63636	99.0	99
1	0.772103	-0.969511	0.981333	-0.805294	-59.27273	99.0	99
1	0.784958	-0.976582	0.972631	-0.773887	-58.90909	99.0	99
1	0.797615	-0.982791	0.962180	-0.740086	-58.54545	99.0	99
1							

```
test_data.head(n=5)
```

	col_0	col_1	col_2	col_3	col_4	col_5	col_6
col_7 \							
0	1	-0.912718	0.666102	-0.303196	-0.112648	0.508833	0 -
0.408591	1	-0.906148	0.642201	-0.257697	-0.175189	0.575195	0 -
0.422962	2	-0.899234	0.617235	-0.210830	-0.238076	0.639003	0 -
0.437469	3	-0.891966	0.591200	-0.162681	-0.301000	0.699643	0 -
0.452102	4	-0.884337	0.564095	-0.113349	-0.363629	0.756487	0 -
0.466850							

	col_8	col_9	col_10	col_11	col_12	col_13	col_14
col_15							
0	0.745861	-0.952928	0.993635	-0.860865	-60.00000	99.0	99.0
1	0.766537	-0.966226	0.984535	-0.818016	-59.42857	99.0	99.0
1	0.786779	-0.977523	0.971247	-0.769204	-58.85714	99.0	99.0
1	0.806525	-0.986679	0.953624	-0.714492	-58.28571	99.0	99.0
1	0.825710	-0.993555	0.931544	-0.654009	-57.71429	99.0	99.0
1							

```
print(train_data.isnull().sum())
print(test_data.isnull().sum())

col_0      0
col_1      0
col_2      0
col_3      0
col_4      0
col_5      0
col_6      0
col_7      0
col_8      0
col_9      0
col_10     0
col_11     0
col_12     0
col_13     0
col_14     0
col_15     0
dtype: int64
col_0      0
col_1      0
col_2      0
col_3      0
col_4      0
col_5      0
col_6      0
col_7      0
col_8      0
col_9      0
col_10     0
col_11     0
col_12     0
col_13     0
col_14     0
col_15     0
dtype: int64

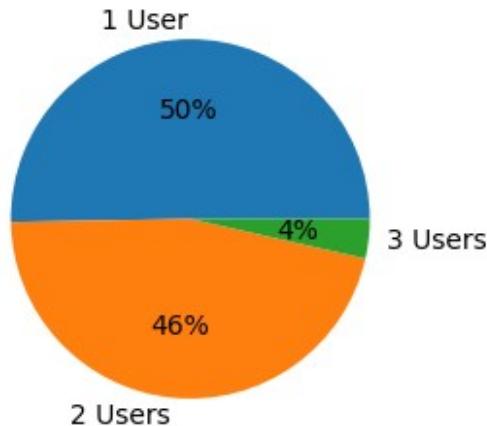
X = train_data.iloc[:, [1, 2, 3, 4, 5, 7, 8, 9, 10, 11]].values
y = train_data.iloc[:, 15].values
X_test = test_data.iloc[:, [1, 2, 3, 4, 5, 7, 8, 9, 10, 11]].values
y_test = test_data.iloc[:, 15].values

X_train, X_val, y_train, y_val = train_test_split(X, y, test_size=0.2,
random_state=42)

plt.figure(figsize=(5, 3))
pie = pd.Series(y_train).value_counts().plot(kind='pie',
autopct='%1.0f%%', labels=['1 User', '2 Users', '3 Users'])
plt.title("Class Distribution in Training Data")
```

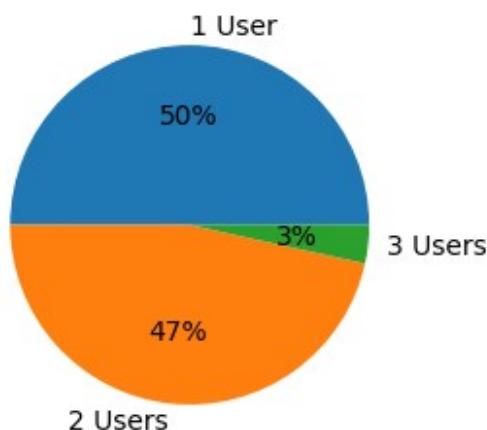
```
plt.ylabel("")  
plt.show()
```

Class Distribution in Training Data



```
plt.figure(figsize=(5, 3))  
pie = pd.Series(y_train).value_counts().plot(kind='pie', autopct='%1.0f %%', labels=['1 User', '2 Users', '3 Users'])  
plt.title("Class Distribution in Training Data")  
plt.ylabel("")  
plt.show()
```

Class Distribution in Test Data



```
def oversample_data(X, y):  
    smote = SMOTE(random_state=42)  
    X_resampled, y_resampled = smote.fit_resample(X, y)  
    return X_resampled, y_resampled  
  
X_train_os, y_train_os = oversample_data(X_train, y_train)
```

```

X_train = torch.tensor(X_train, dtype=torch.float32)
y_train = torch.tensor(y_train, dtype=torch.long)
X_train_os = torch.tensor(X_train_os, dtype=torch.float32)
y_train_os = torch.tensor(y_train_os, dtype=torch.long)
X_val = torch.tensor(X_val, dtype=torch.float32)
y_val = torch.tensor(y_val, dtype=torch.long)
X_test = torch.tensor(X_test, dtype=torch.float32)
y_test = torch.tensor(y_test, dtype=torch.long)

batch_sizes = [32, 64, 128]
train_dataset_no_oversample = TensorDataset(X_train, y_train)
train_dataset_with_oversample = TensorDataset(X_train_os, y_train_os)
val_dataset = TensorDataset(X_val, y_val)
test_dataset = TensorDataset(X_test, y_test)

class MLP(nn.Module):
    def __init__(self, input_size, hidden_layers, activation_fn):
        super(MLP, self).__init__()
        layers = []
        for hidden_size in hidden_layers:
            layers.append(nn.Linear(input_size, hidden_size))
            layers.append(nn.BatchNorm1d(hidden_size))
            layers.append(activation_fn())
            layers.append(nn.Dropout(p=0.5))
            input_size = hidden_size
        layers.append(nn.Linear(input_size, 3))
        self.model = nn.Sequential(*layers)

    def forward(self, x):
        return self.model(x)

hidden_layer_configs = [[5, [10], [20], [5, 5], [10, 10], [20, 20],
[5, 5, 5], [10, 10, 10], [20, 20, 20]]]
activation_fns = [nn.ReLU, nn.Sigmoid]
optimizers = [optim.Adam, optim.SGD]
loss_functions = {
    'CrossEntropy': nn.CrossEntropyLoss()
}
learning_rate = 0.001
num_epochs = 50

results = []
global_best_model = None
global_best_path = None
global_best_val_accuracy = 0

def plot_train_history(history, oversample_flag, batch_size,
hidden_layers, activation_fn, optimizer, loss_name):
    plt.figure(figsize=(15, 6))
    plt.plot(history['loss'], label='Training Loss', color='blue')

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    plt.plot(history['val_loss'], label='Validation Loss',
color='orange')
    plt.title(f'Training and Validation Loss\n{oversample_flag} |  

Batch Size: {batch_size} | Hidden Layers: {hidden_layers}\nActivation:  

{activation_fn} | Optimizer: {optimizer} | Loss: {loss_name}',  

fontsize=12)
    plt.xlabel('Epochs', fontsize=12)
    plt.ylabel('Loss', fontsize=12)
    plt.legend(fontsize=10)
    plt.grid(True, linestyle='--', alpha=0.5)
    plt.show()

for train_dataset, oversample_flag in [(train_dataset_no_oversample,
'No Oversampling'), (train_dataset_with_oversample, 'With  

Oversampling')]:
    for batch_size in batch_sizes:
        train_loader = DataLoader(train_dataset,
batch_size=batch_size, shuffle=True)
        val_loader = DataLoader(val_dataset, batch_size=batch_size,
shuffle=False)
        test_loader = DataLoader(test_dataset, batch_size=batch_size,
shuffle=False)

        for hidden_layers in hidden_layer_configs:
            for activation_fn in activation_fns:
                for optimizer_fn in optimizers:
                    for loss_name, criterion in
loss_functions.items():

                        model = MLP(input_size=10,
hidden_layers=hidden_layers, activation_fn=activation_fn)
                        optimizer = optimizer_fn(model.parameters(),
lr=learning_rate)

                        start_time = time.time()
                        best_val_accuracy = 0
                        best_val_loss = float('inf')
                        history = {'loss': [], 'val_loss': []}

                        for epoch in range(num_epochs):
                            model.train()
                            epoch_loss = 0
                            for X_batch, y_batch in train_loader:
                                optimizer.zero_grad()
                                outputs = model(X_batch)
                                y_batch = y_batch - 1
                                loss = criterion(outputs, y_batch)
                                loss.backward()
                                optimizer.step()
                                epoch_loss += loss.item()

                            val_outputs = model(val_loader.dataset)
                            val_loss = criterion(val_outputs, val_loader.dataset)
                            val_accuracy = accuracy_fn(val_outputs, val_loader.dataset)

                            if val_accuracy > best_val_accuracy:
                                best_val_accuracy = val_accuracy
                                best_val_loss = val_loss
                                best_model = model

                            history['loss'].append(epoch_loss)
                            history['val_loss'].append(val_loss)

                        end_time = time.time()
                        total_time = end_time - start_time
                        print(f'Training completed. Total time: {total_time:.2f} seconds.  

Best validation accuracy: {best_val_accuracy:.2f}. Best validation loss: {best_val_loss:.2f}.')

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                history['loss'].append(epoch_loss /
len(train_loader))

        model.eval()
        val_loss = 0
        val_preds = []
        val_targets = []
        with torch.no_grad():
            for X_batch, y_batch in val_loader:
                outputs = model(X_batch)
                y_batch = y_batch - 1
                loss = criterion(outputs, y_batch)
                val_loss += loss.item()
                preds = torch.argmax(outputs,
dim=1)
                val_preds.extend(preds.tolist())

        val_targets.extend(y_batch.tolist())
                history['val_loss'].append(val_loss /
len(val_loader))

        val_accuracy = accuracy_score(val_targets,
val_preds)
        if val_accuracy > best_val_accuracy:
            best_val_accuracy = val_accuracy

        if val_loss < best_val_loss:
            best_val_loss = val_loss
            model_path =
f'best_model_{oversample_flag}_{batch_size}_{hidden_layers}.pth'
            torch.save(model.state_dict(),
model_path)

        if val_accuracy >
global_best_val_accuracy:
            global_best_val_accuracy =
val_accuracy
            global_best_path = model_path

        if len(history['val_loss']) > 25 and all(l
>= history['val_loss'][-1] for l in history['val_loss'][-25:]):
            print("Early stopping triggered")
            break

        end_time = time.time()
        model.eval()
        test_preds = []
        test_targets = []
        with torch.no_grad():
            for X_batch, y_batch in test_loader:

```

```

        outputs = model(X_batch)
        y_batch = y_batch - 1
        preds = torch.argmax(outputs, dim=1)
        test_preds.extend(preds.tolist())
        test_targets.extend(y_batch.tolist())

    test_accuracy = accuracy_score(test_targets,
test_preds)
    precision, recall, f1, _ =
precision_recall_fscore_support(test_targets, test_preds,
average='weighted')
    conf_matrix = confusion_matrix(test_targets,
test_preds)

    results.append({
        'oversample': oversample_flag,
        'batch_size': batch_size,
        'hidden_layers': hidden_layers,
        'activation_fn': activation_fn.__name__,
        'optimizer': optimizer_fn.__name__,
        'loss_function': loss_name,
        'val_accuracy': best_val_accuracy,
        'test_accuracy': test_accuracy,
        'precision': precision,
        'recall': recall,
        'f1_score': f1,
        'confusion_matrix': conf_matrix,
        'time': end_time - start_time
    })

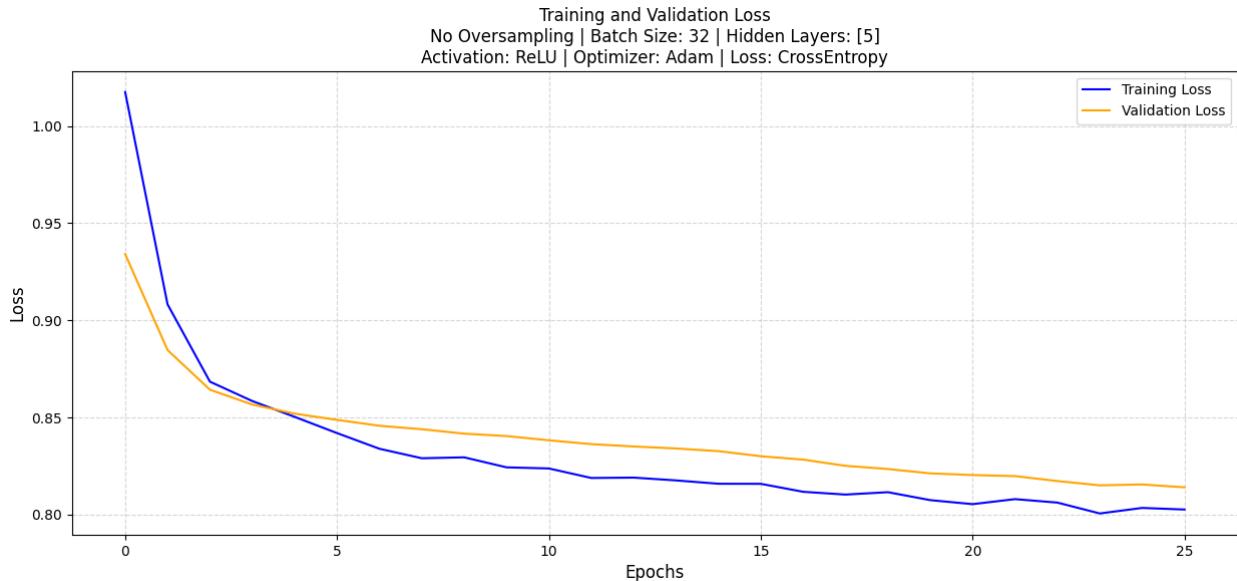
    plot_train_history(history, oversample_flag,
batch_size, hidden_layers, activation_fn.__name__,
optimizer_fn.__name__, loss_name)

print(f"Global best model is saved at: {global_best_path} with
validation accuracy: {global_best_val_accuracy}")

Early stopping triggered

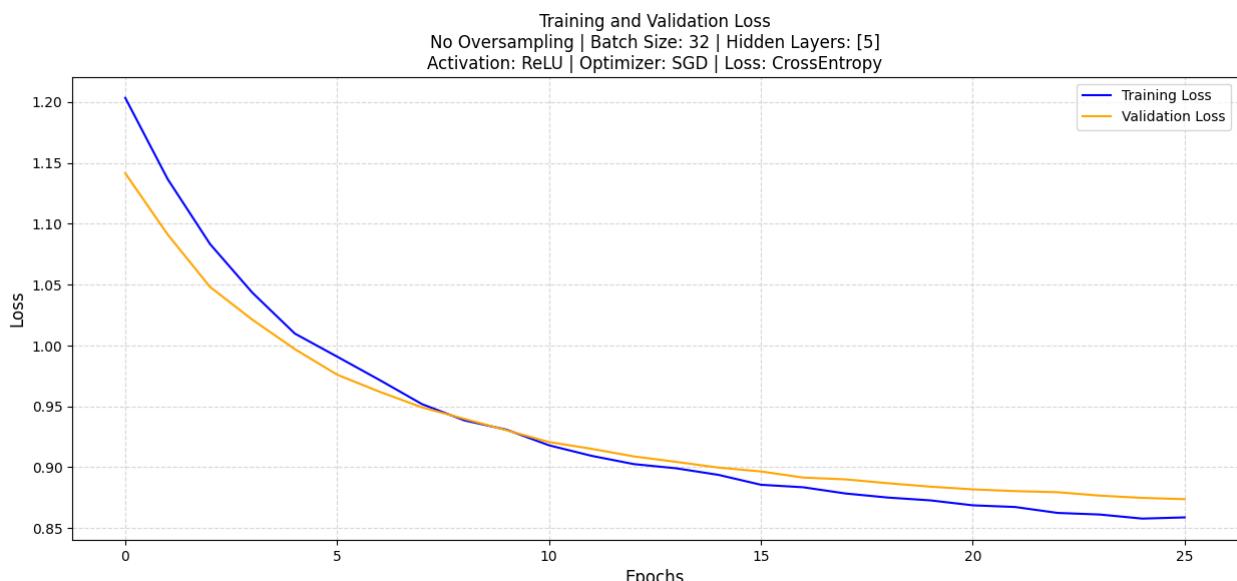
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))

```



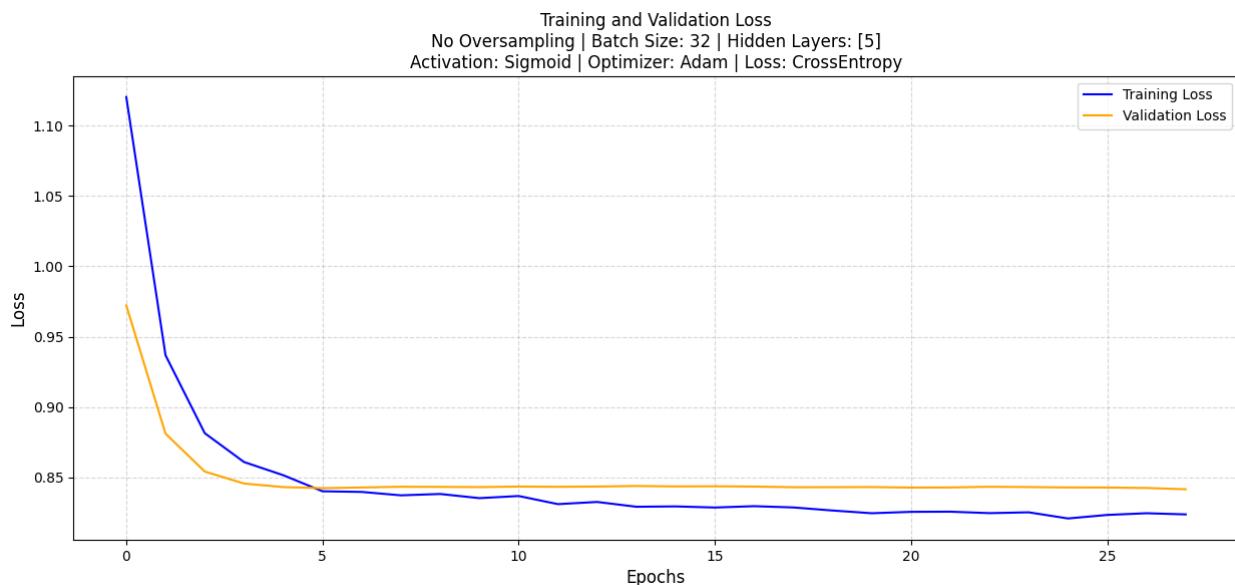
Early stopping triggered

```
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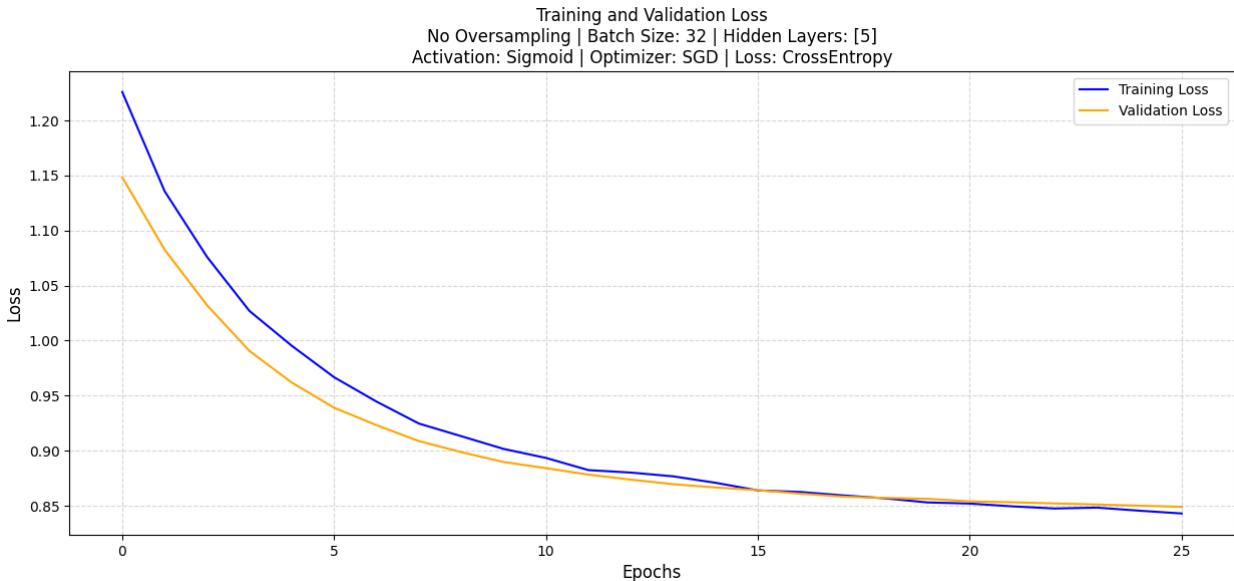
Early stopping triggered

```
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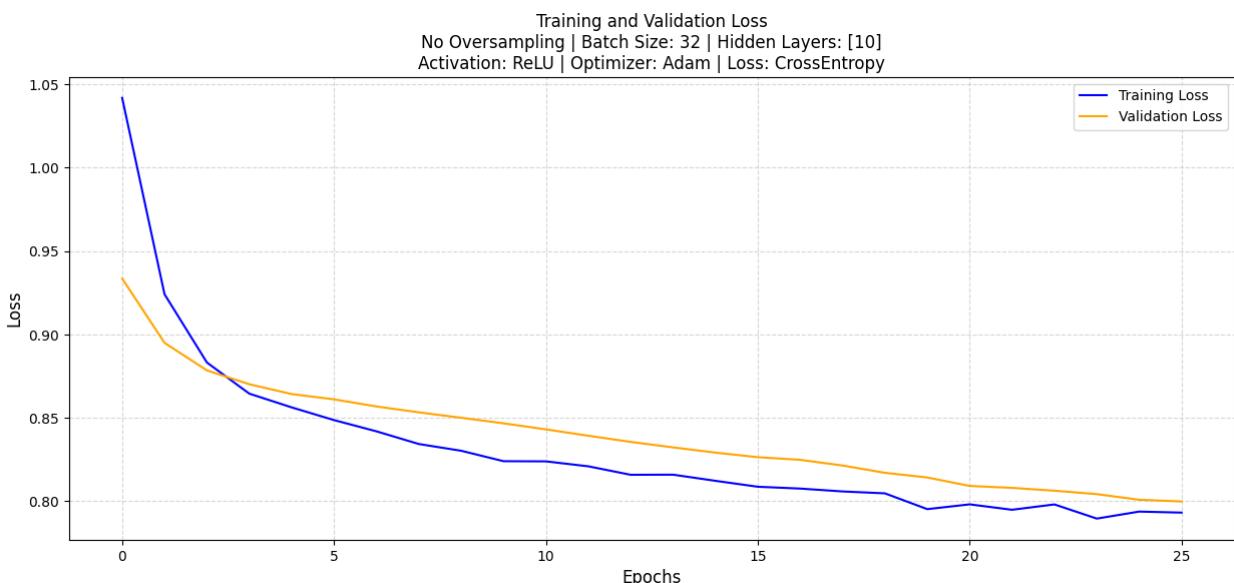
Early stopping triggered

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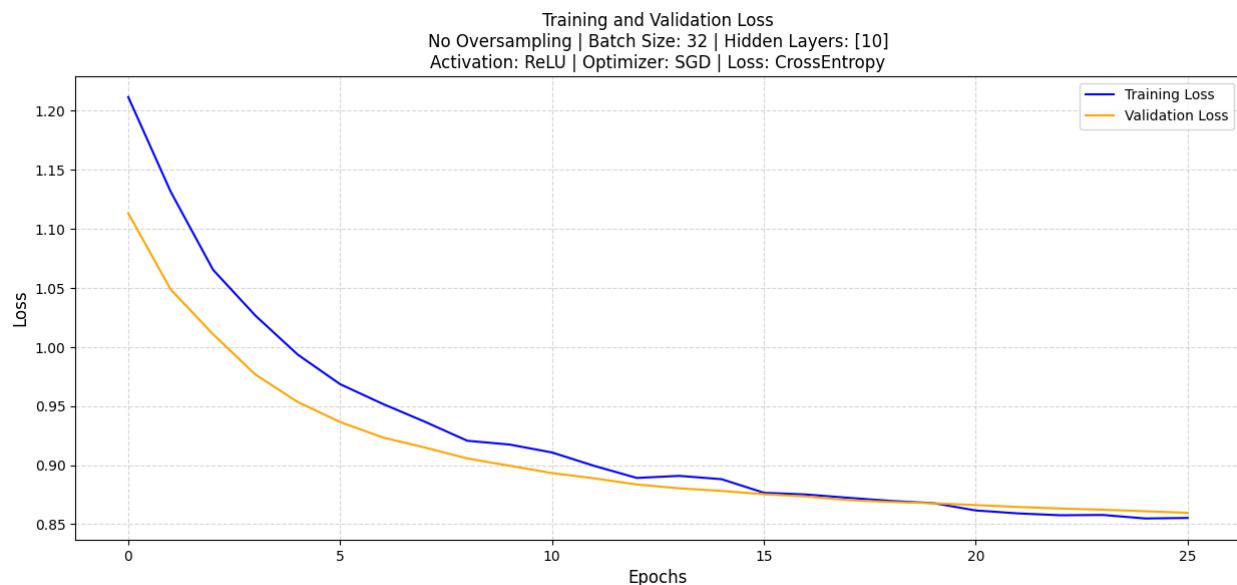
Early stopping triggered

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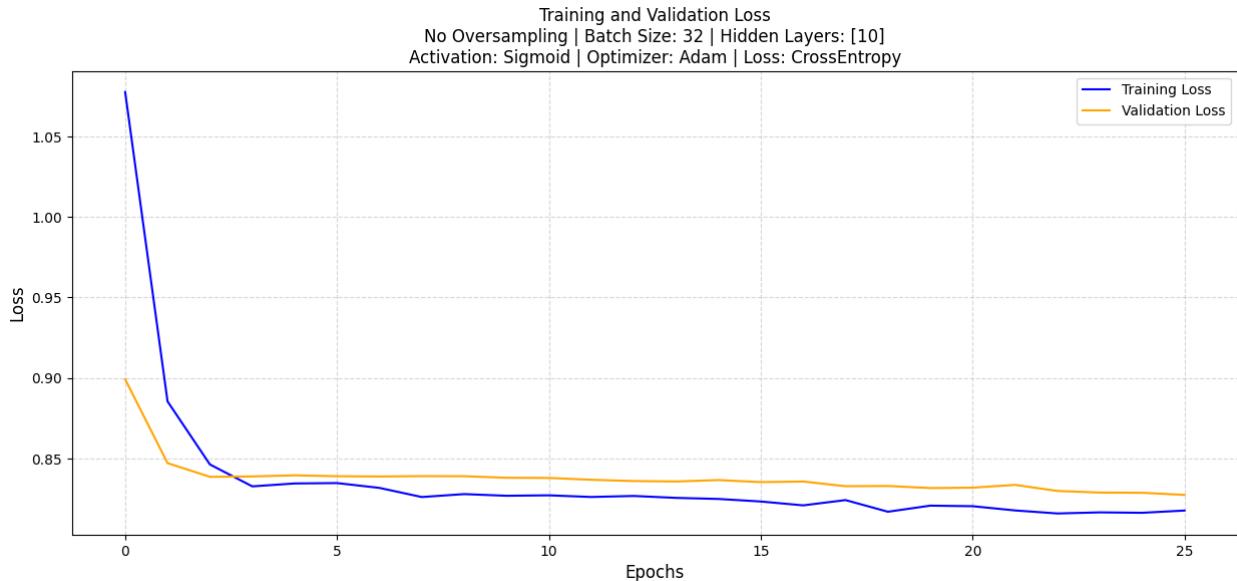
Early stopping triggered

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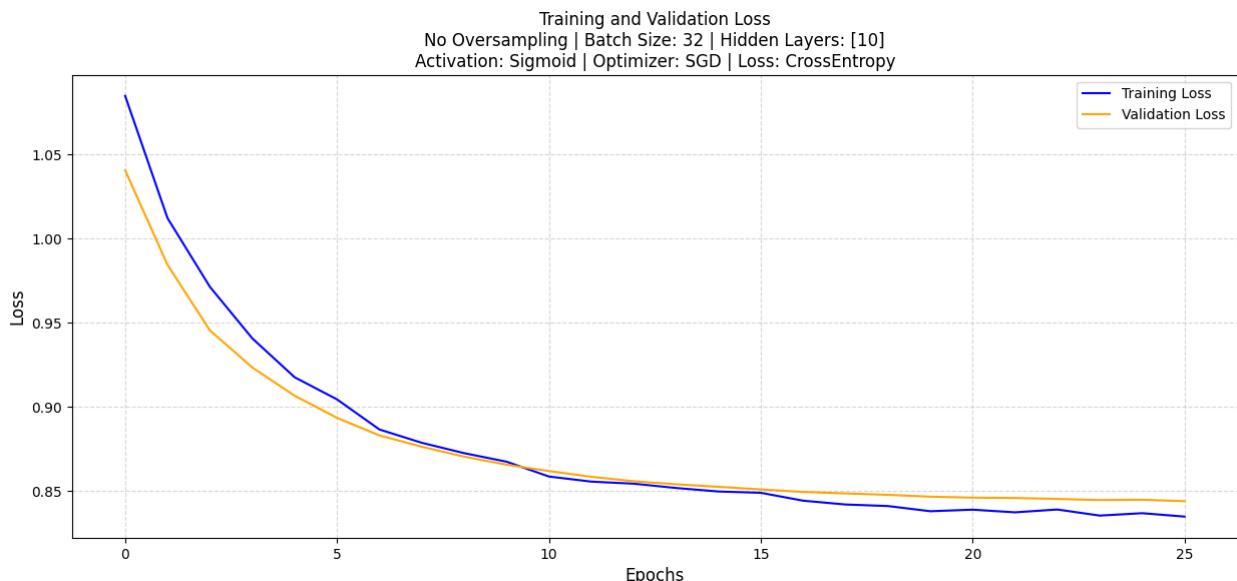
Early stopping triggered

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```



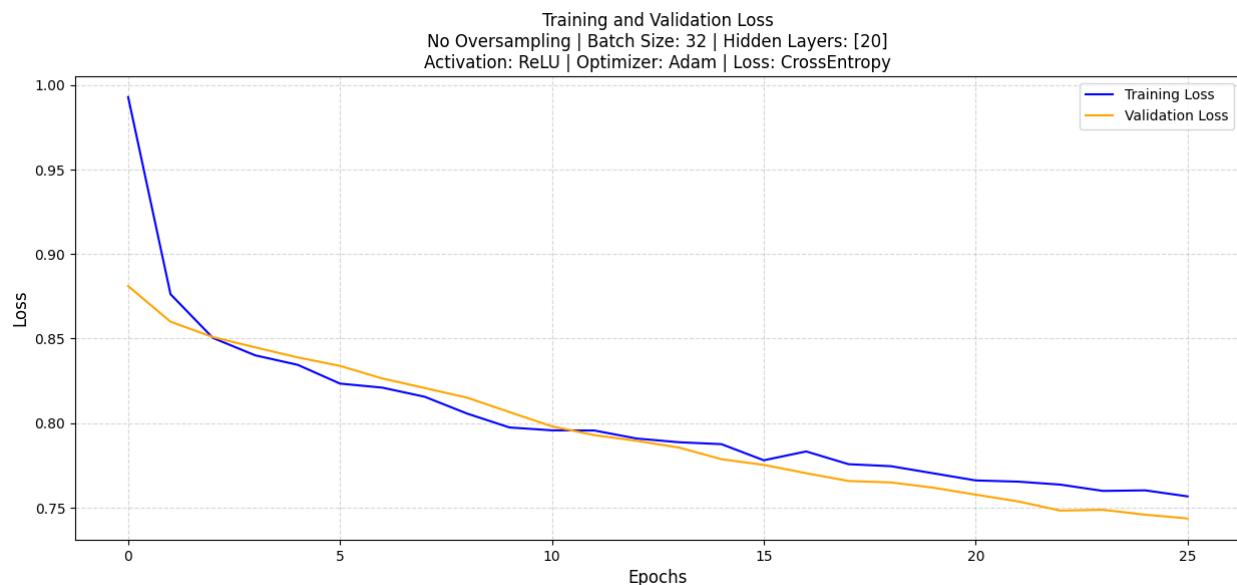
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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```



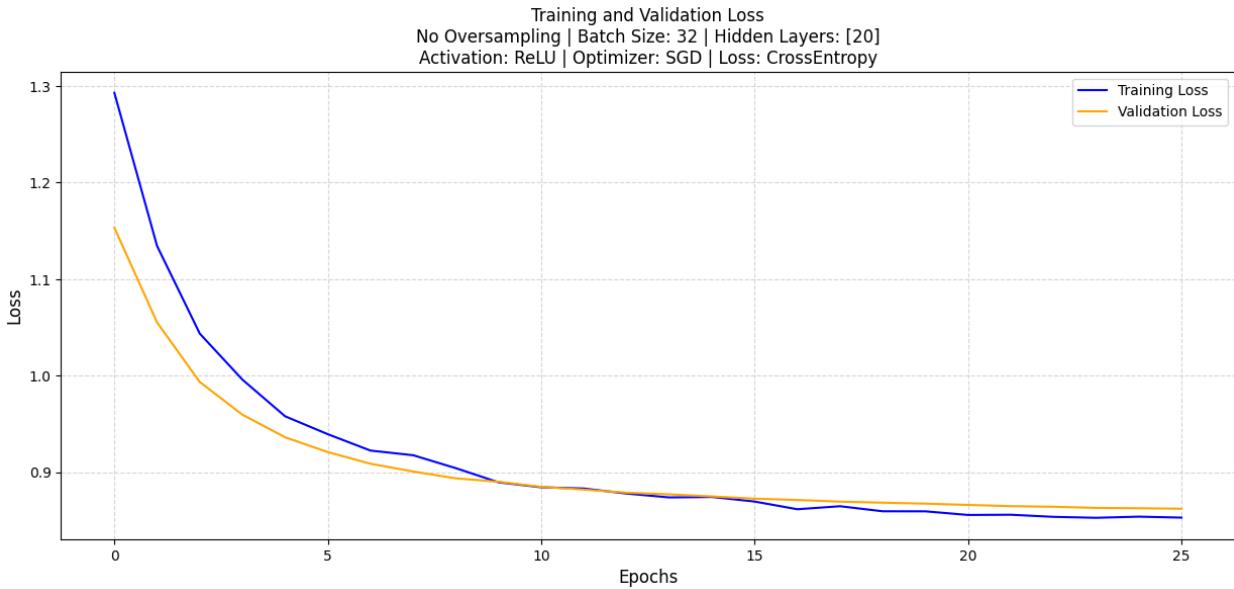
Early stopping triggered

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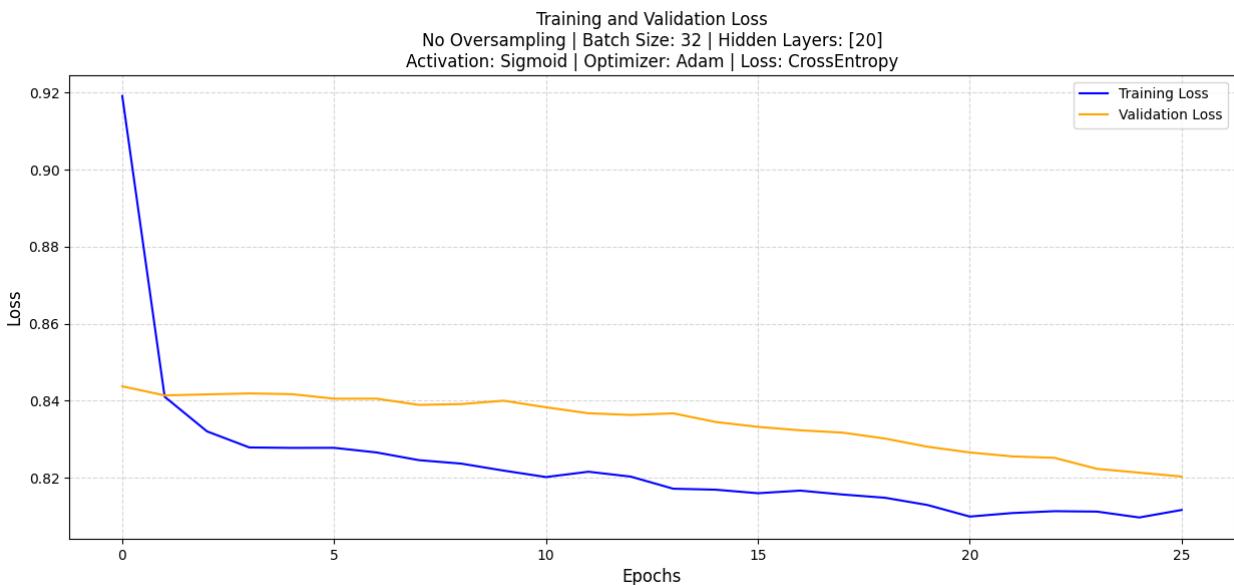
Early stopping triggered

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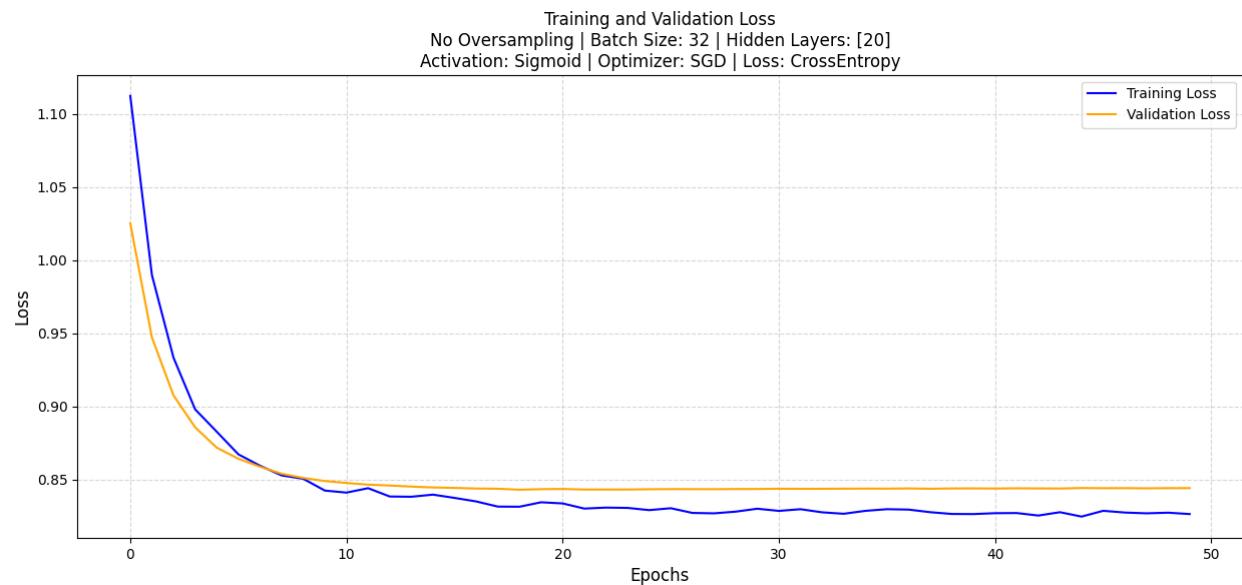
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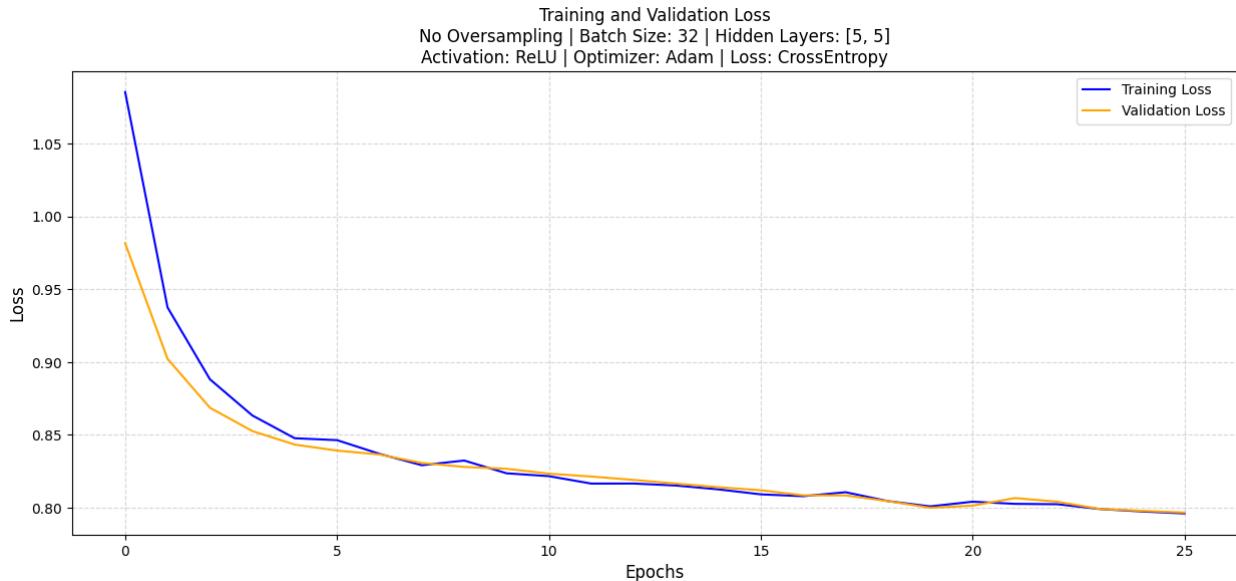
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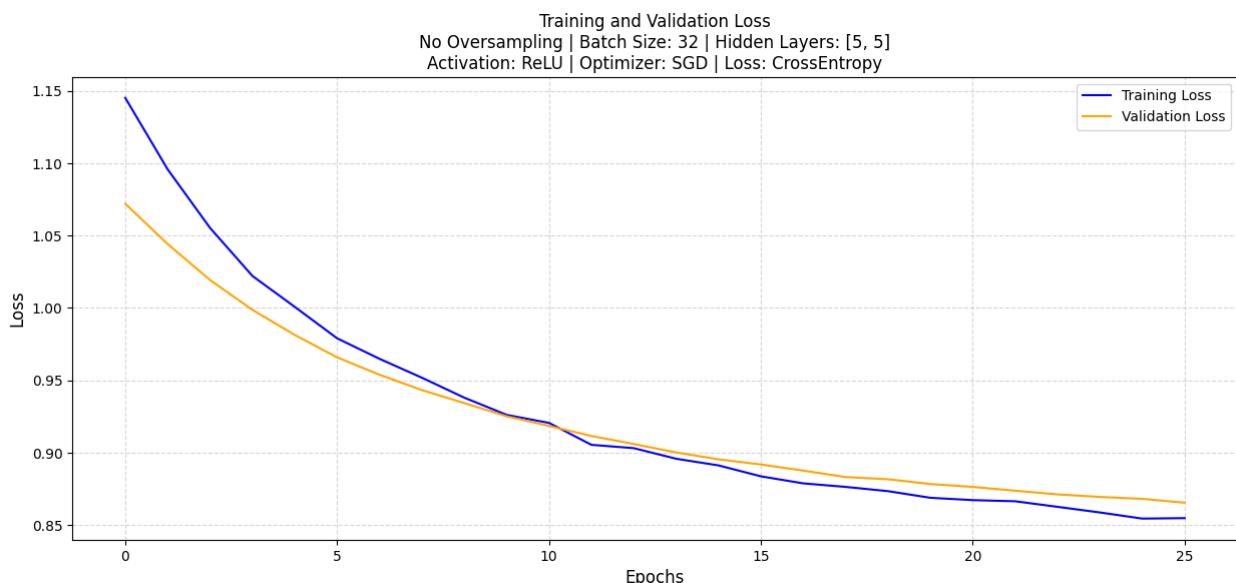
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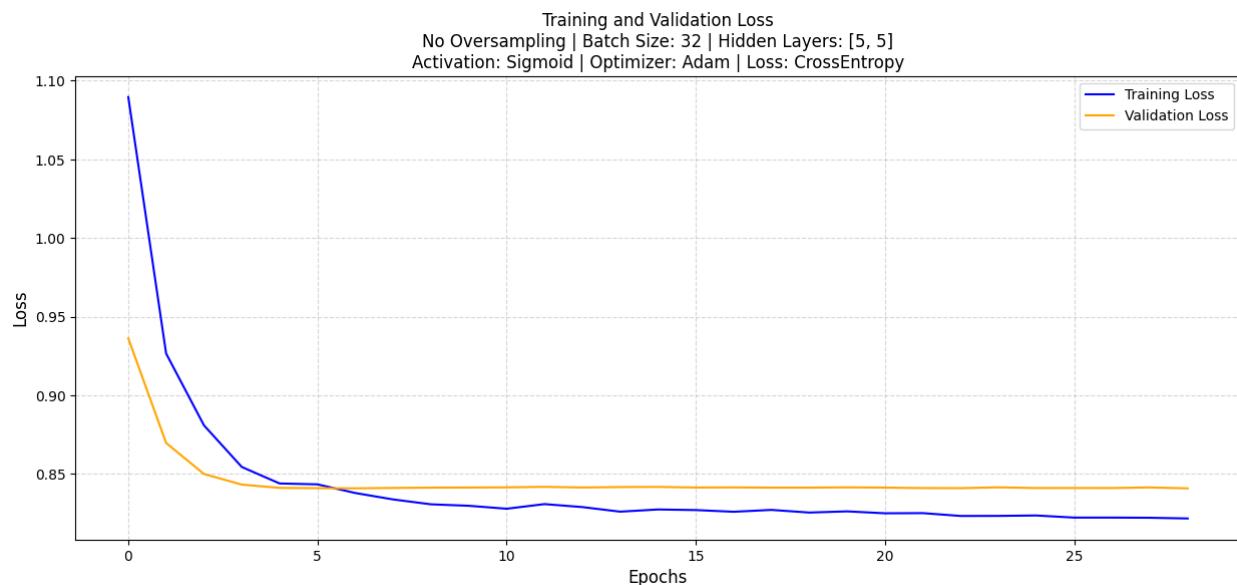
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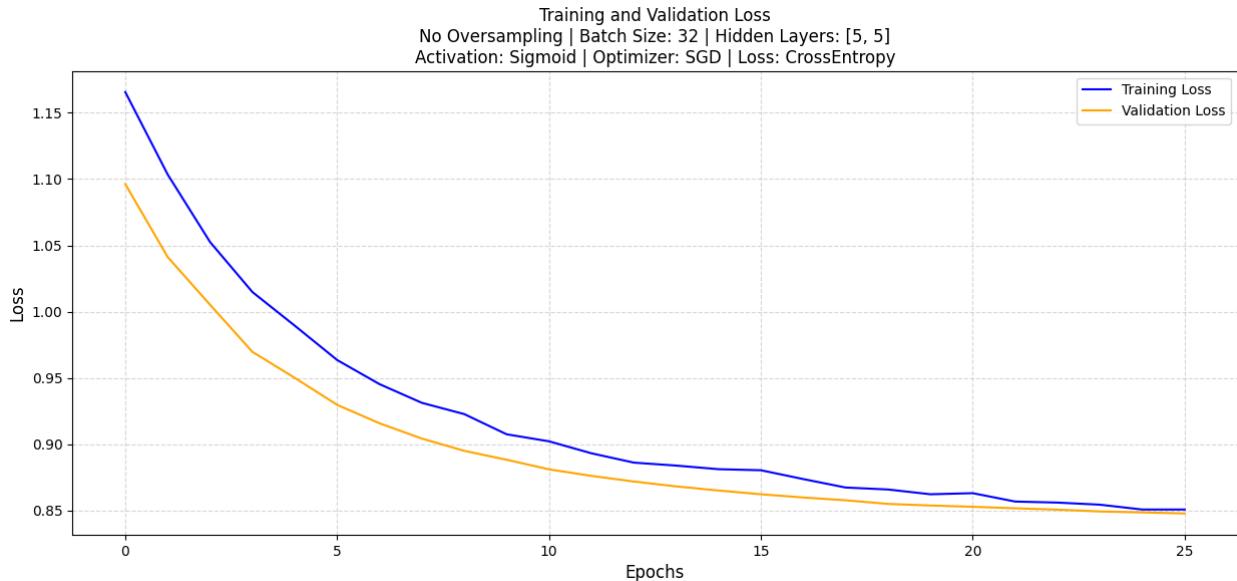
Early stopping triggered

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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



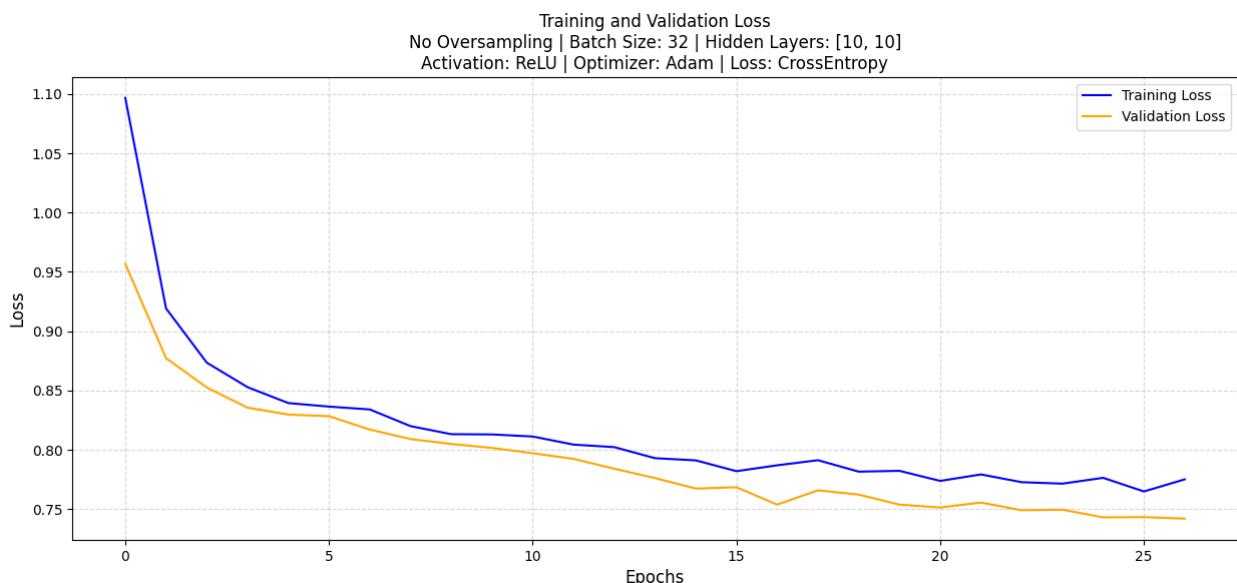
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



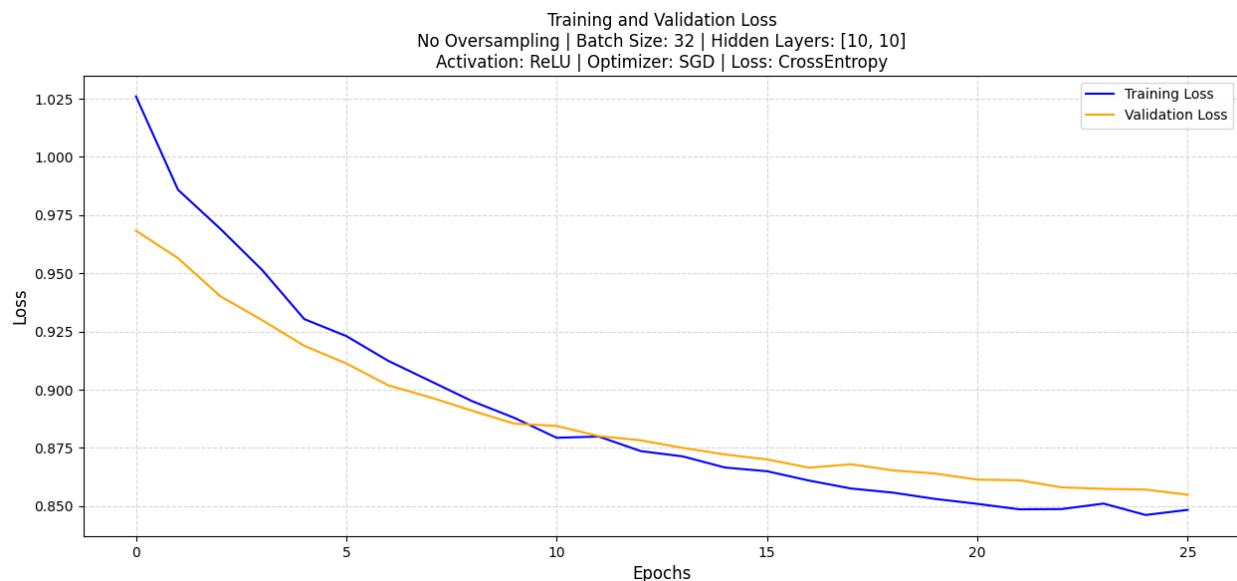
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



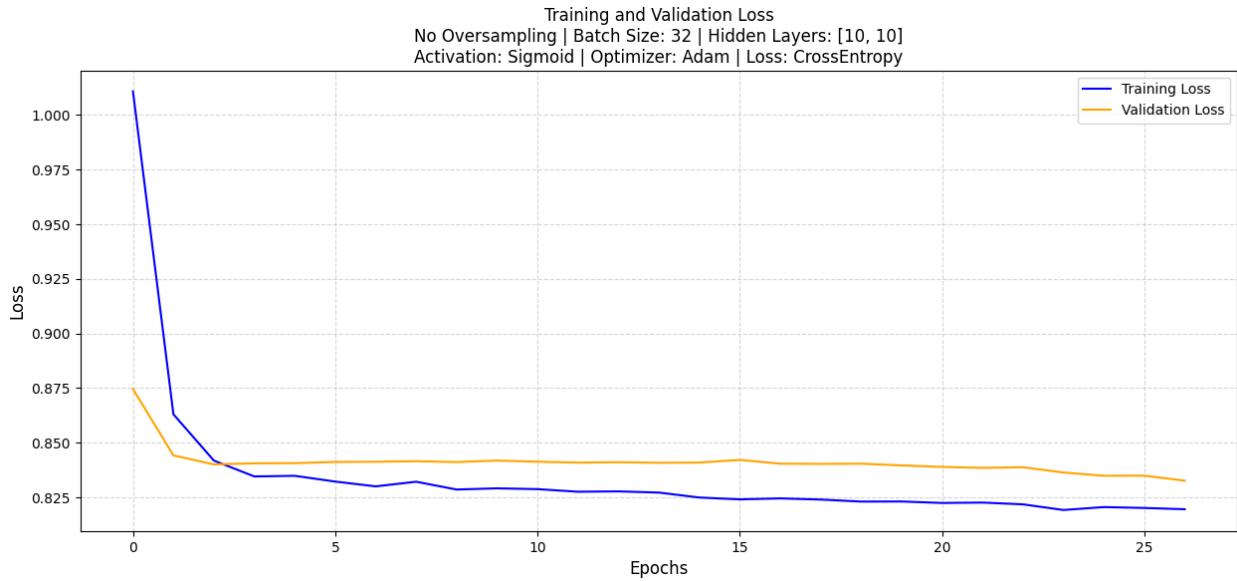
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



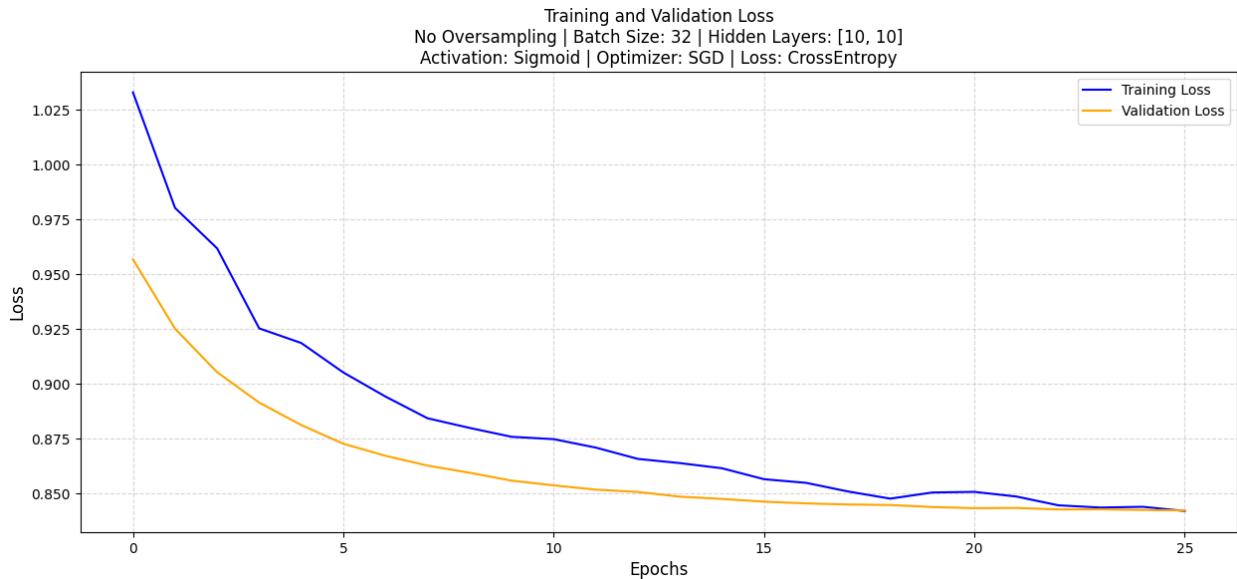
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



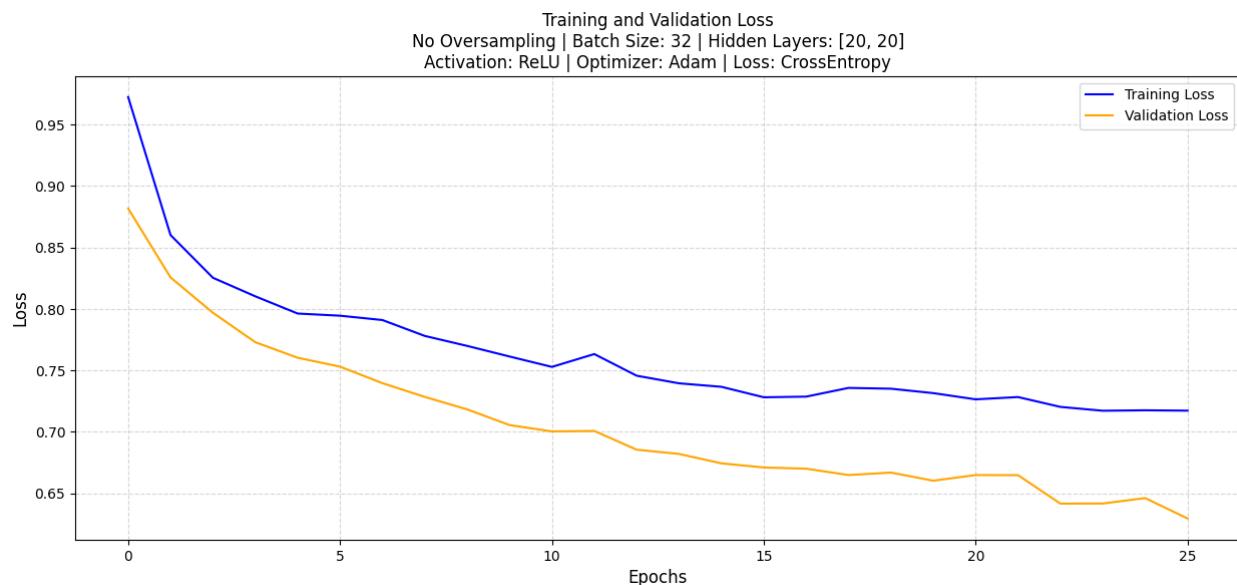
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
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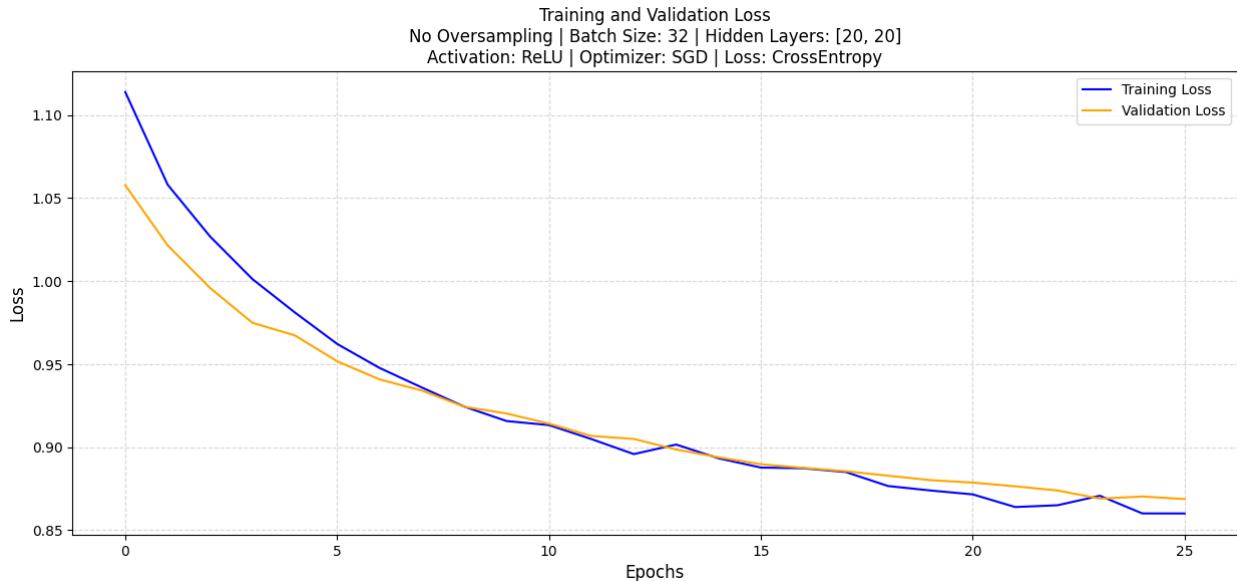
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



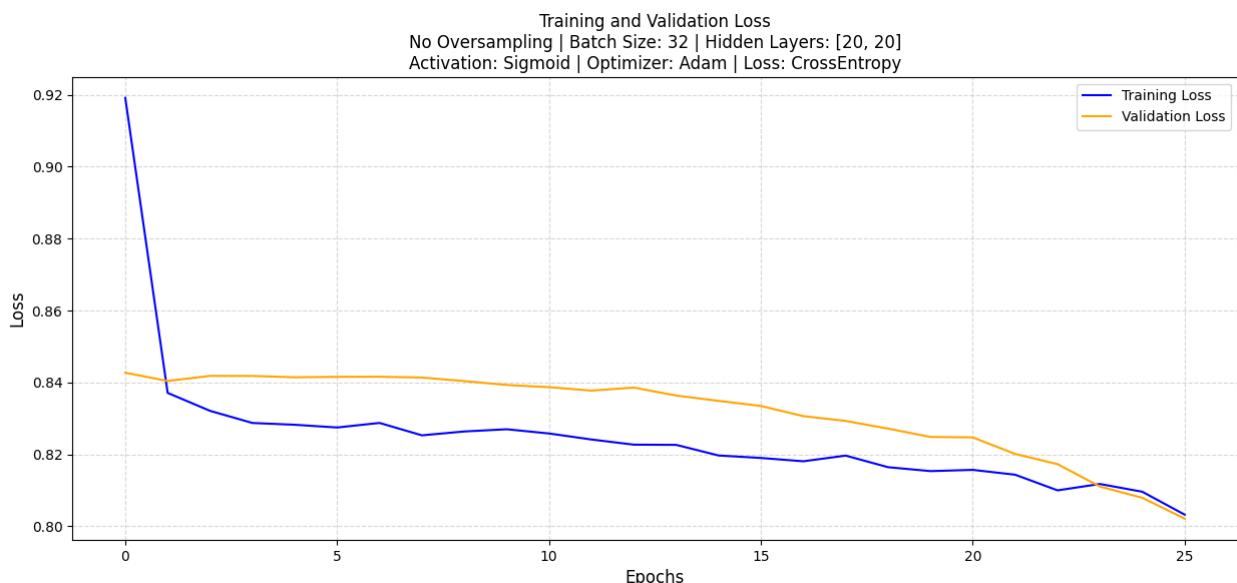
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



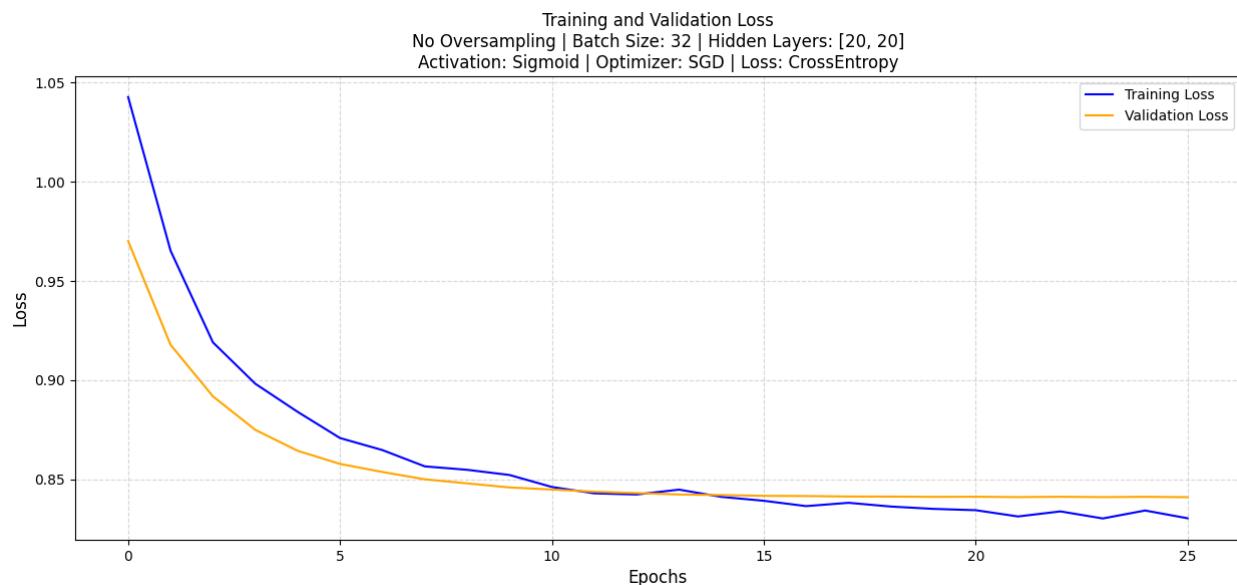
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



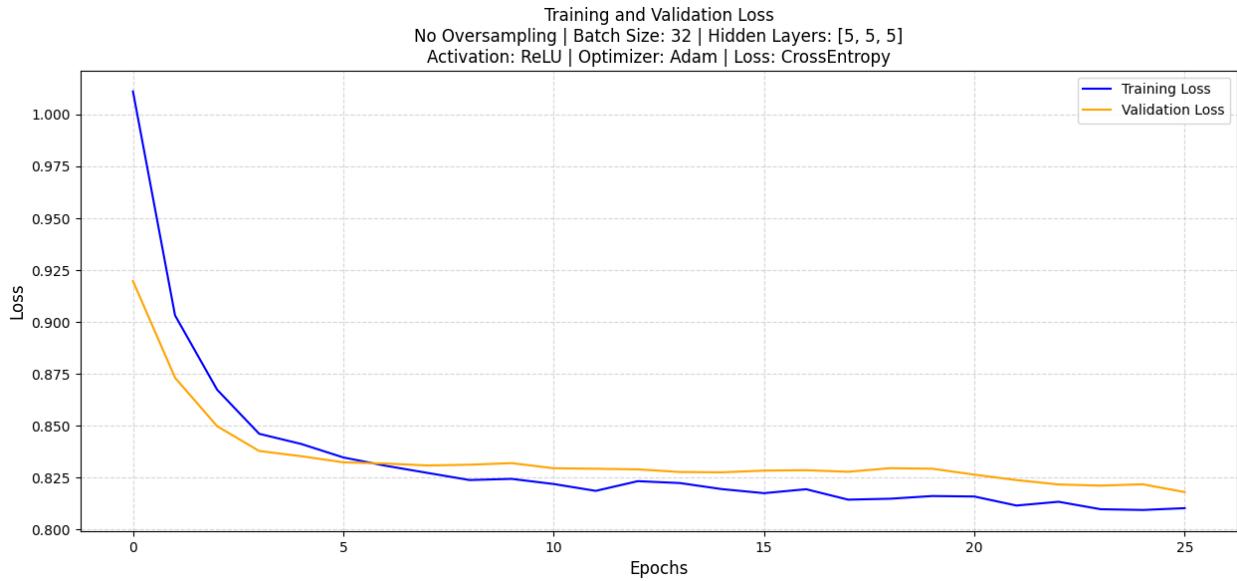
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



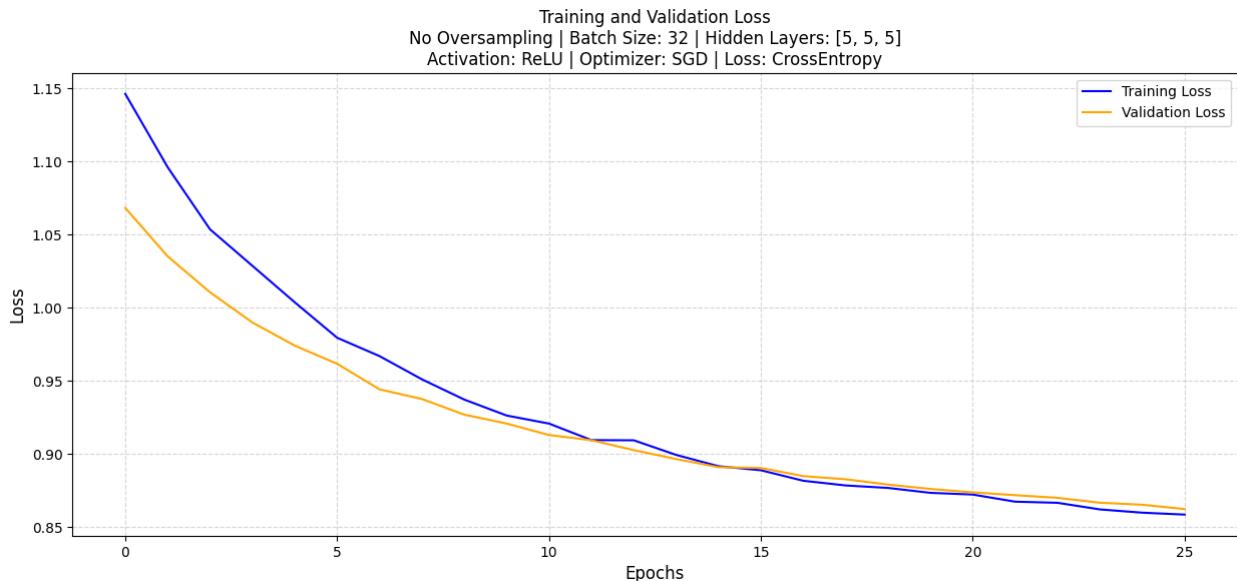
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



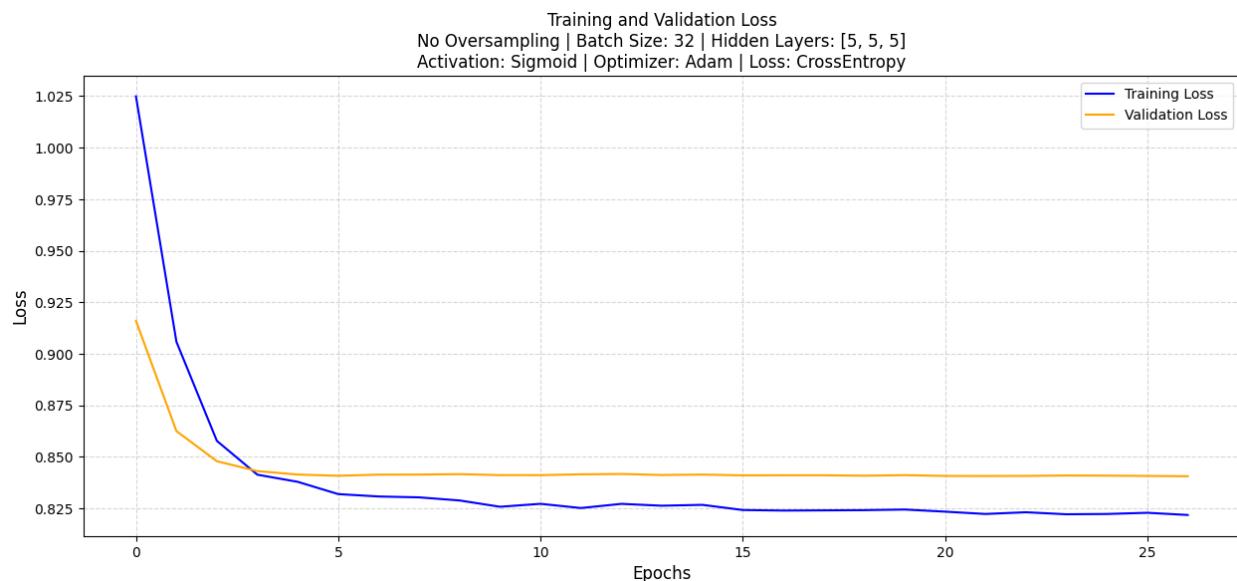
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
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```



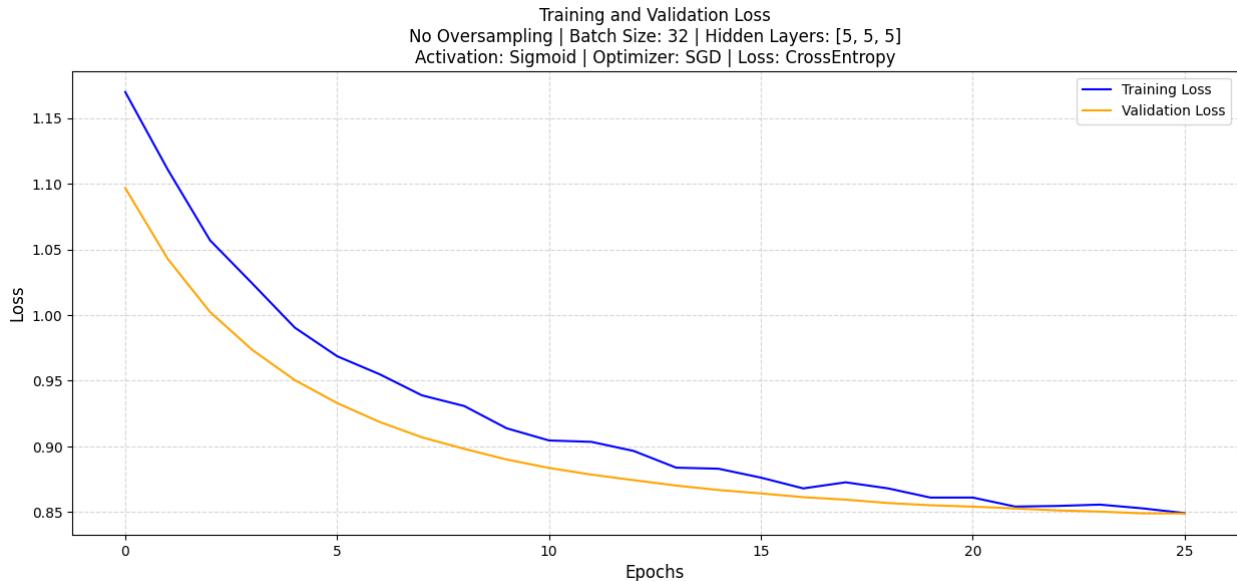
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



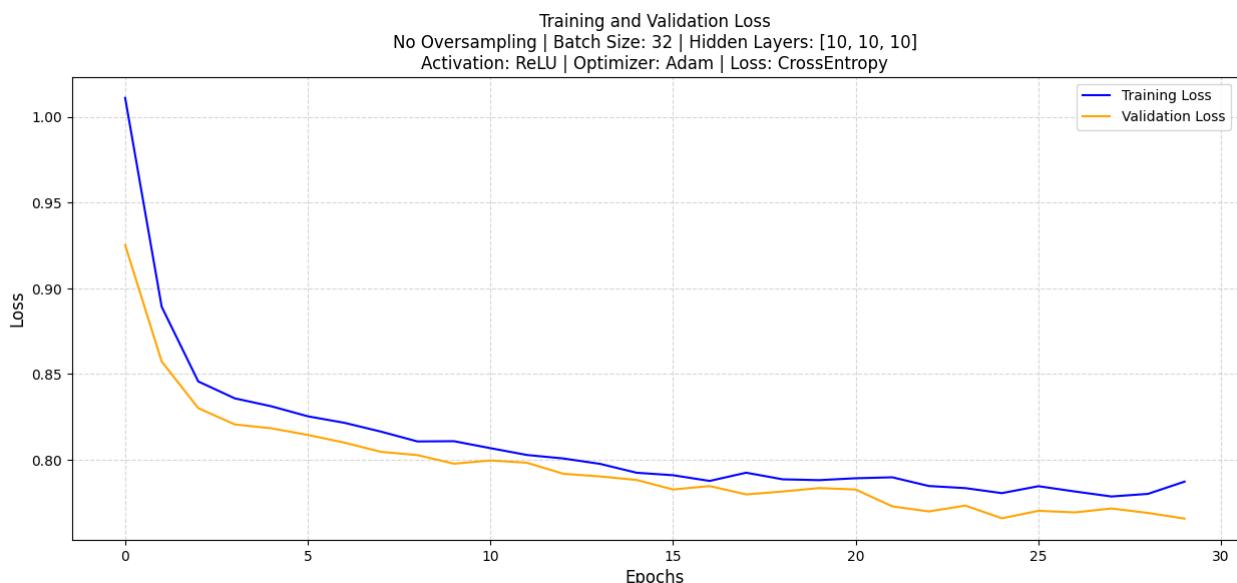
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



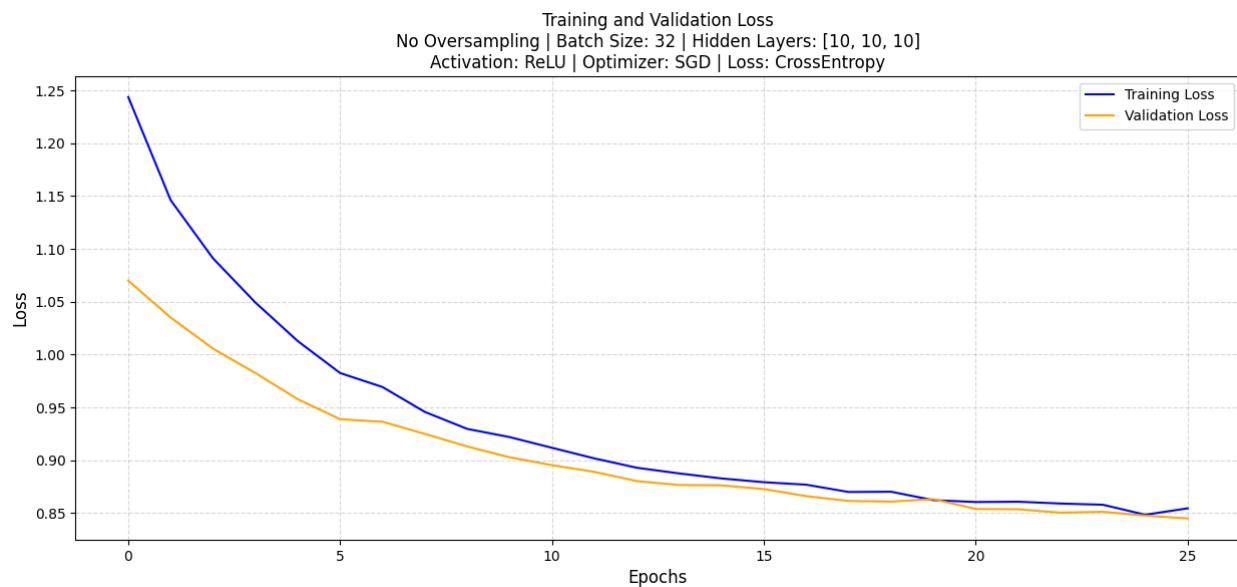
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



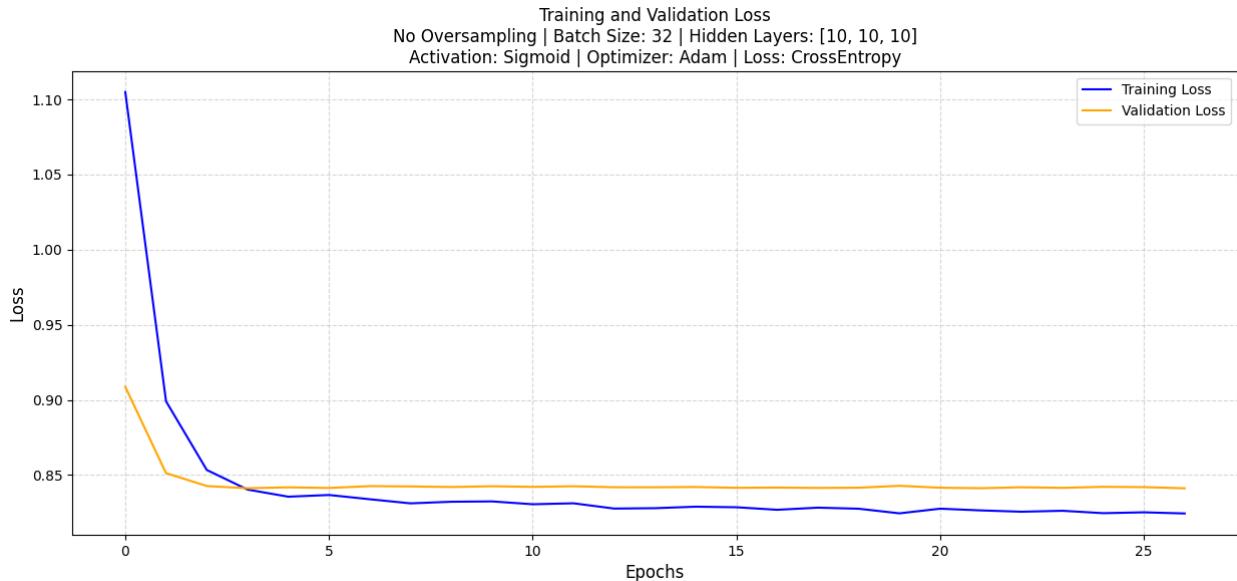
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



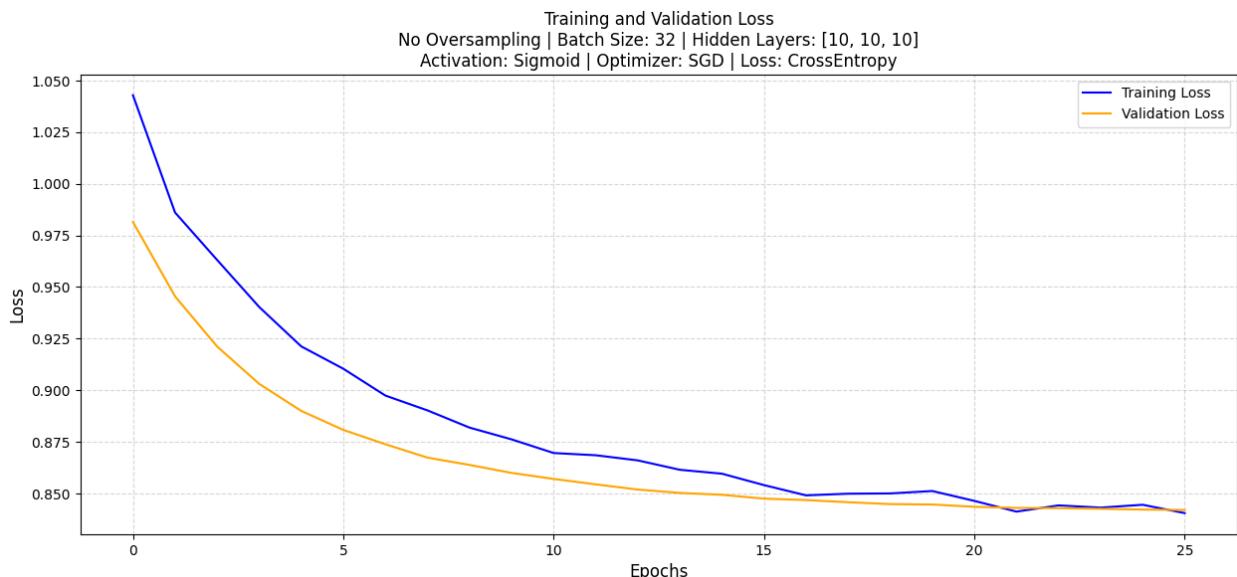
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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in labels with no predicted samples. Use `zero_division` parameter to  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



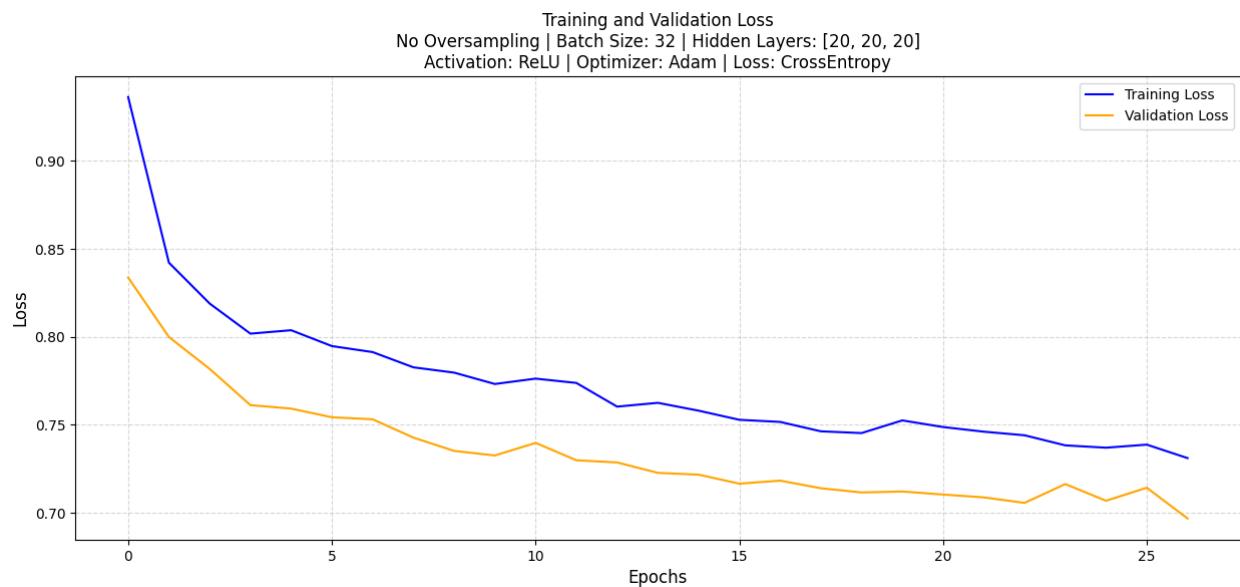
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



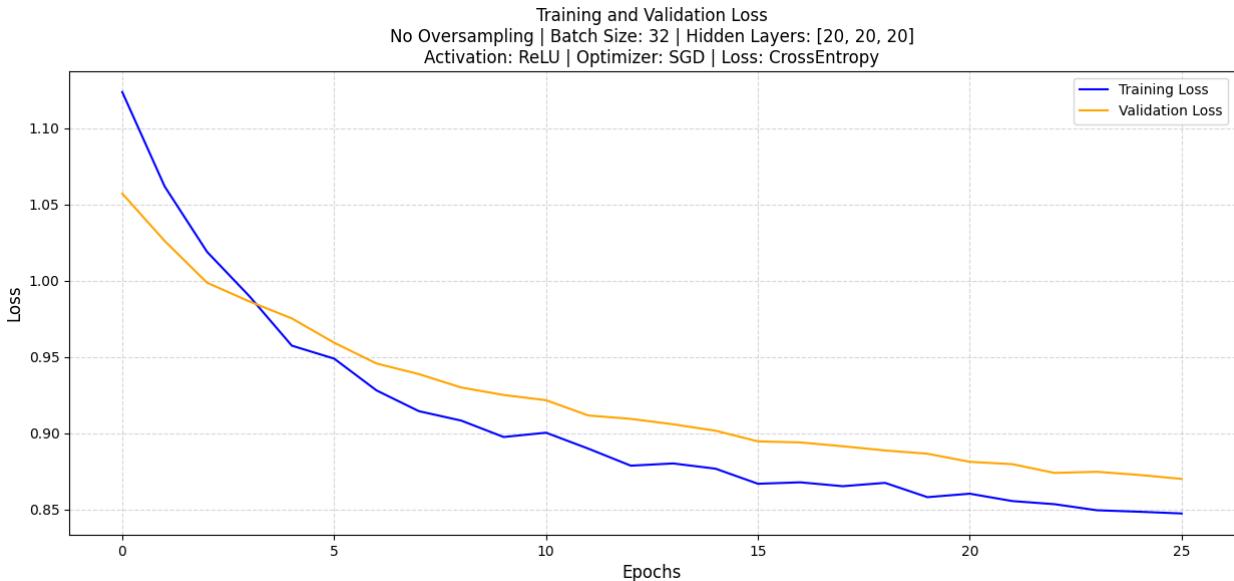
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



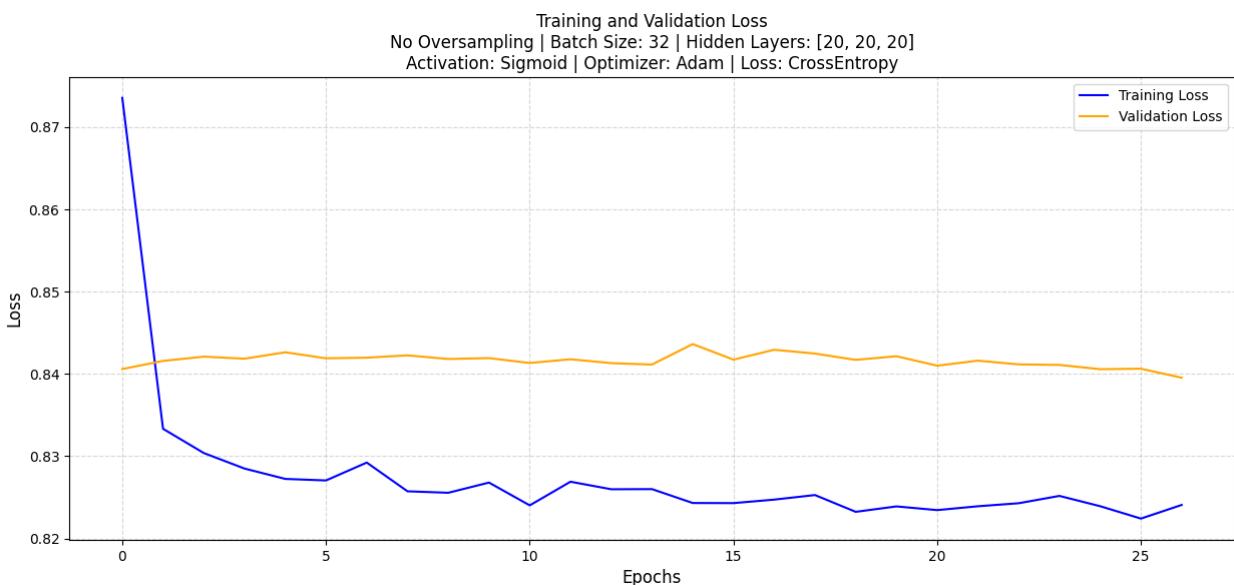
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



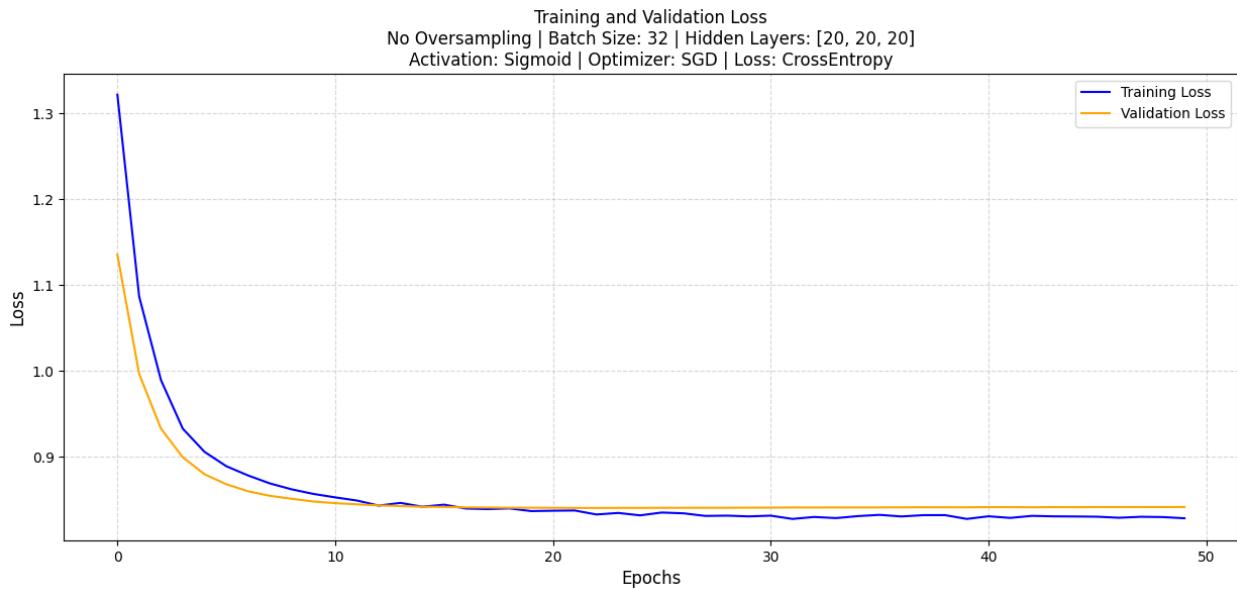
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



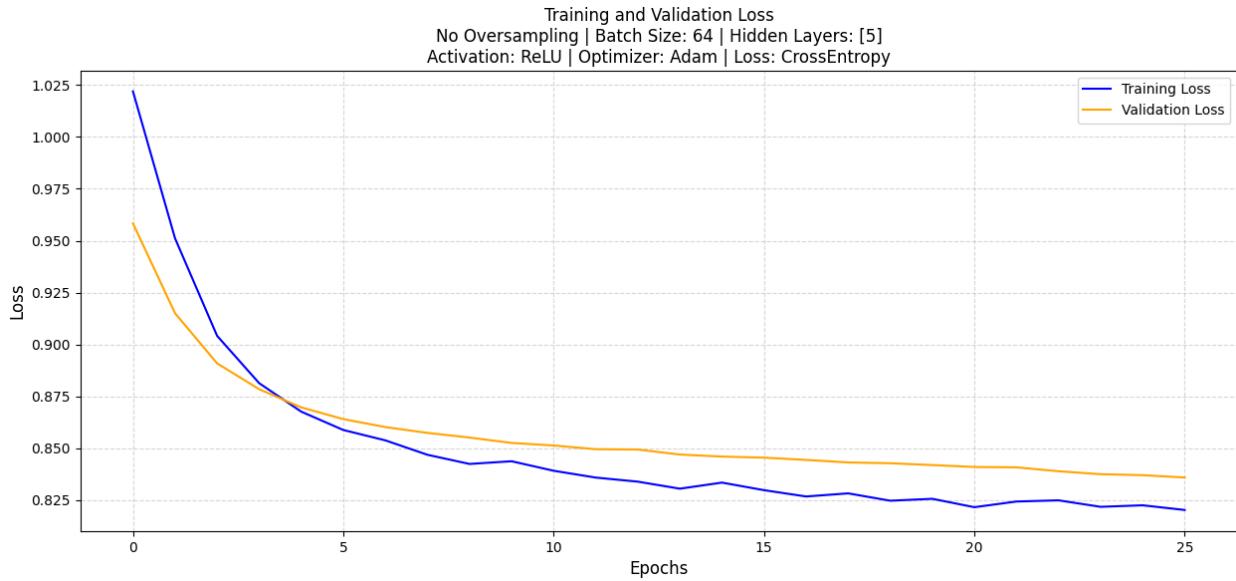
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
```

```
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



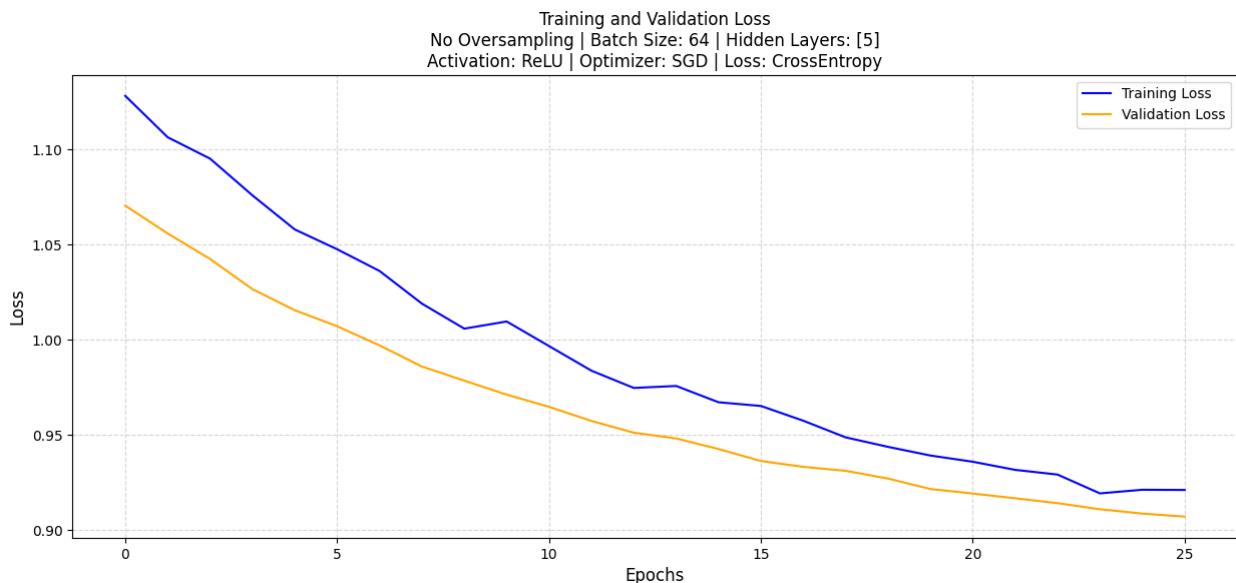
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



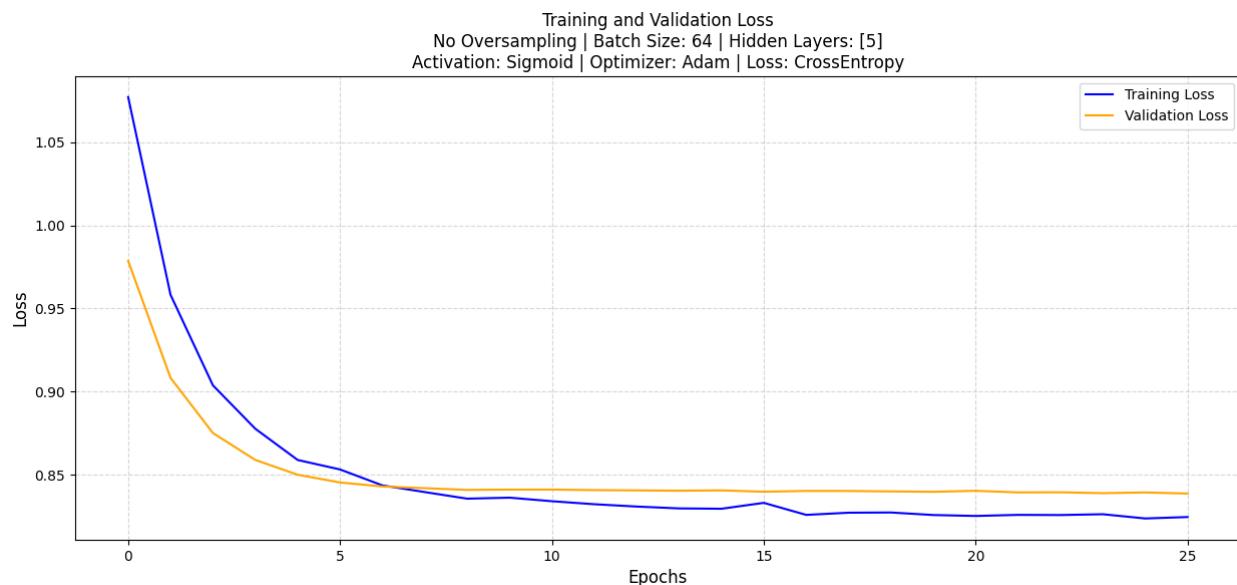
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
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```



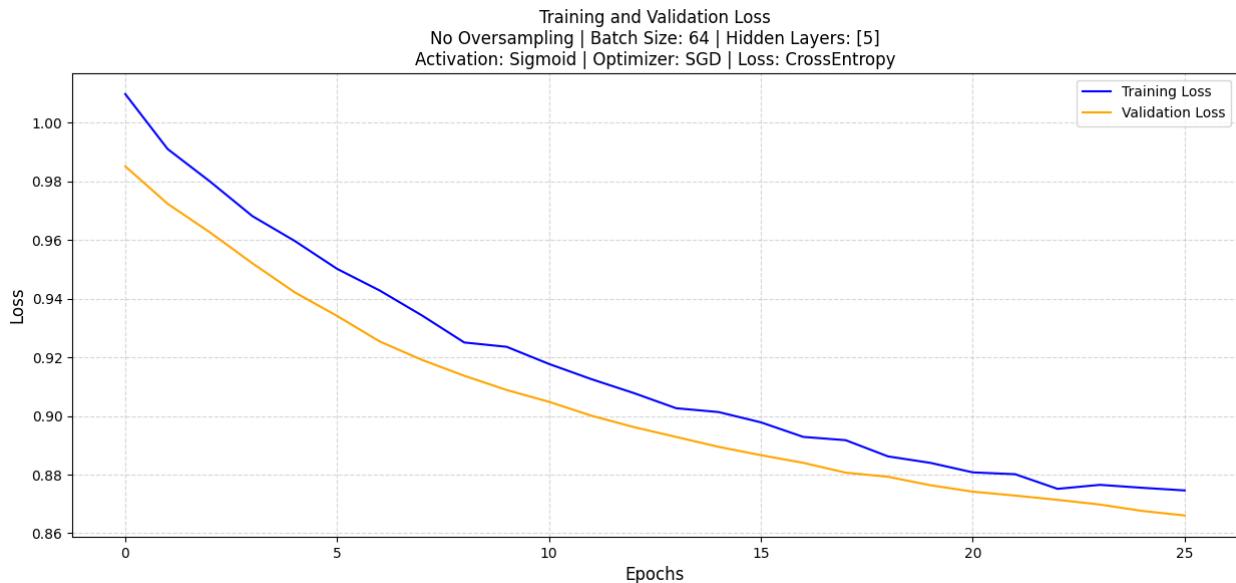
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
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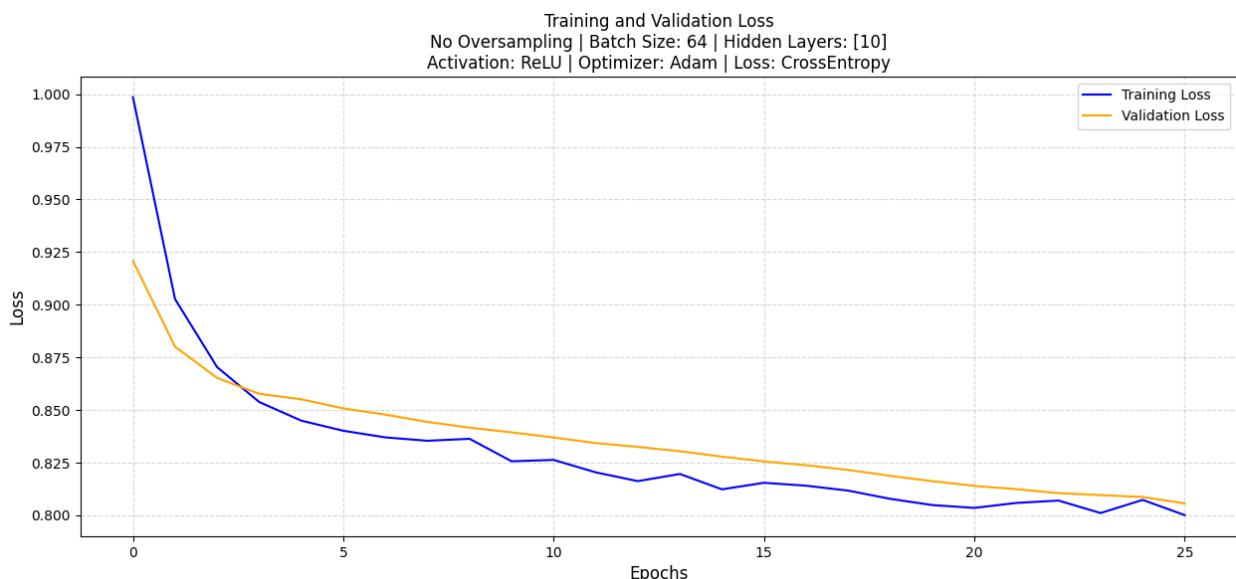
Early stopping triggered

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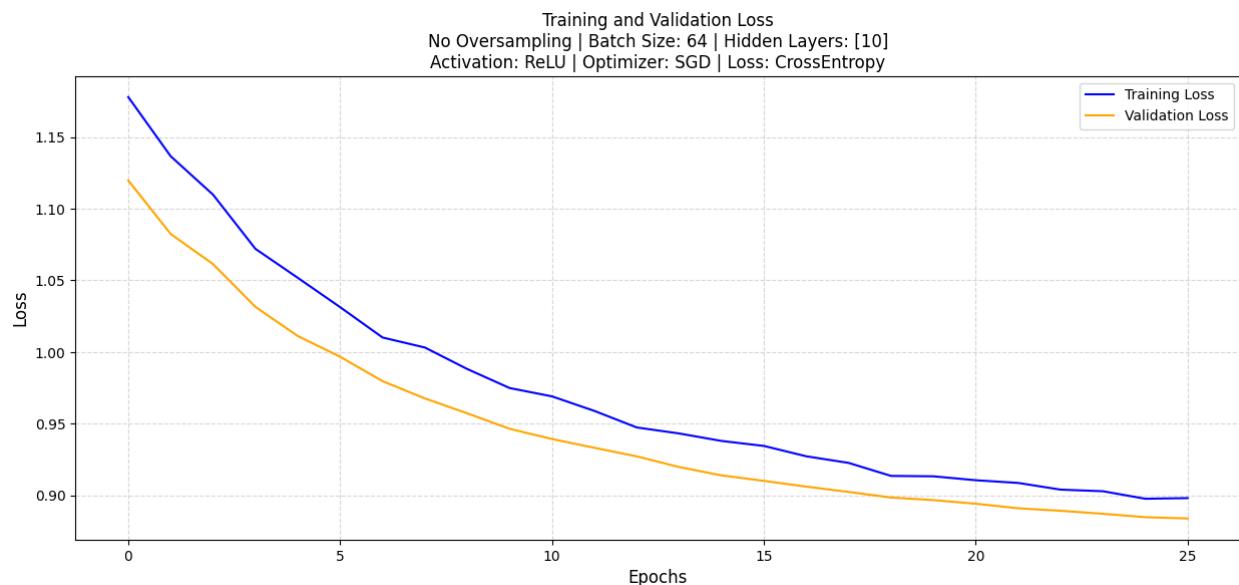
Early stopping triggered

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UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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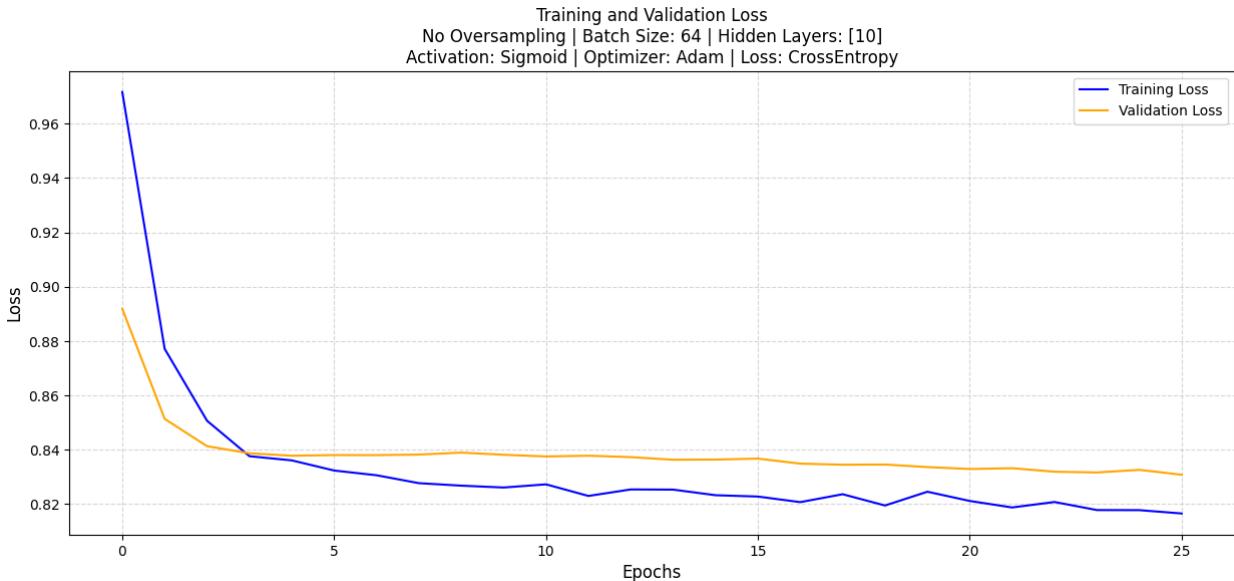
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



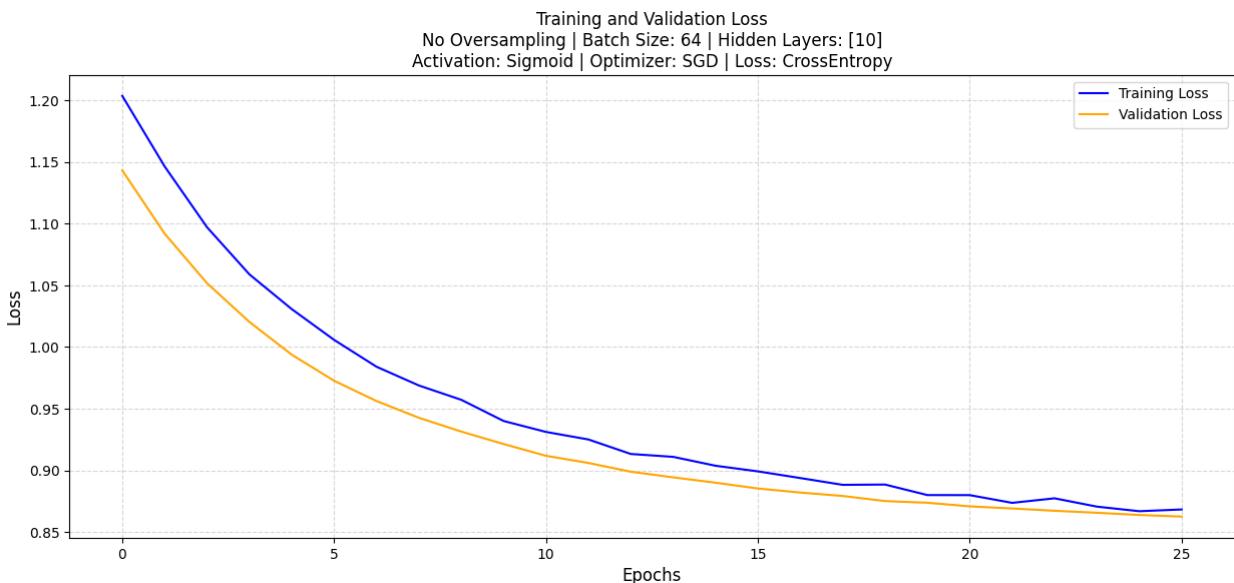
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



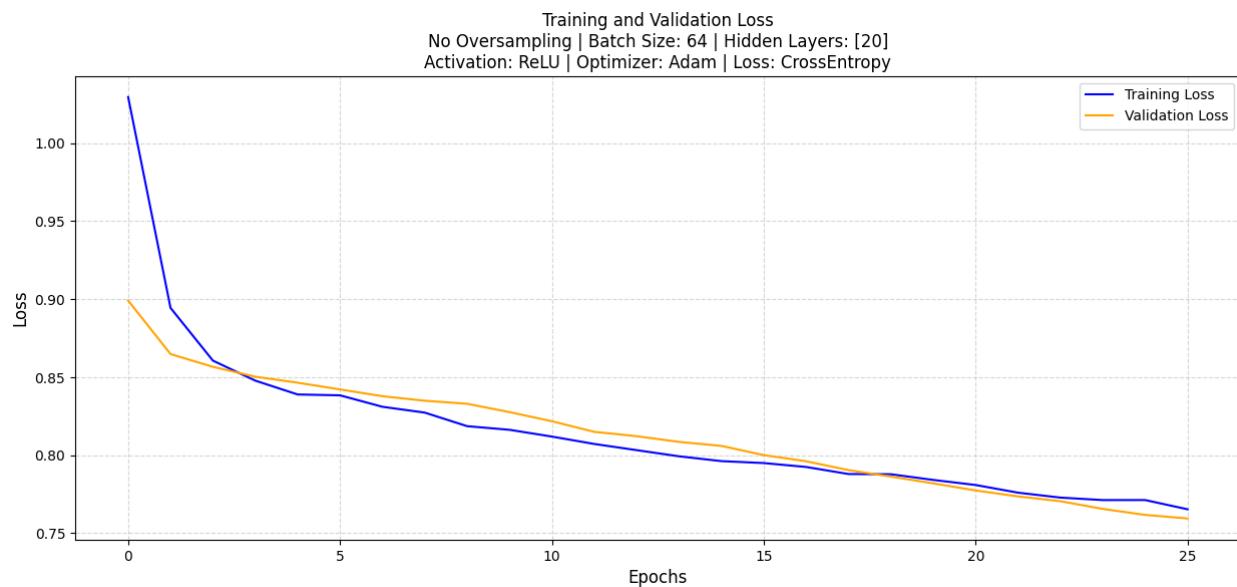
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
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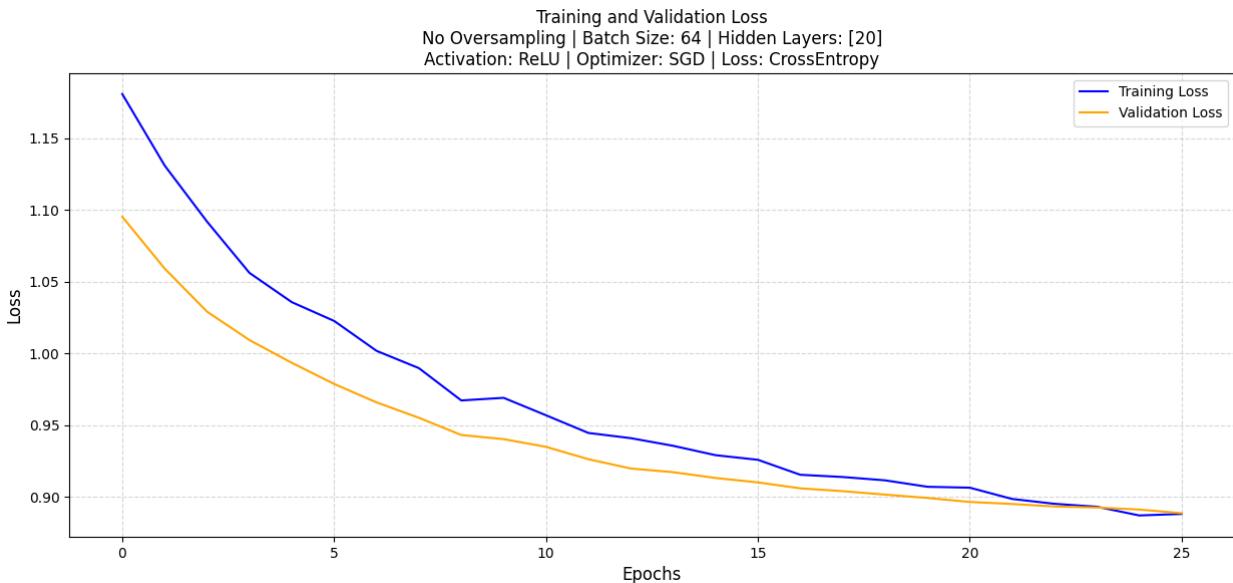
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
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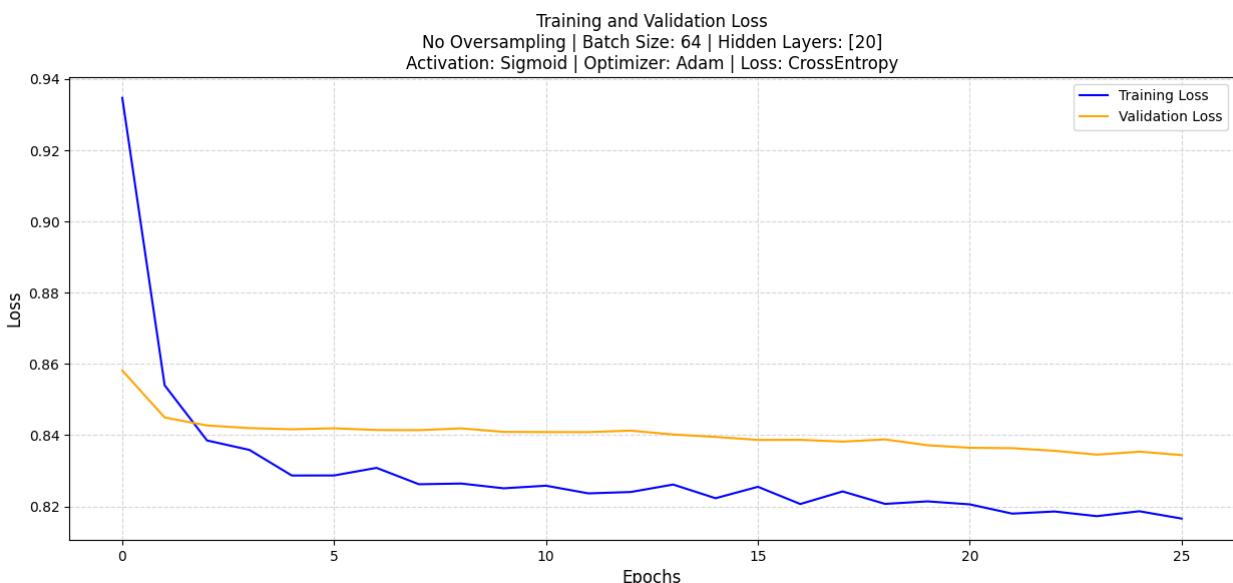
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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len(result))
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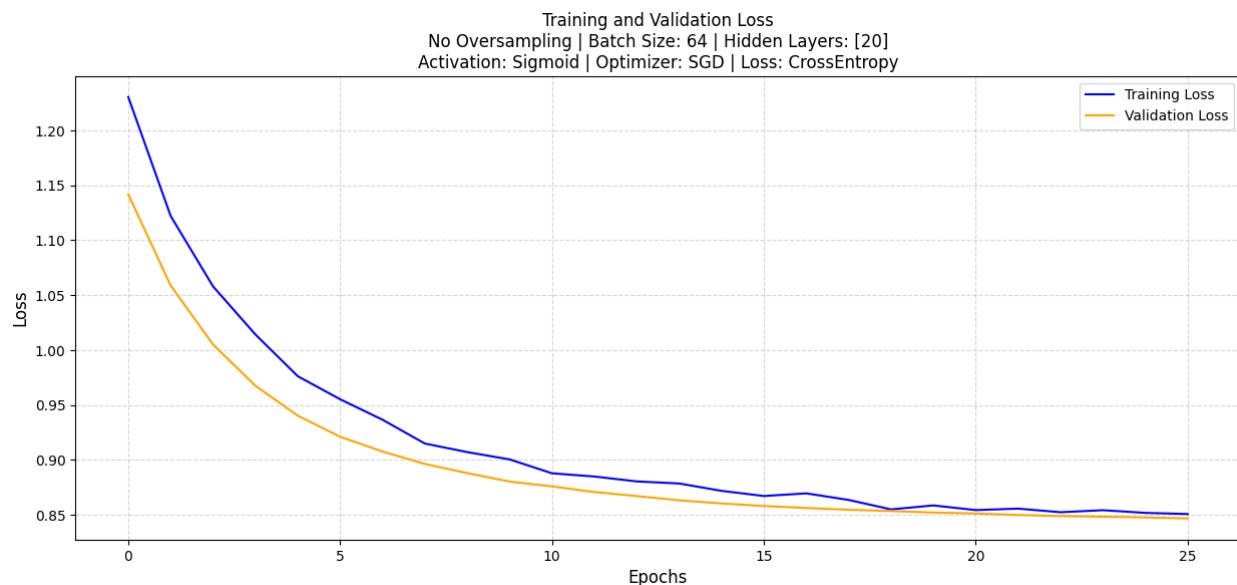
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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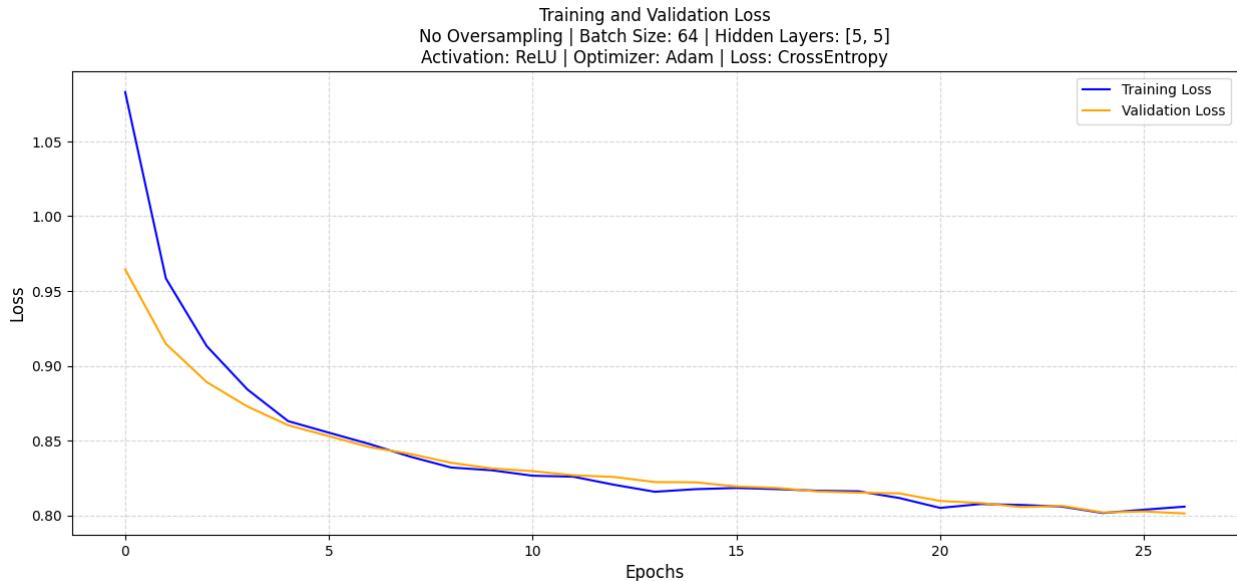
Early stopping triggered

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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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len(result))
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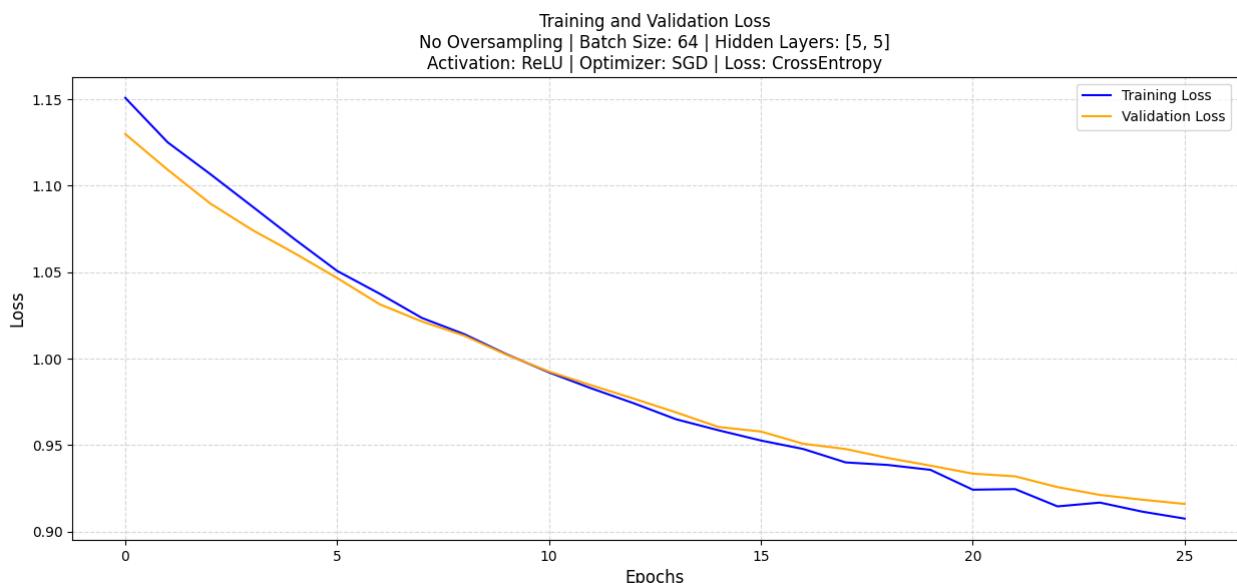
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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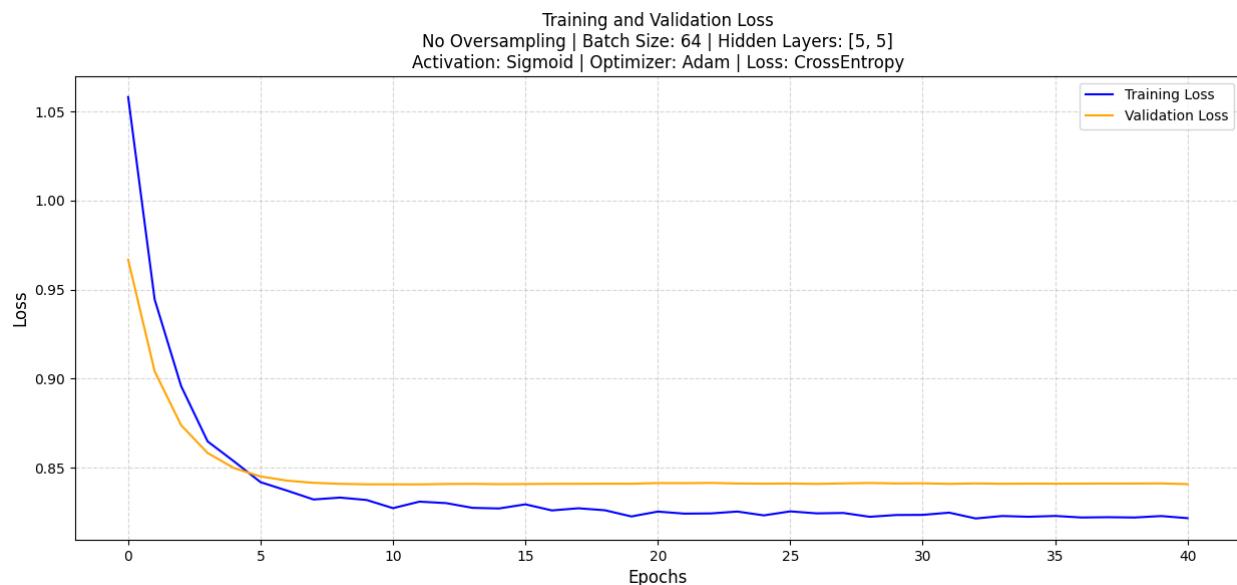
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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len(result))
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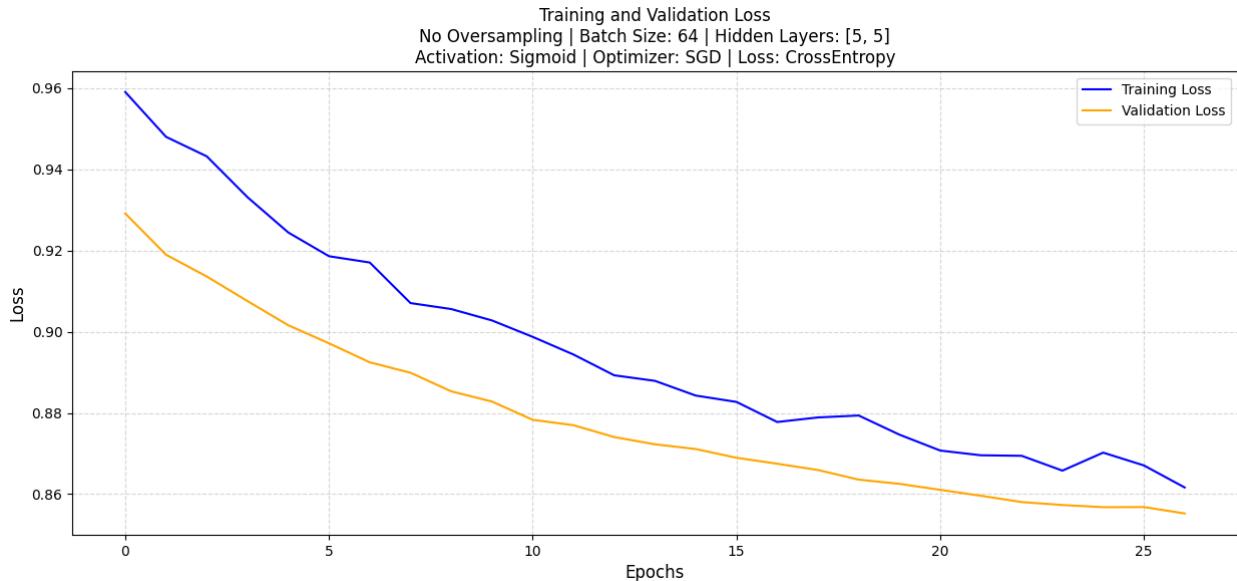
Early stopping triggered

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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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len(result))
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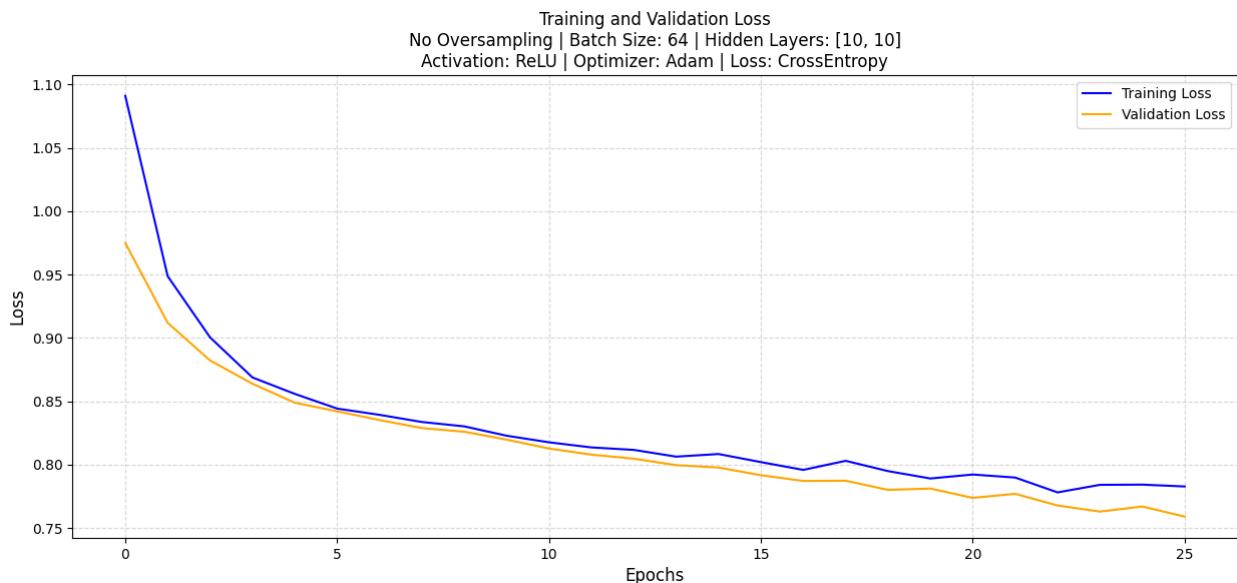
Early stopping triggered

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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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len(result))
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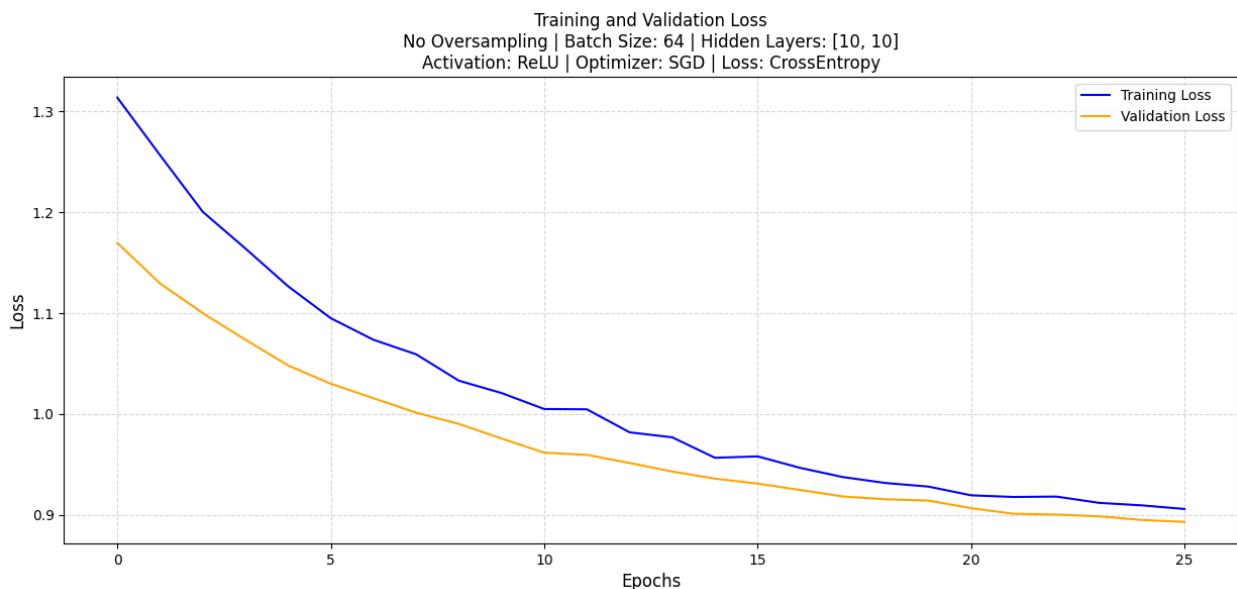
Early stopping triggered

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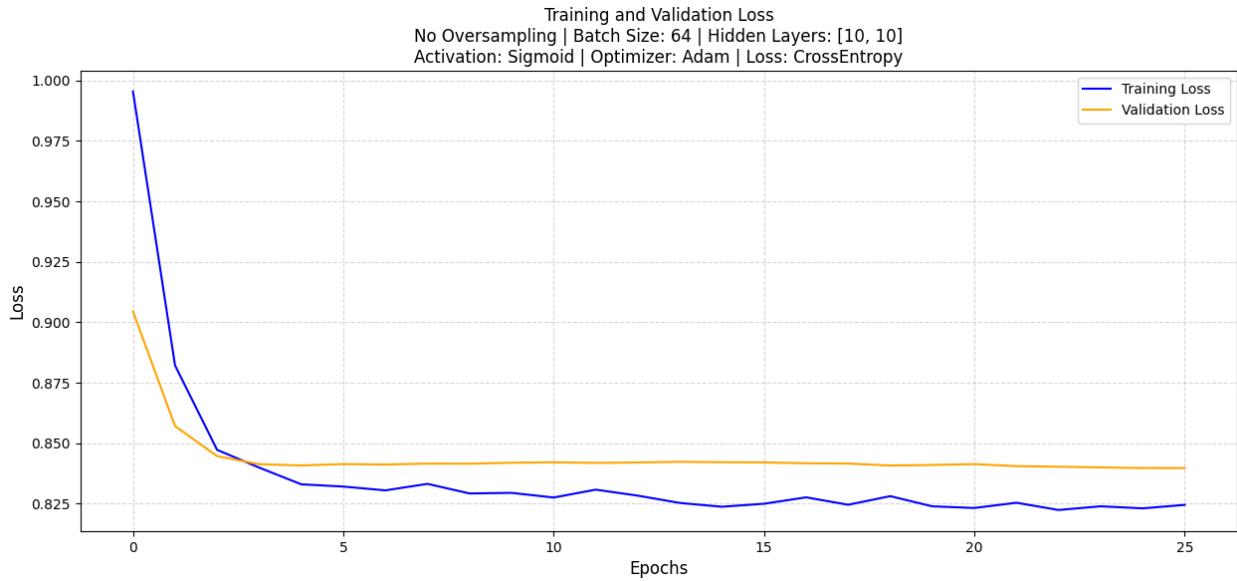
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



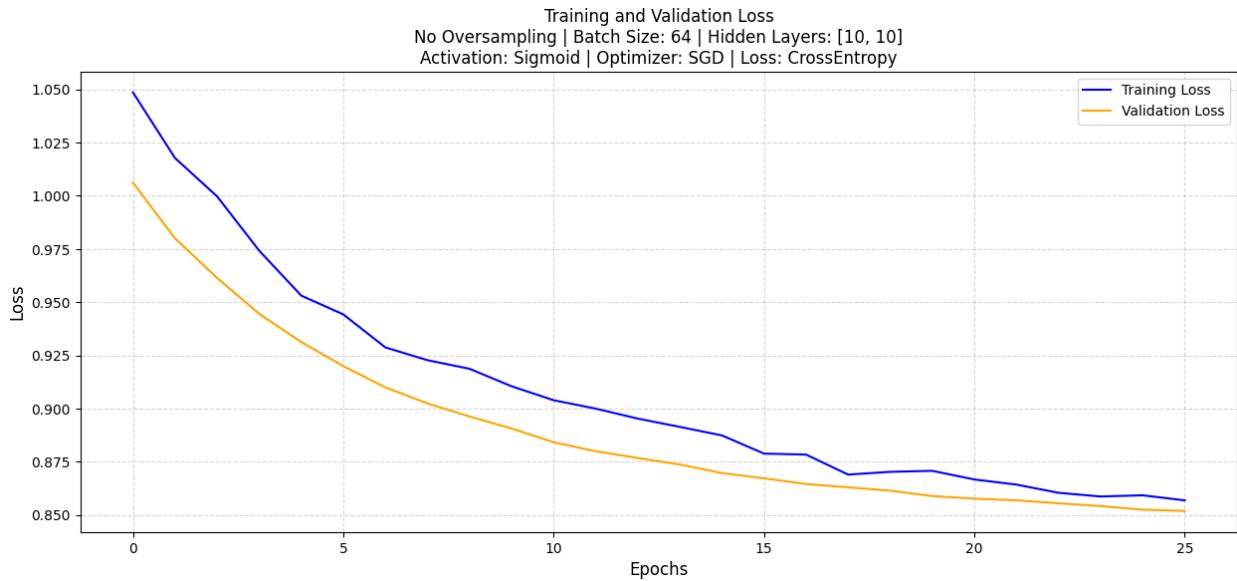
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



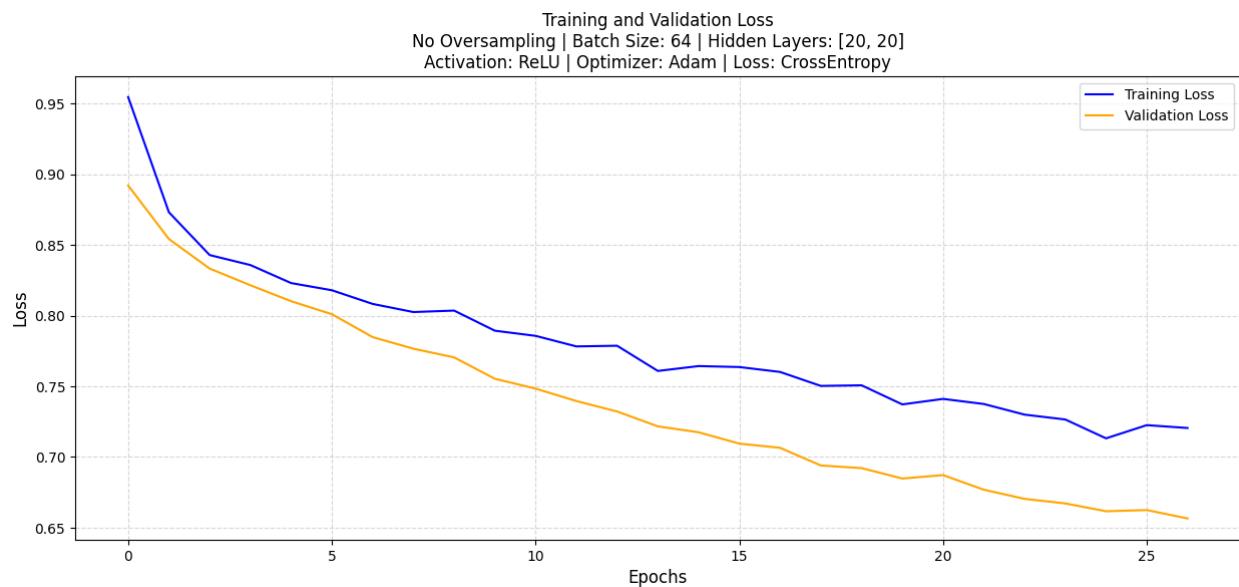
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



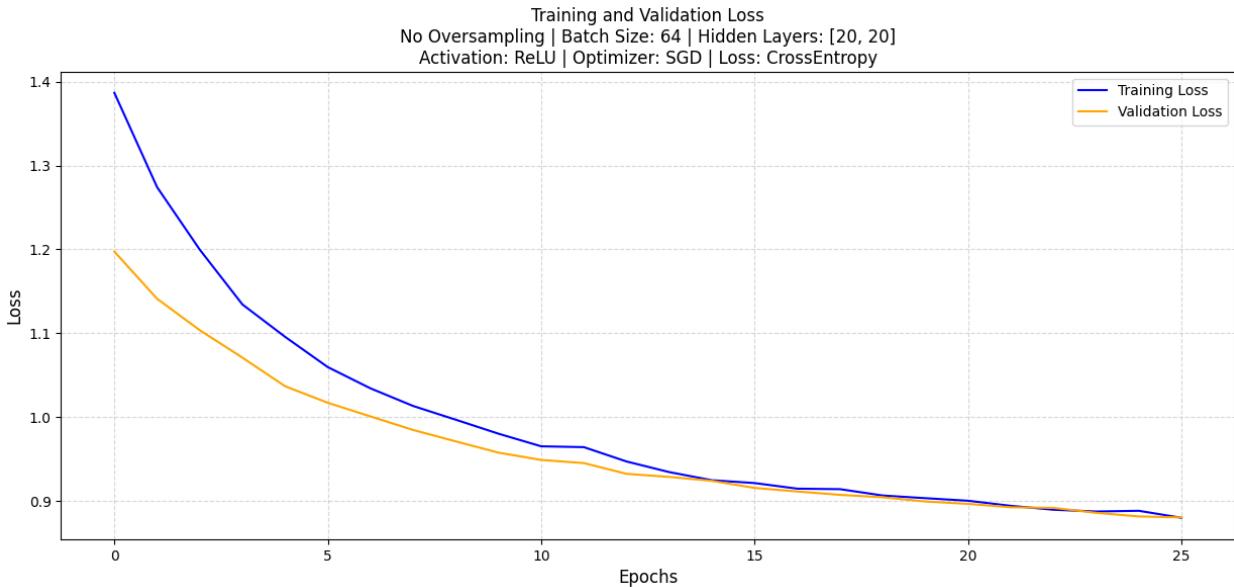
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



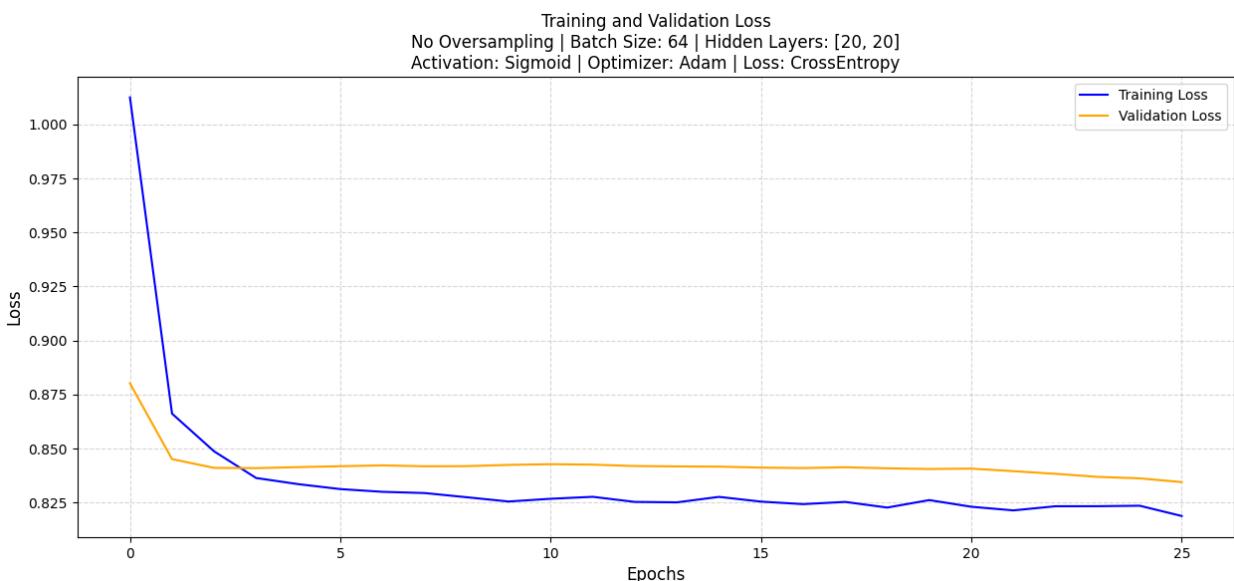
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



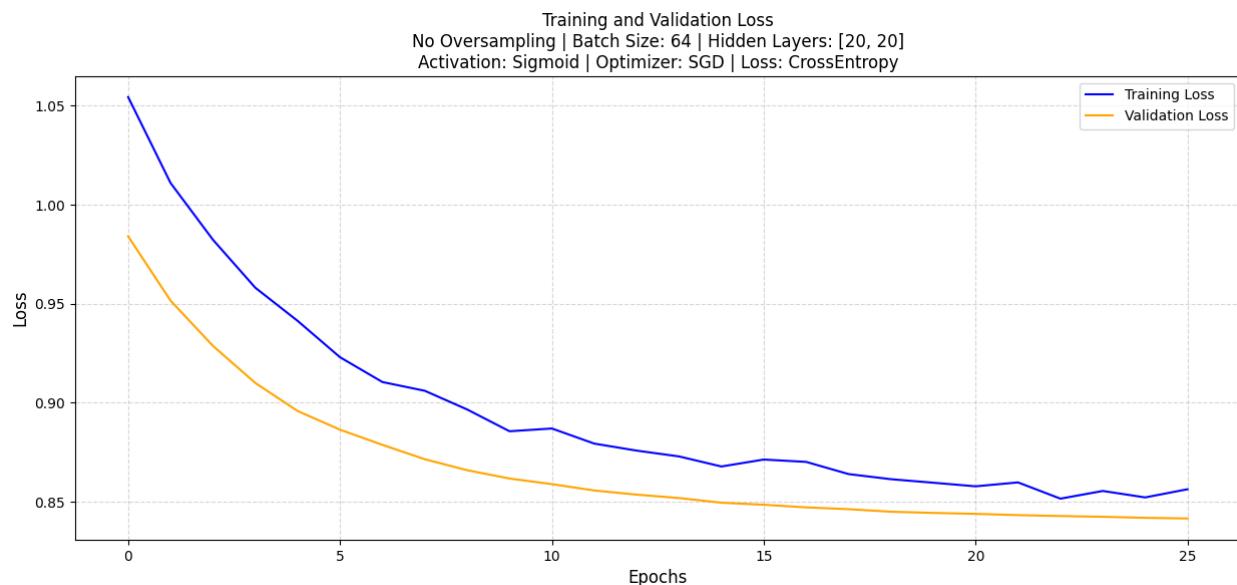
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



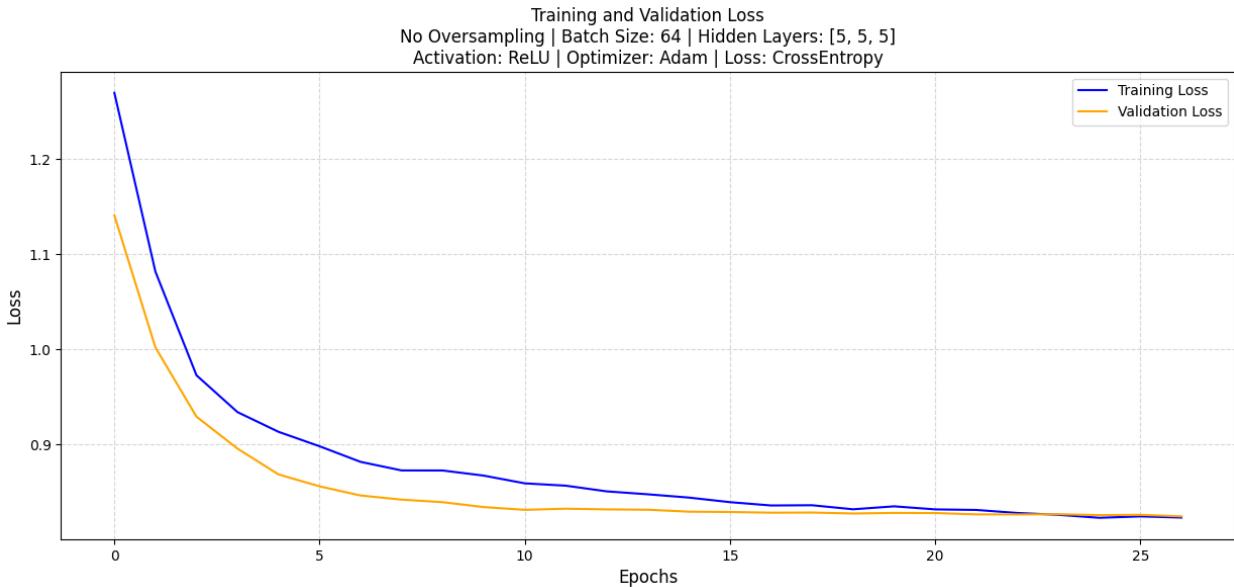
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



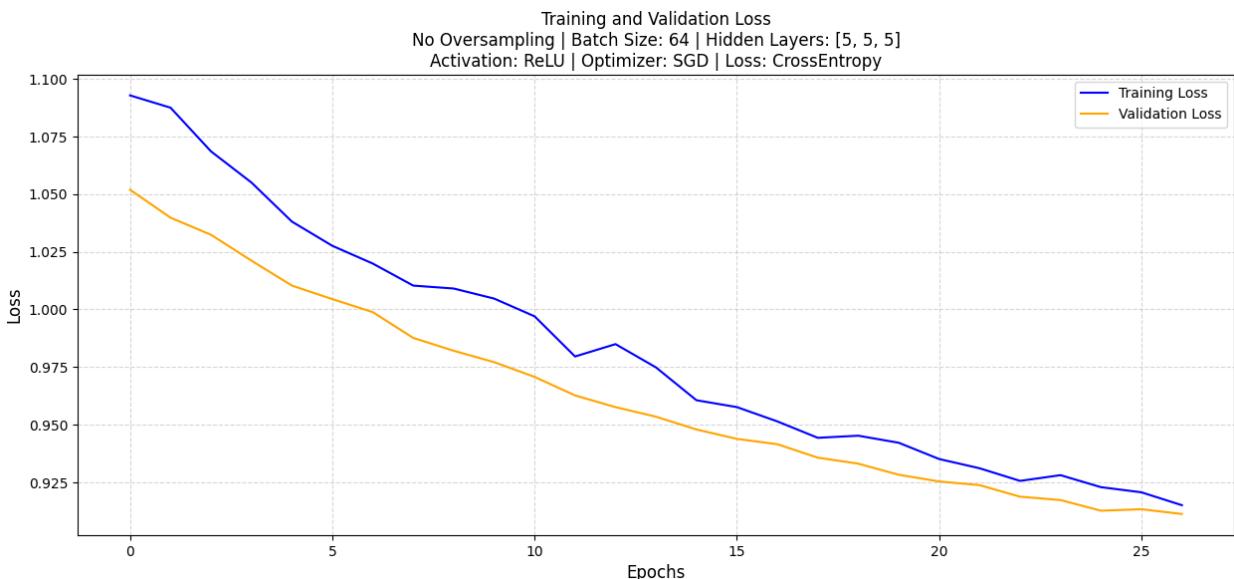
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



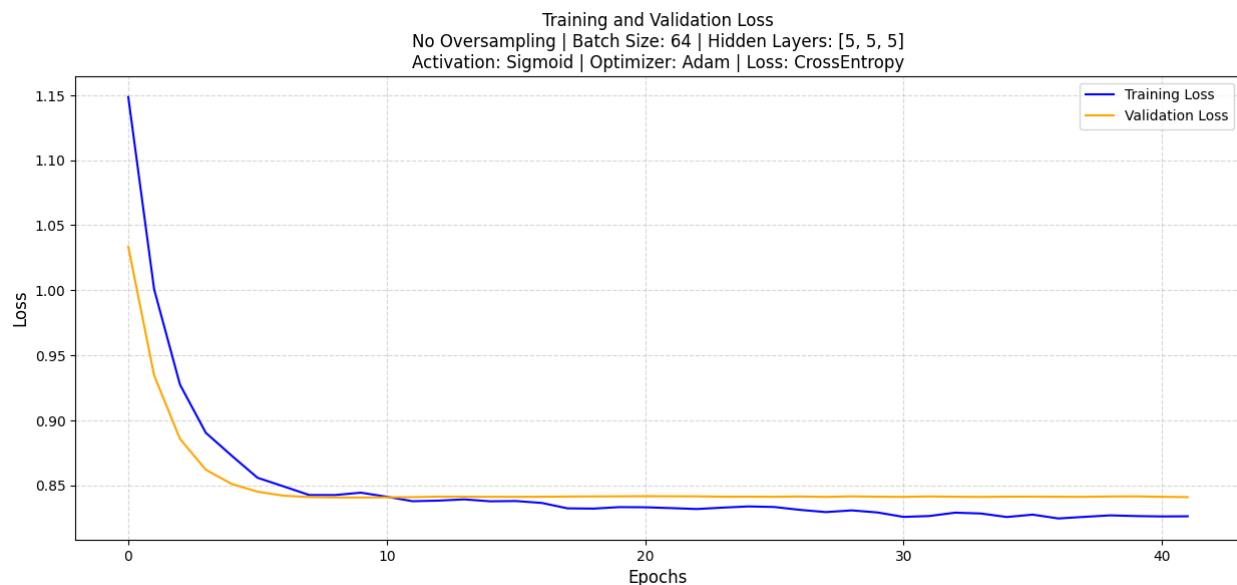
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



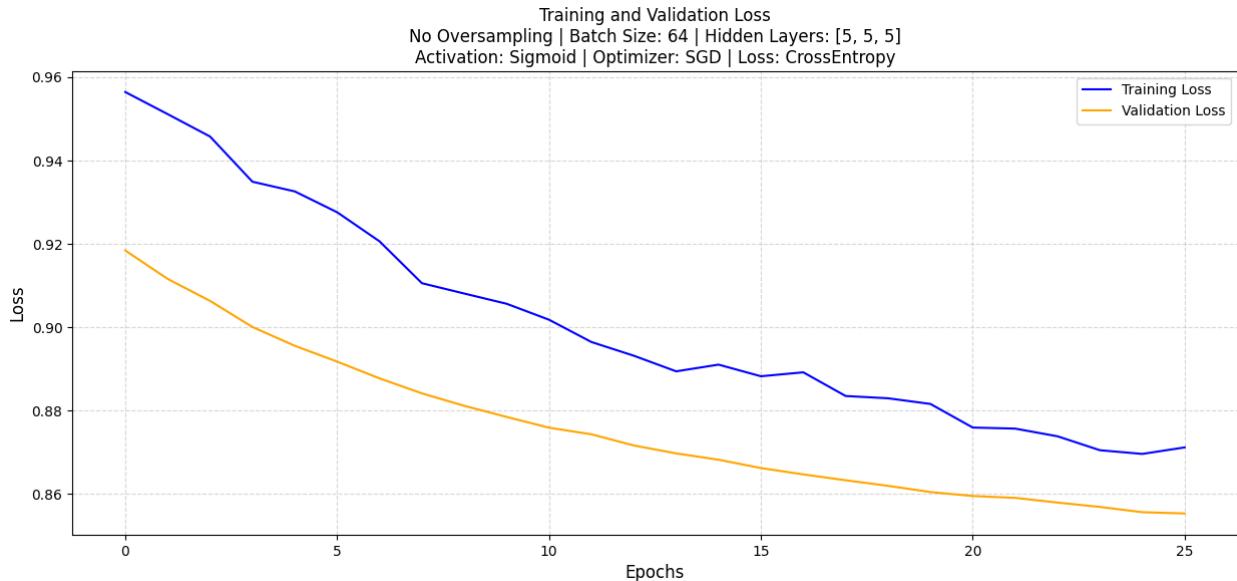
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



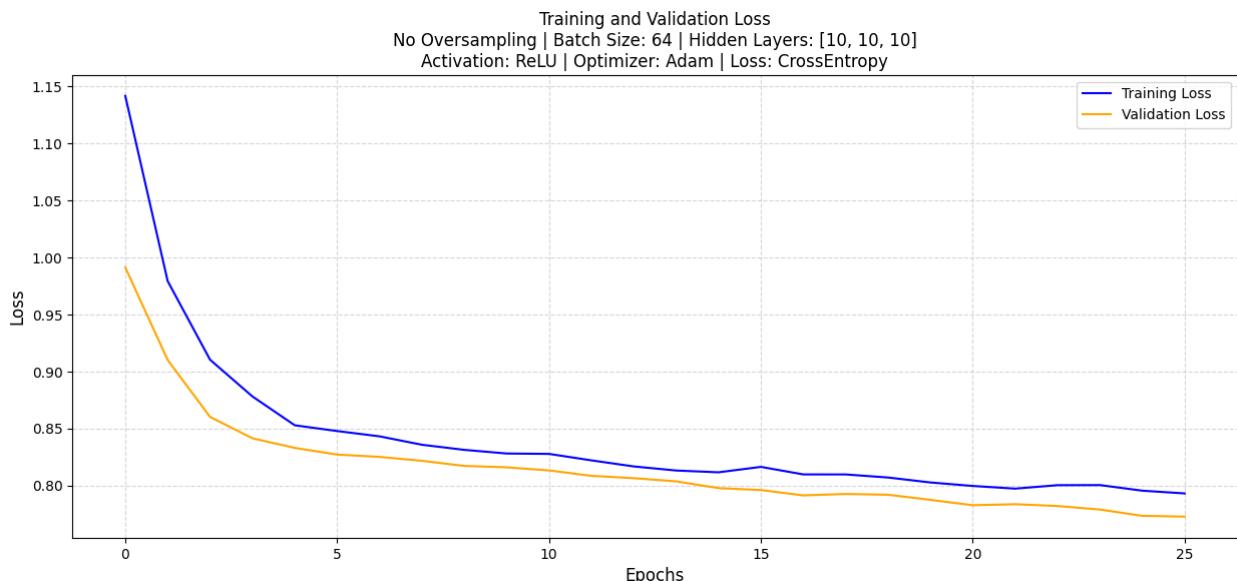
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



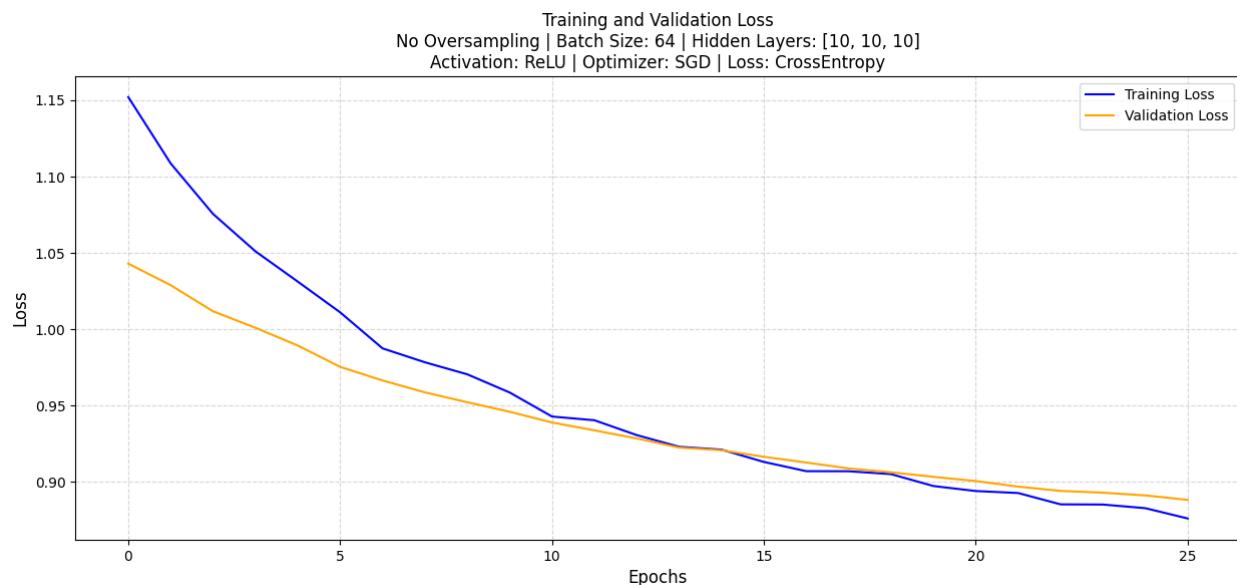
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



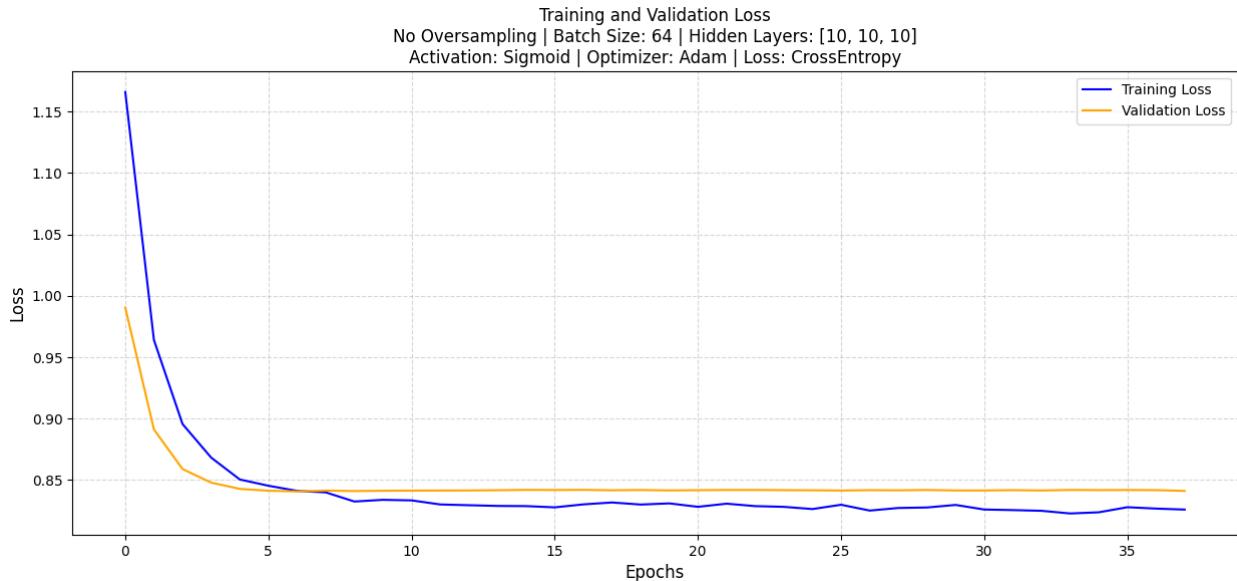
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



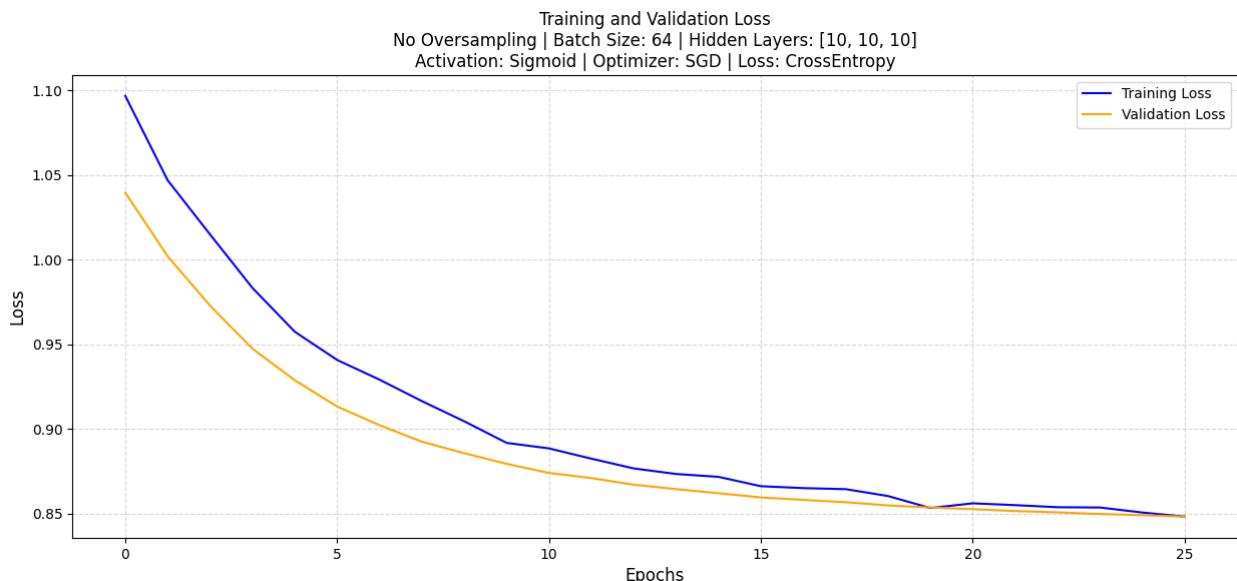
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



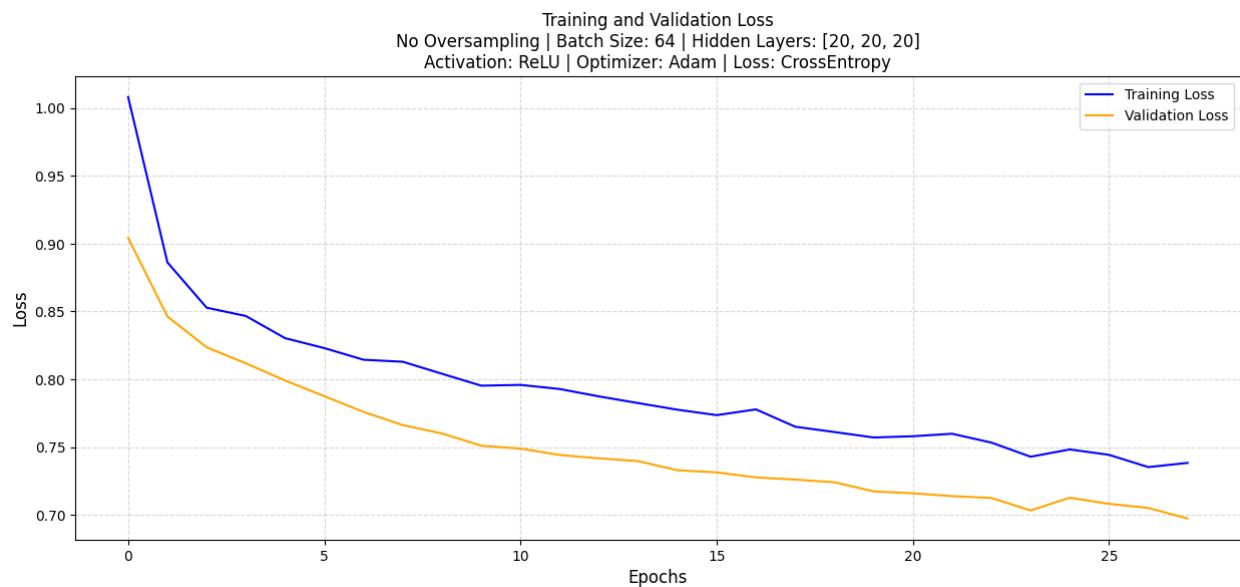
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



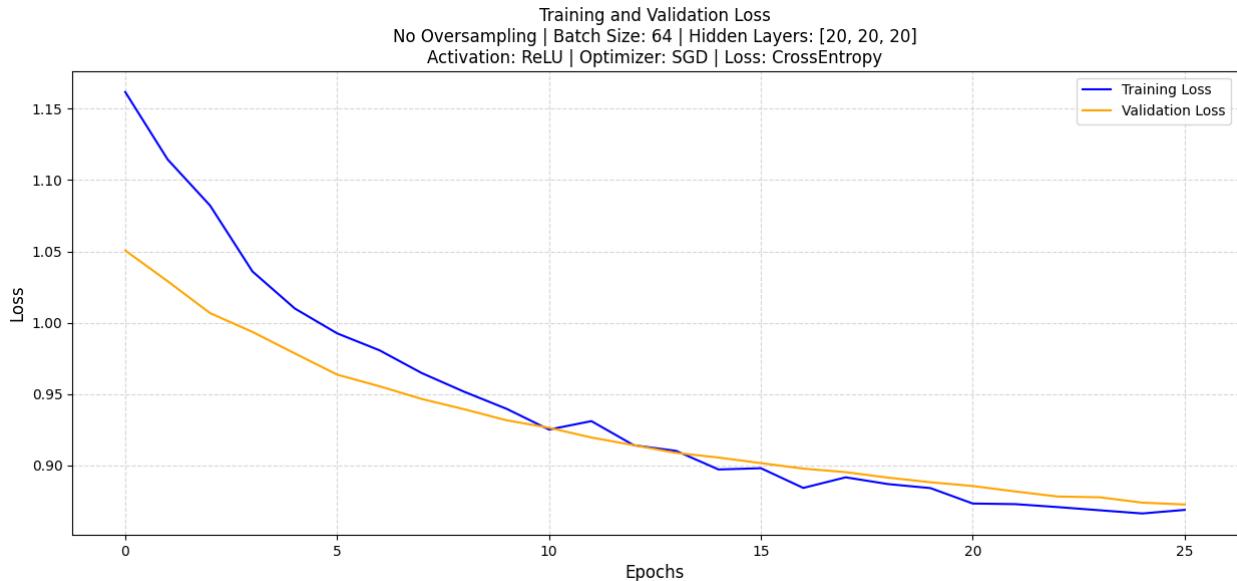
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



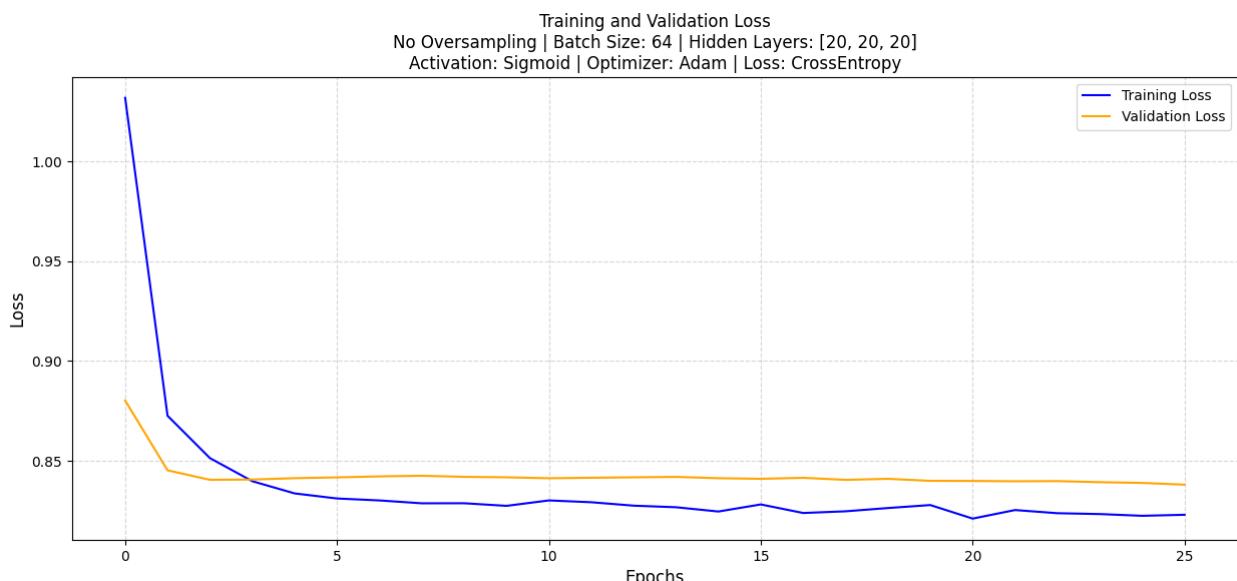
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



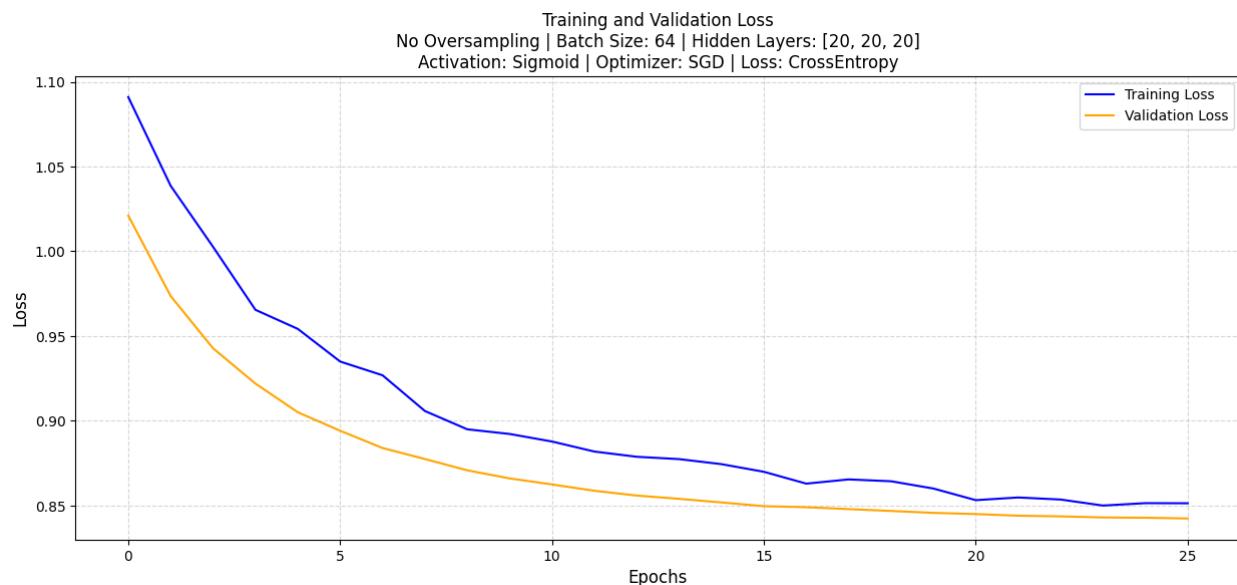
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



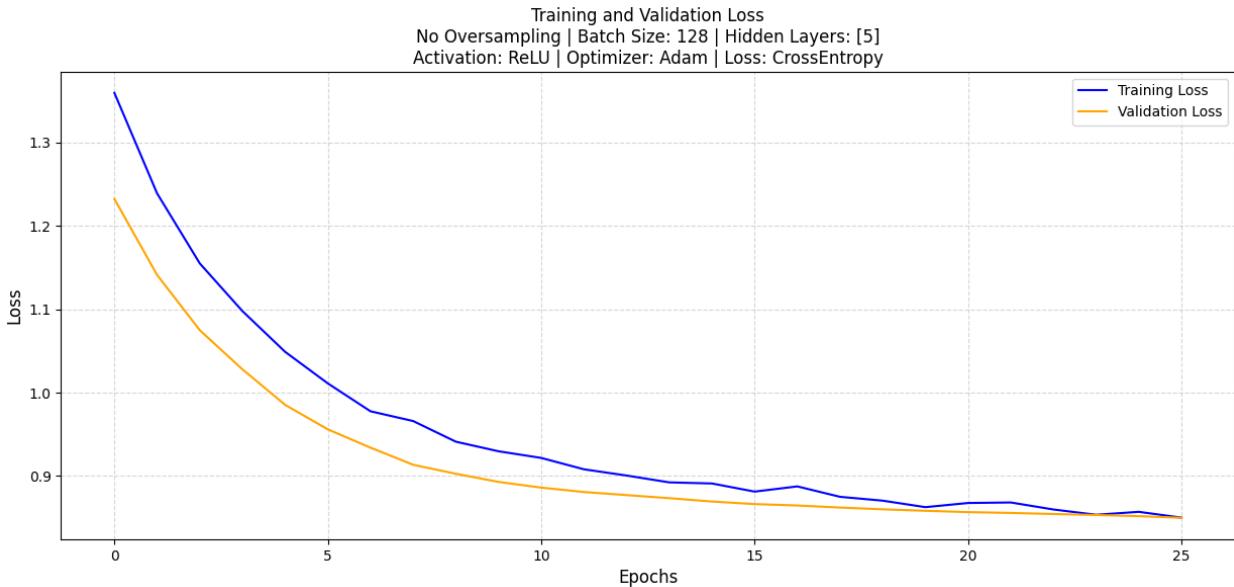
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



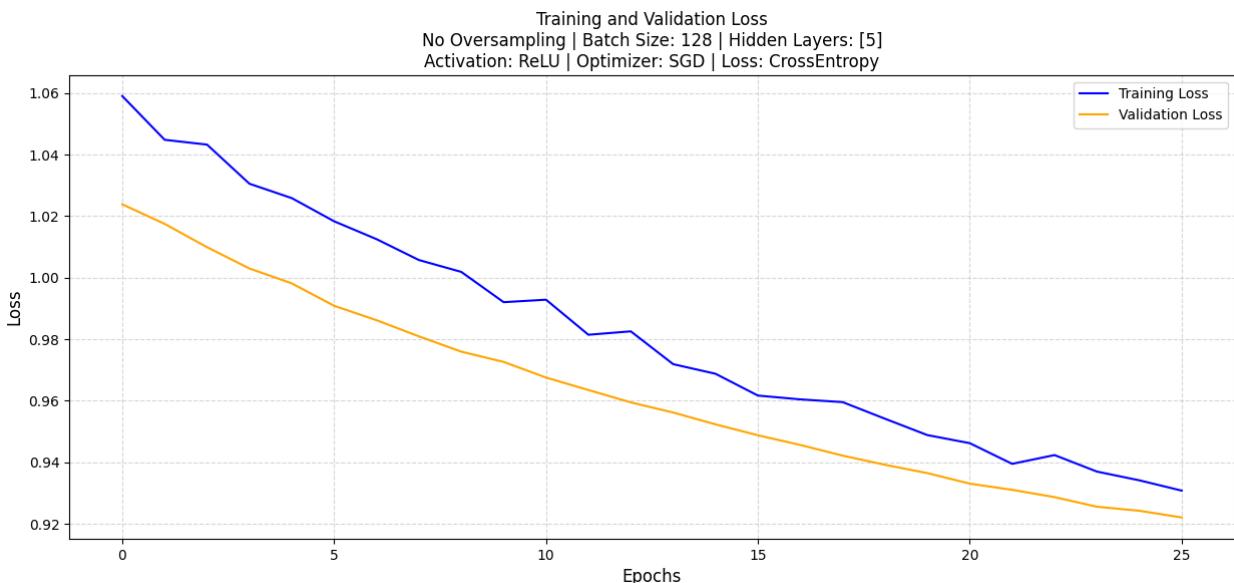
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



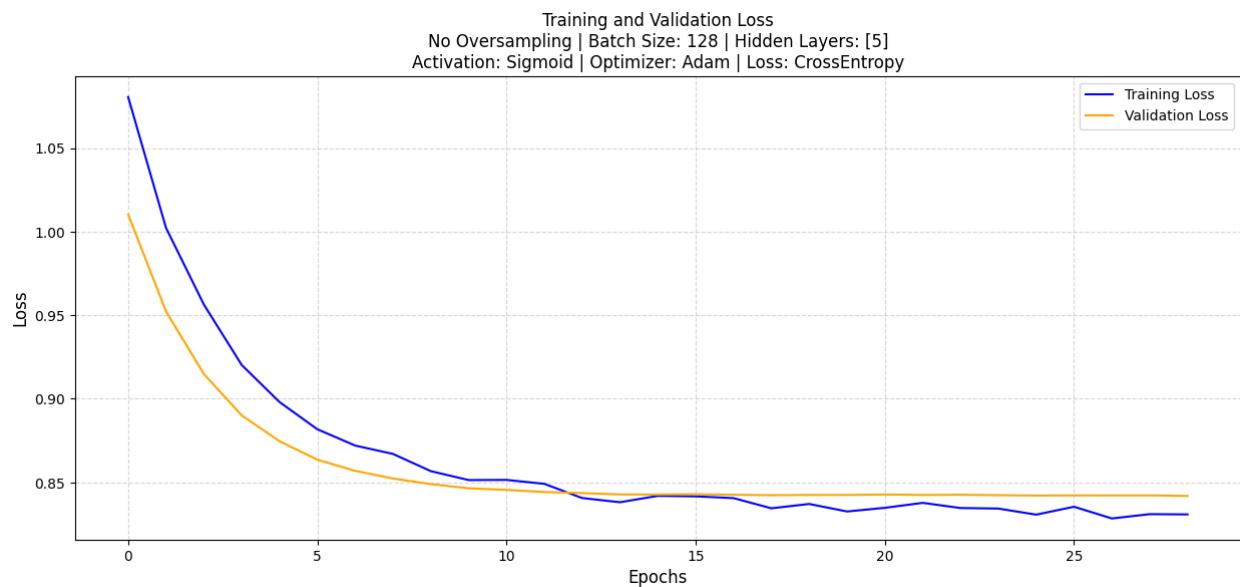
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



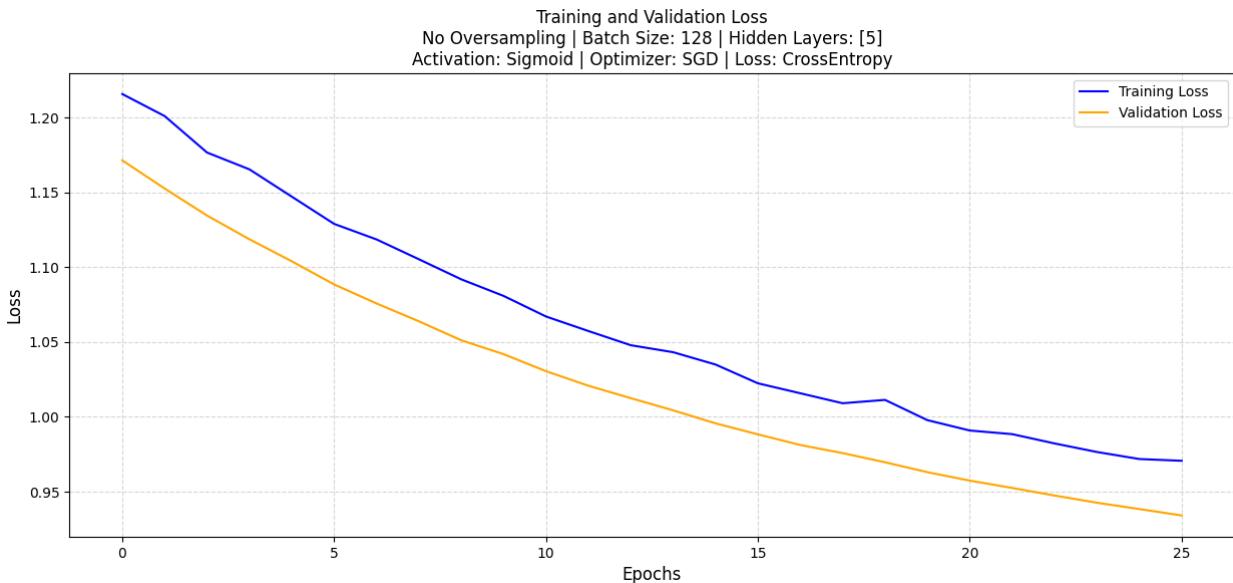
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
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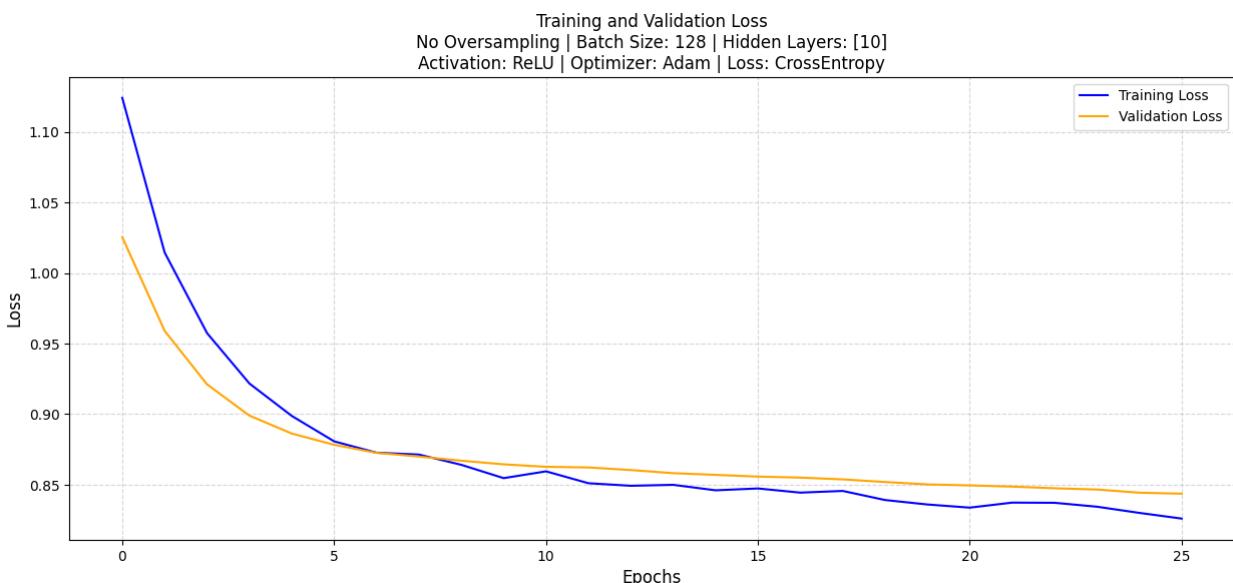
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
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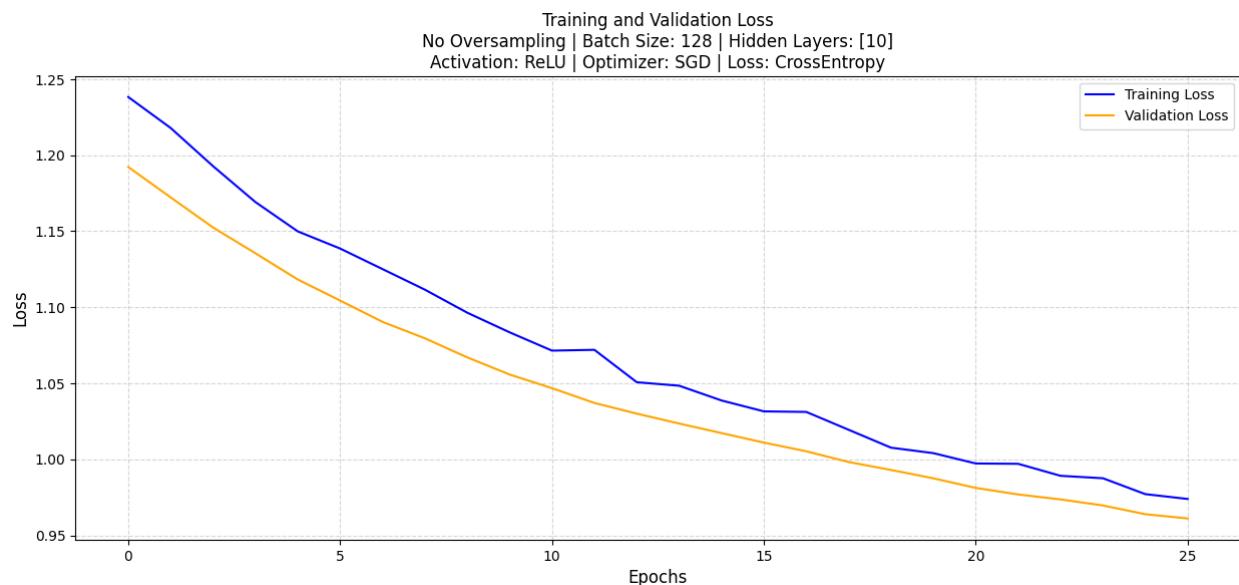
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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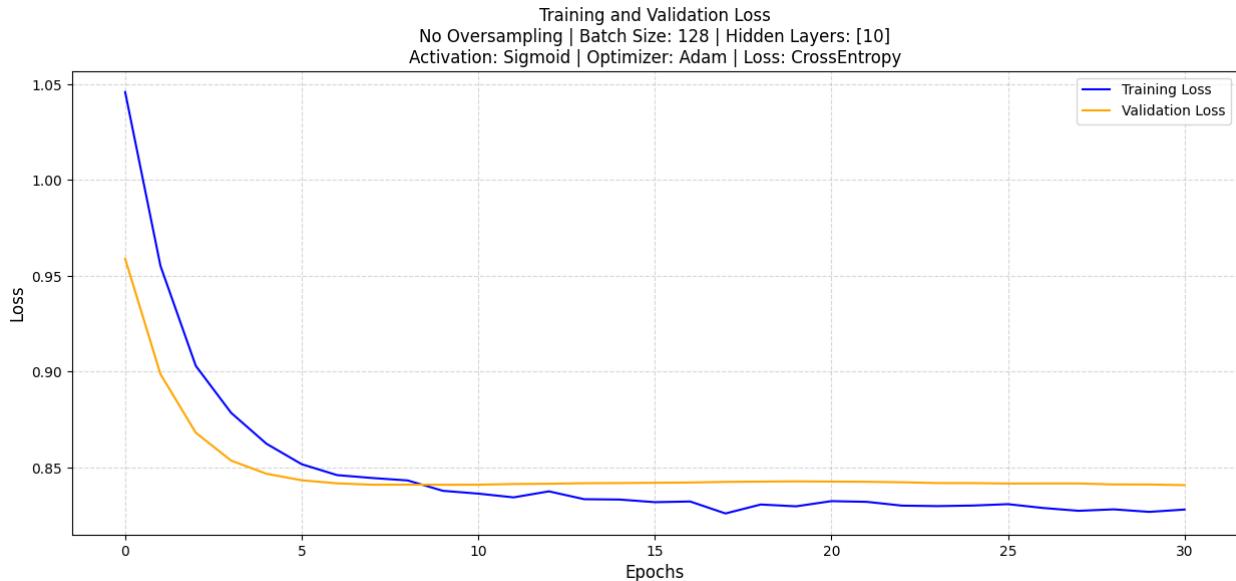
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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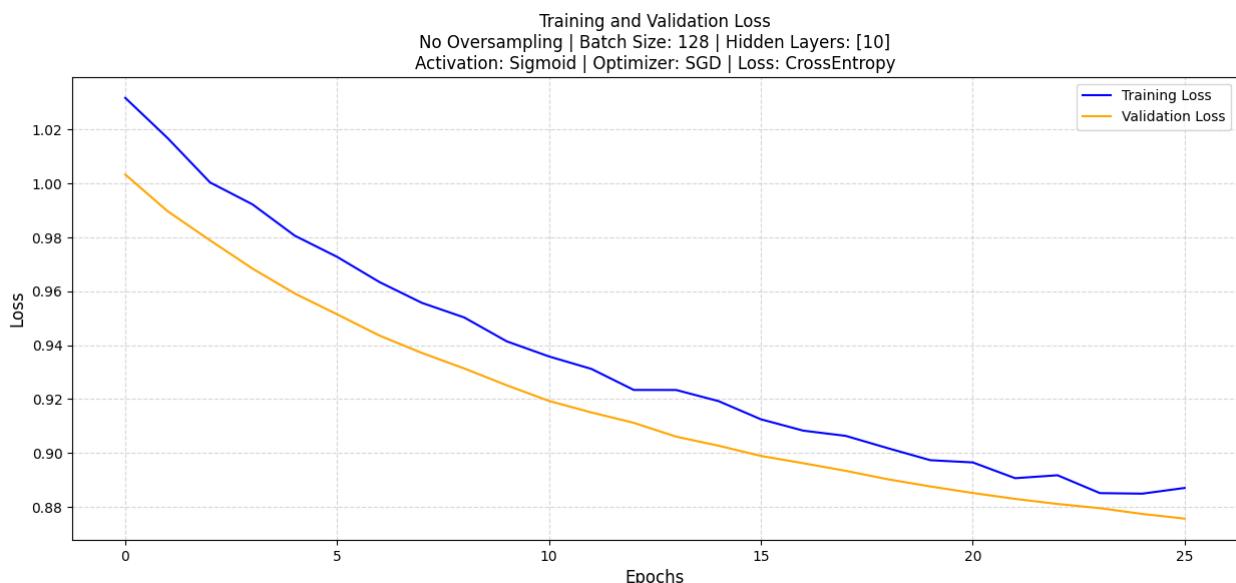
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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len(result))
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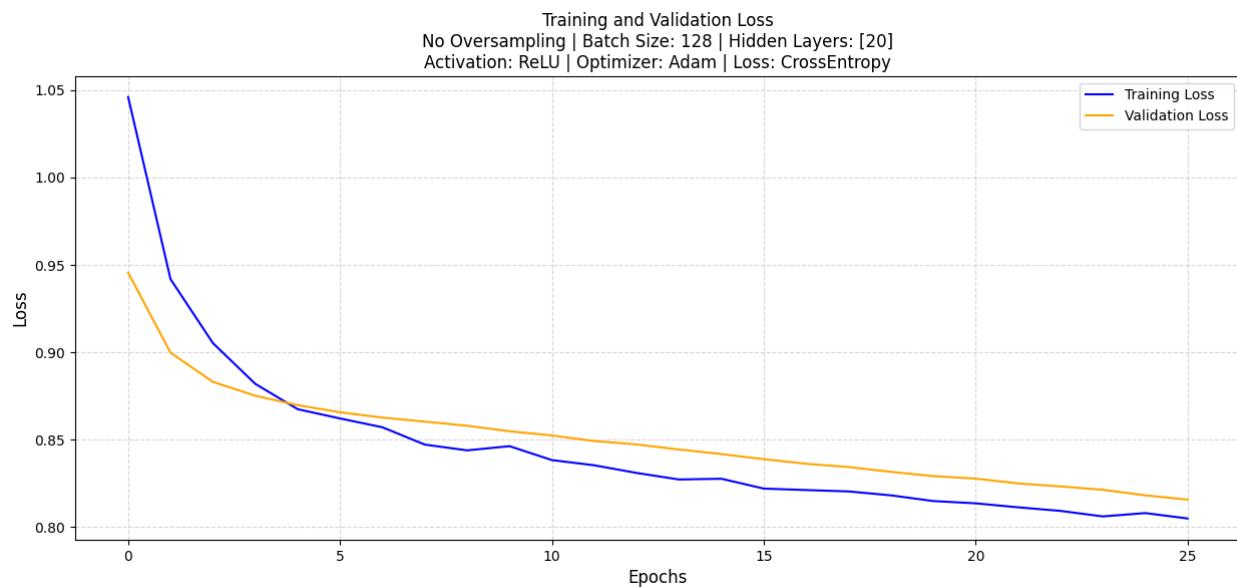
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
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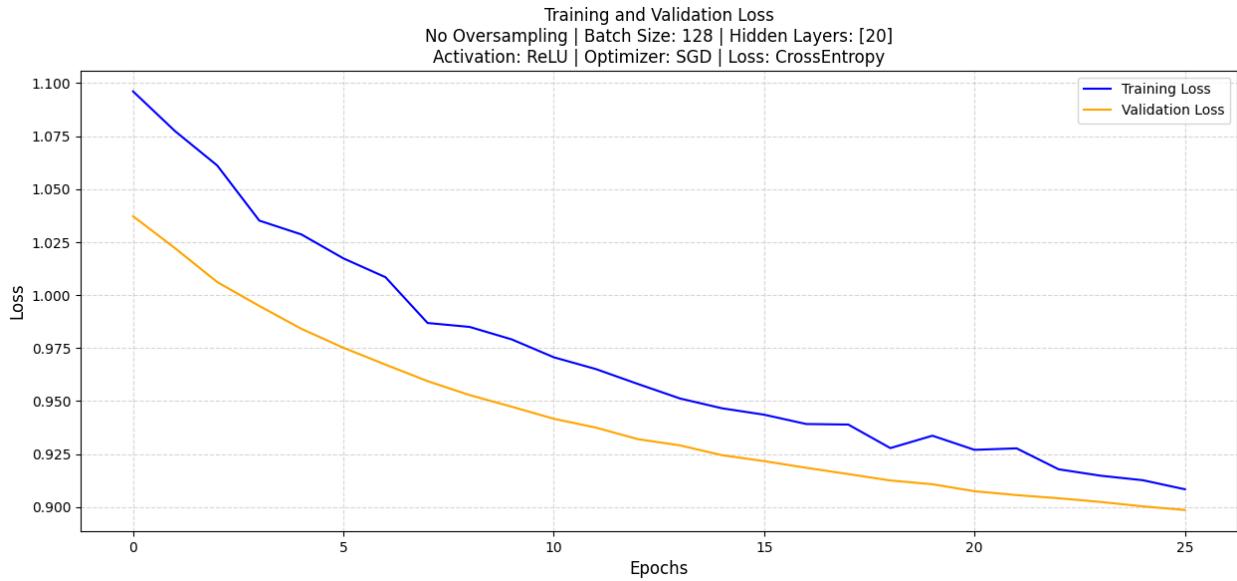
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
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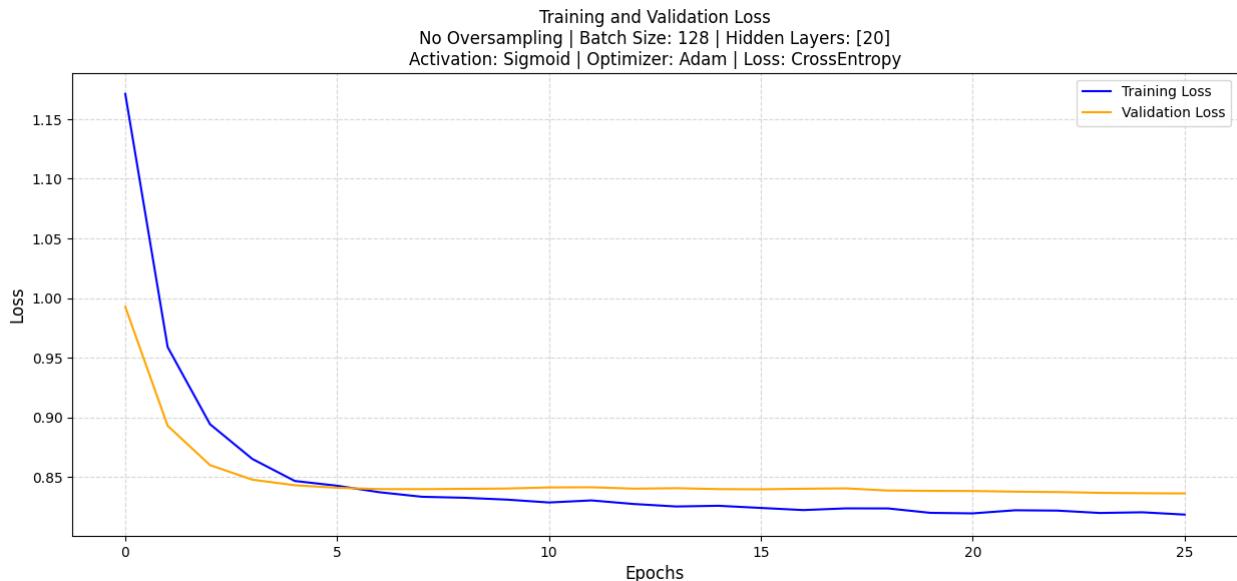
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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len(result))
```



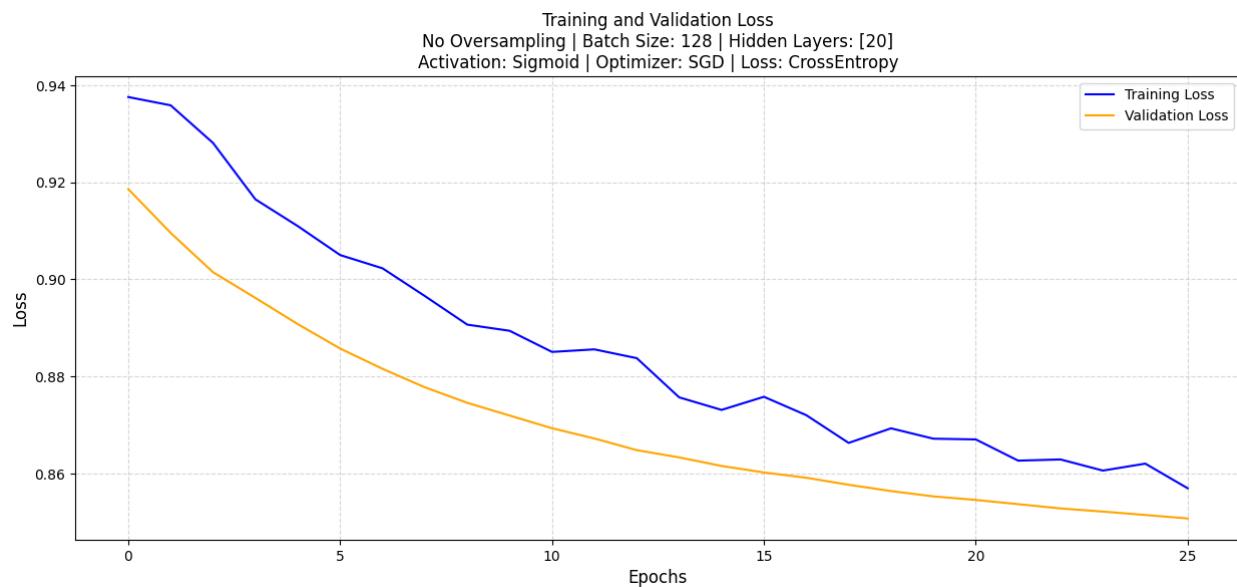
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



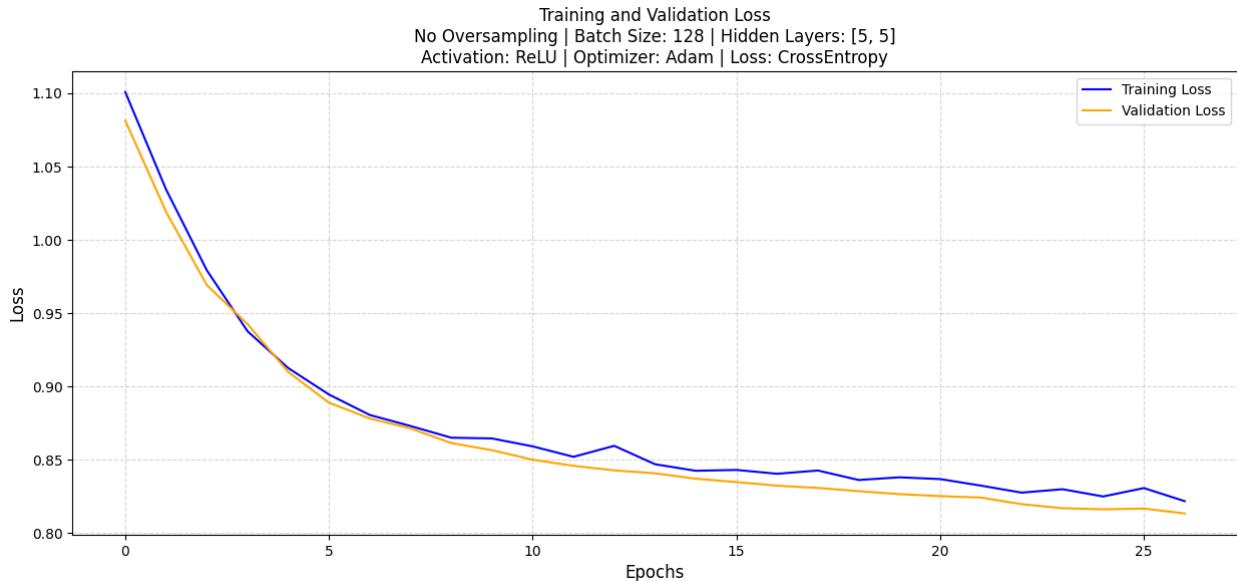
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
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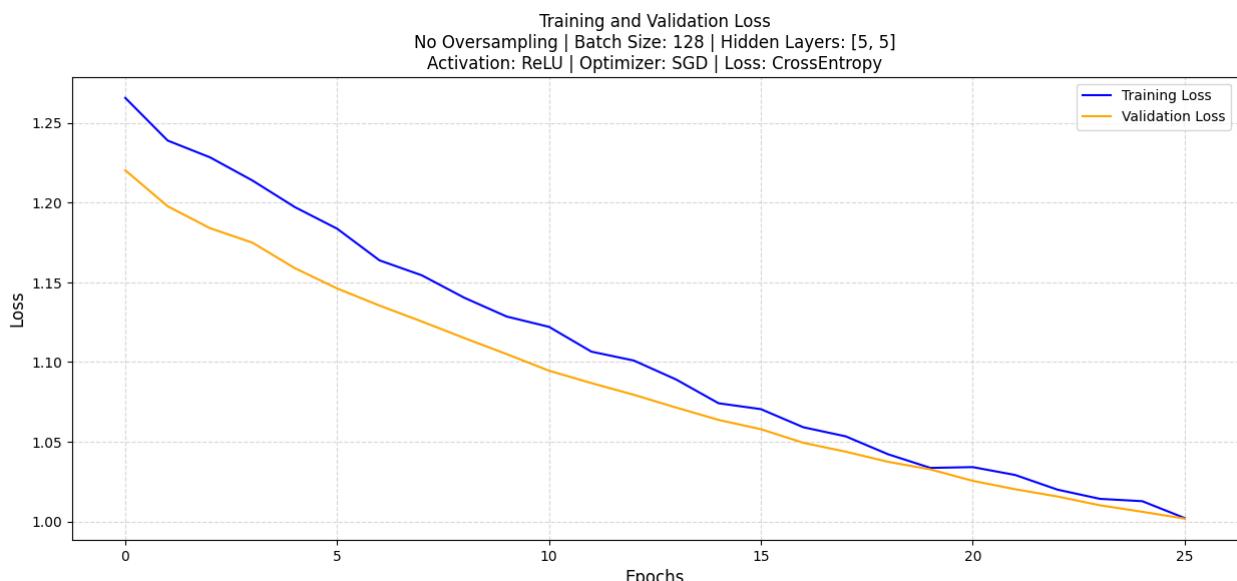
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



Early stopping triggered

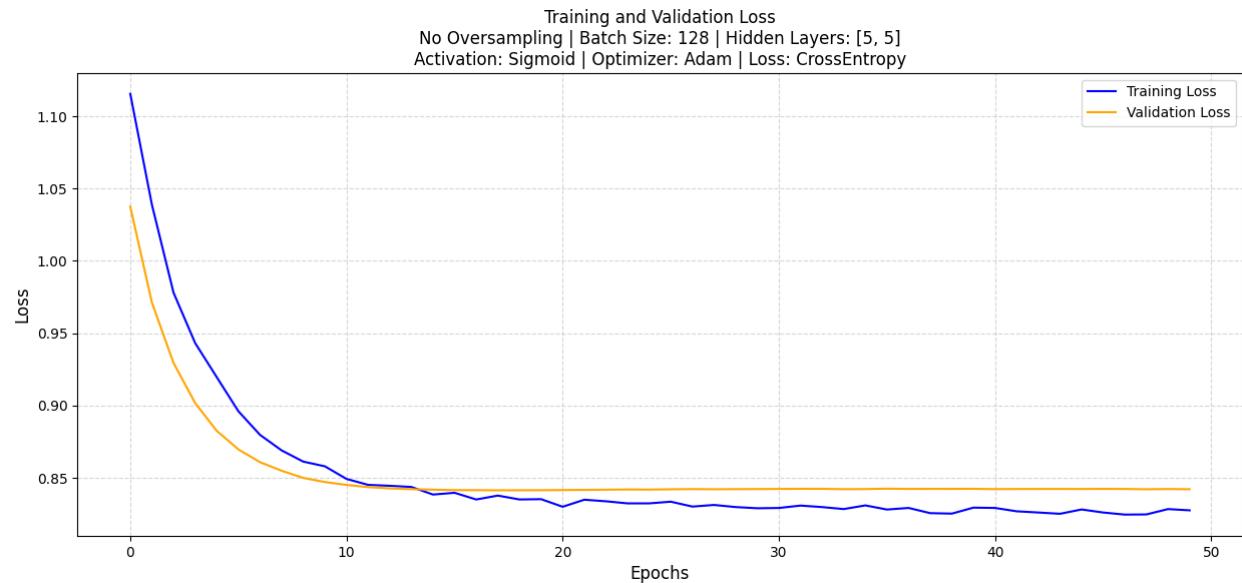
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
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```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
```

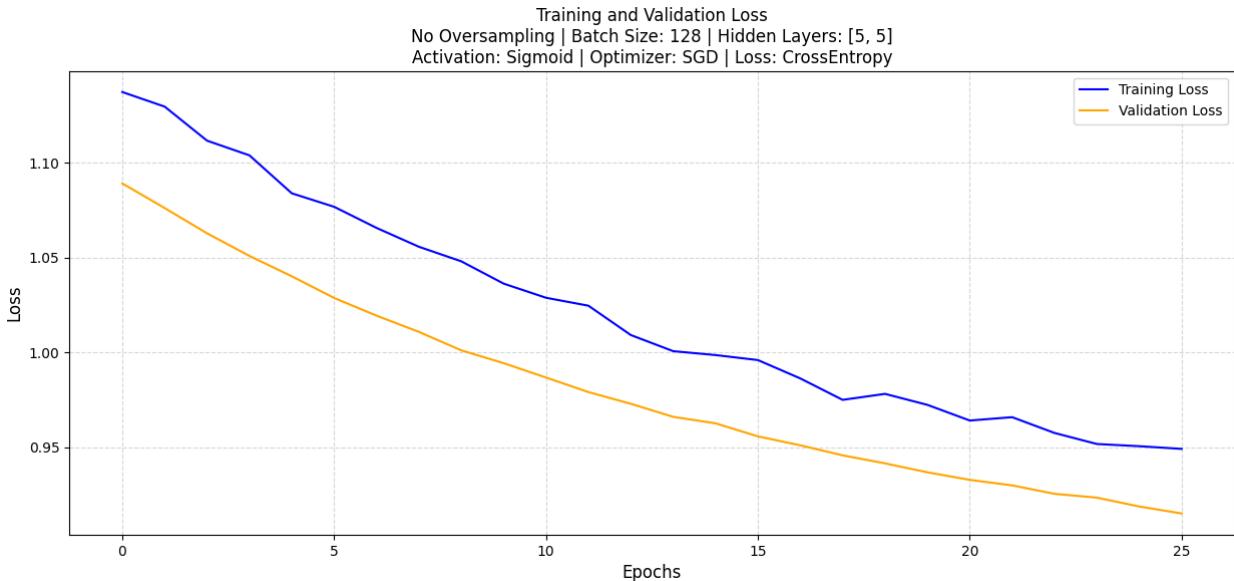
```
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.
```

```
_warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



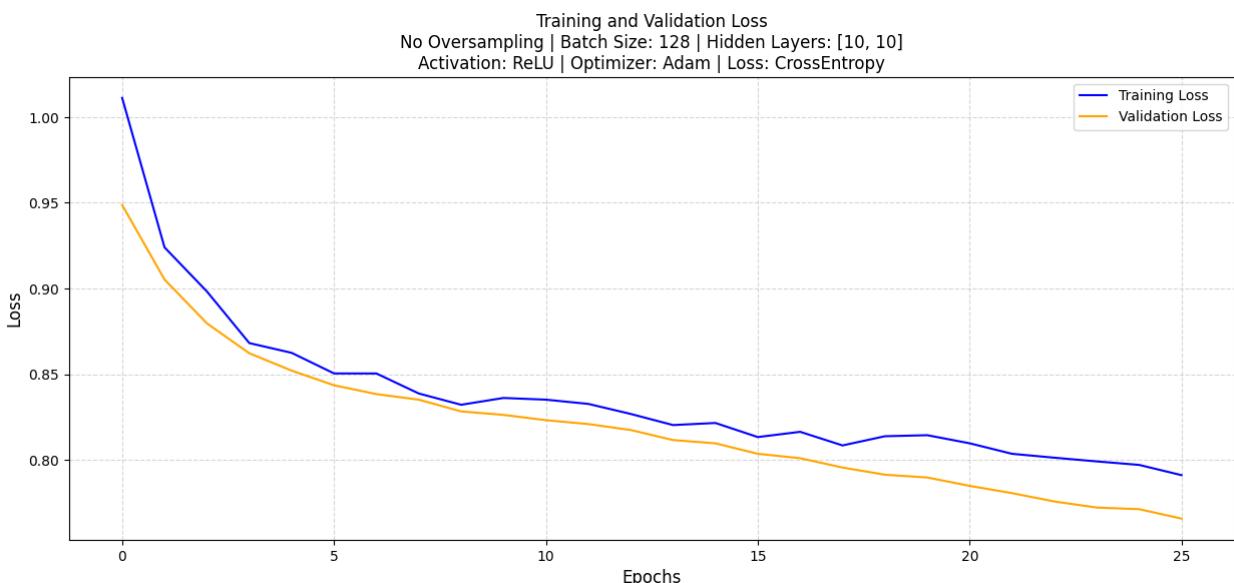
```
Early stopping triggered
```

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-  
packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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_warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
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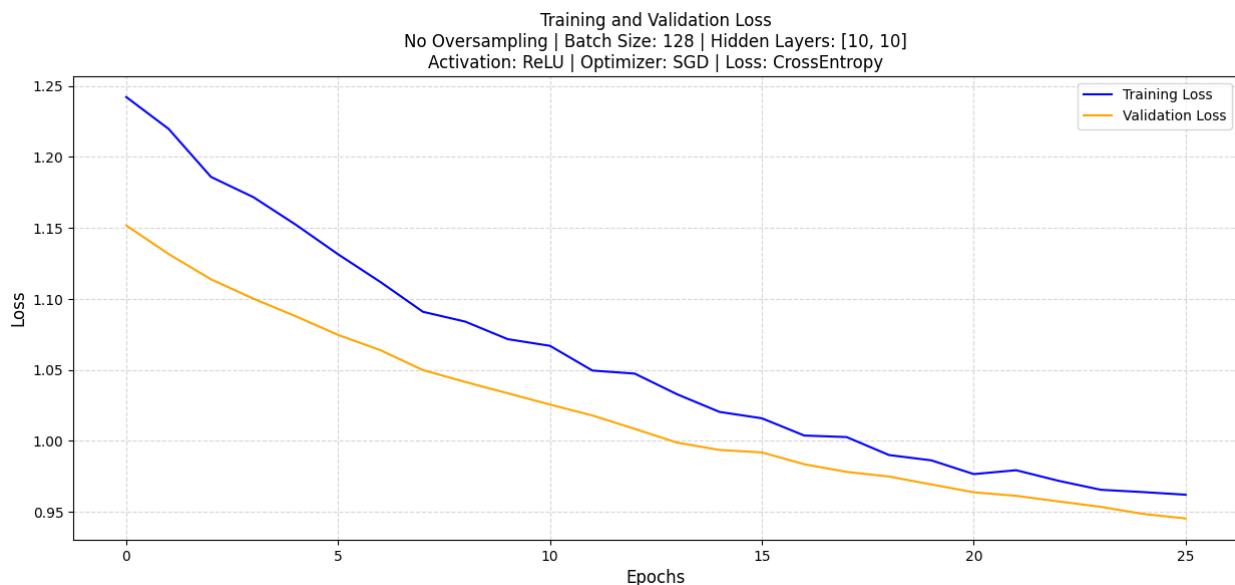
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



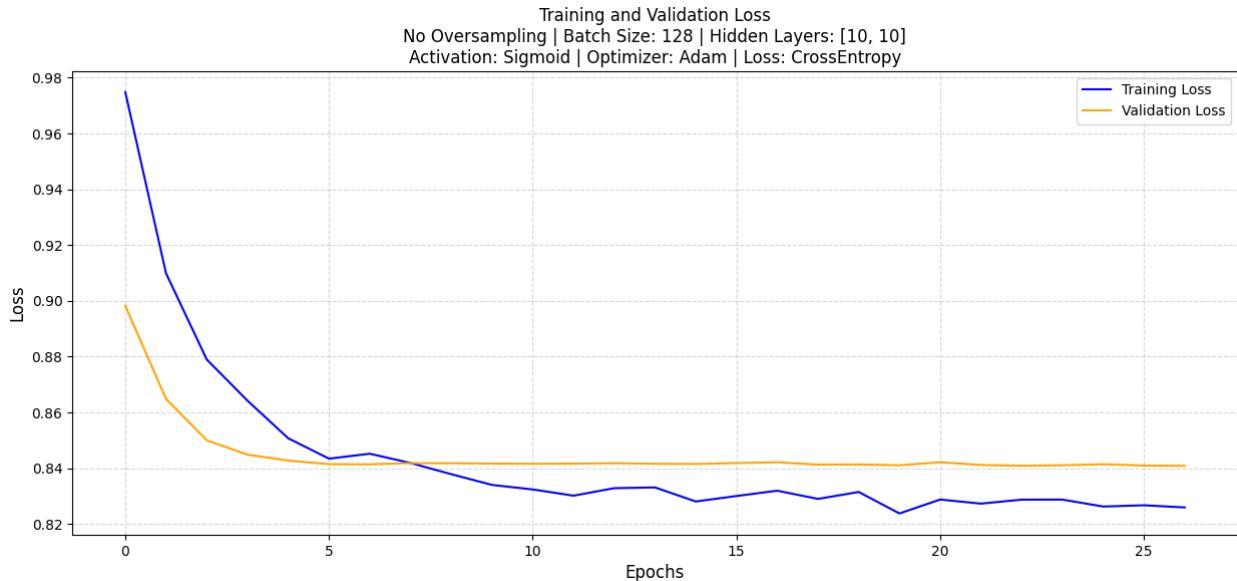
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



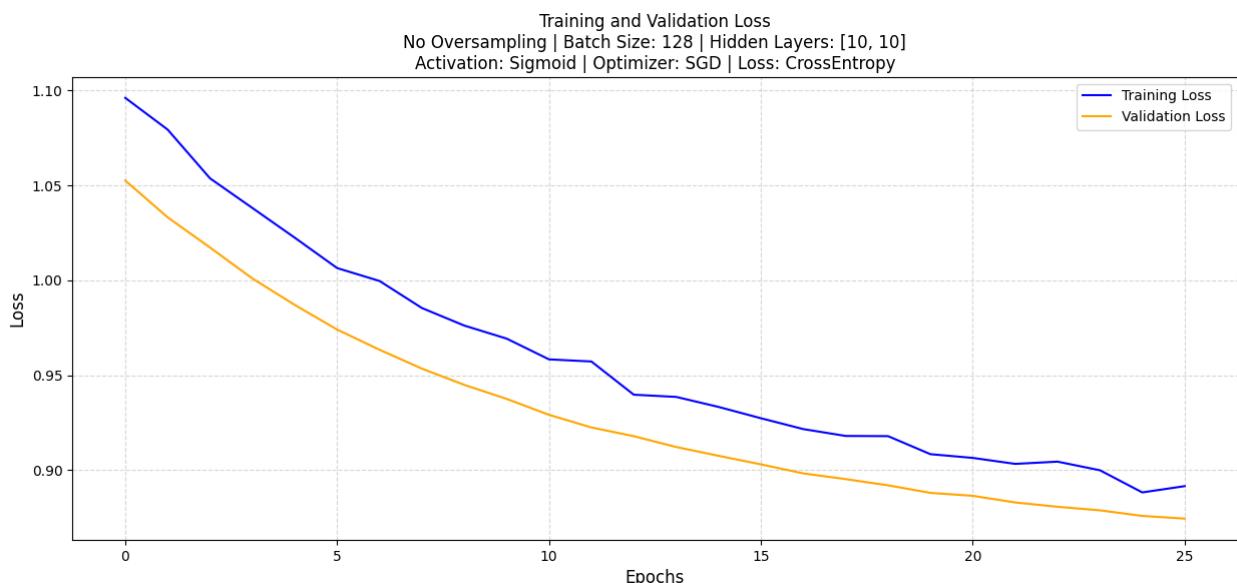
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



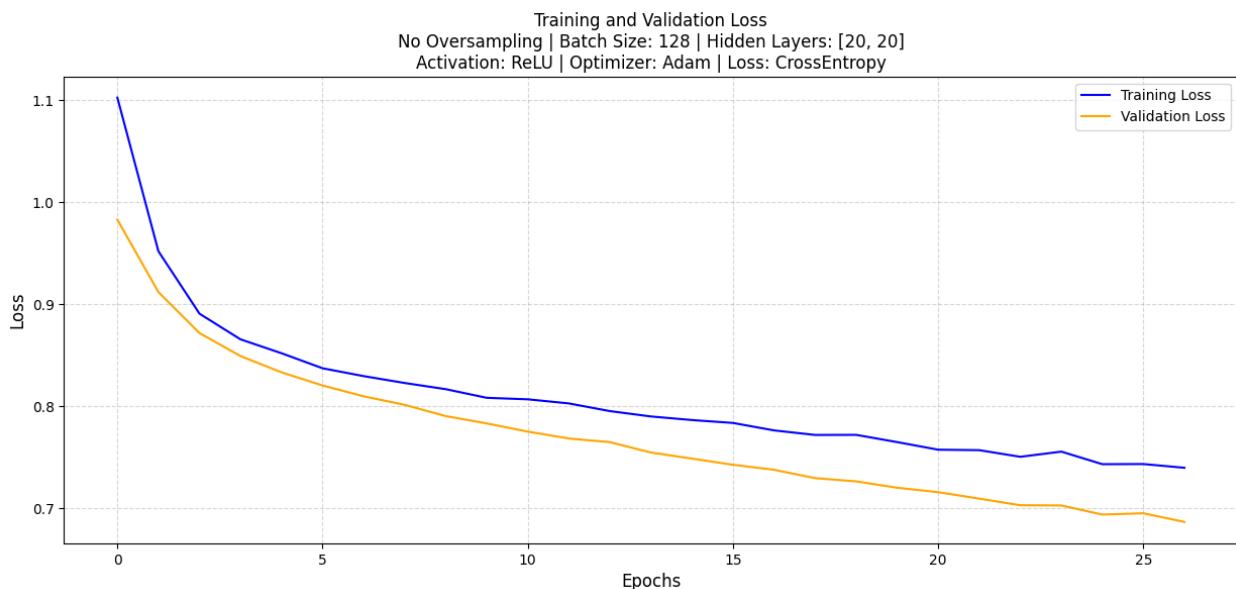
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



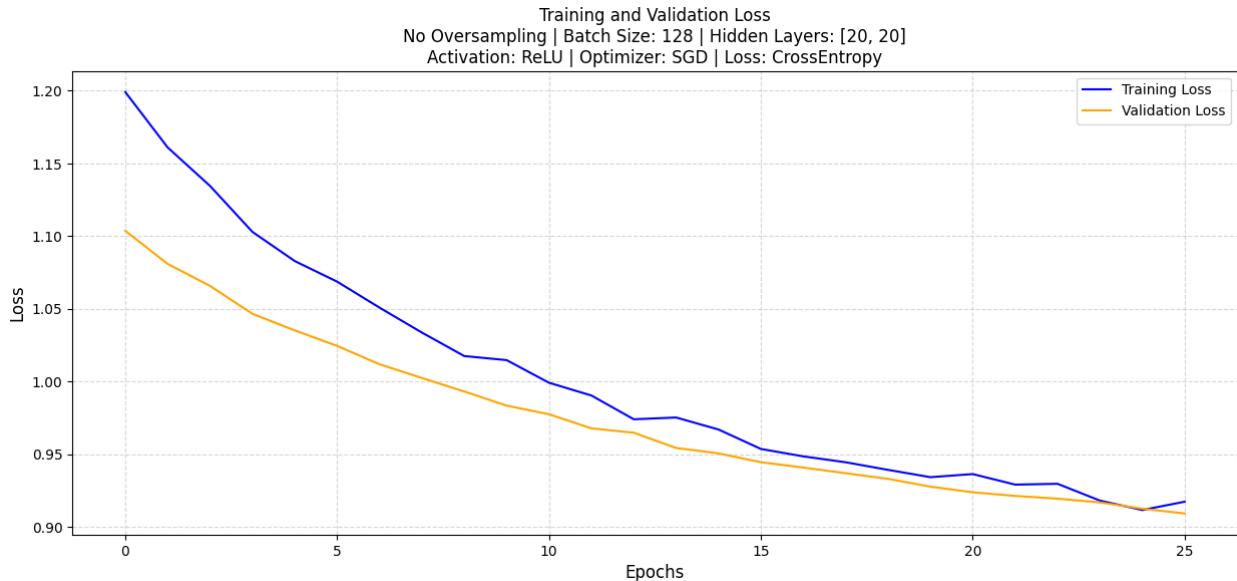
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



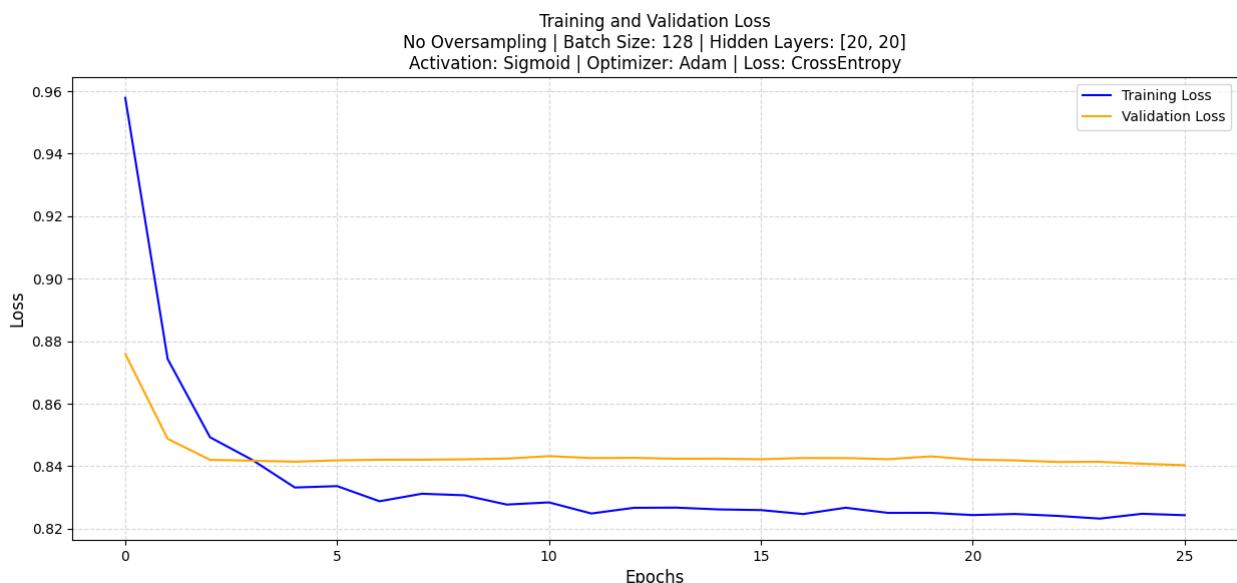
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



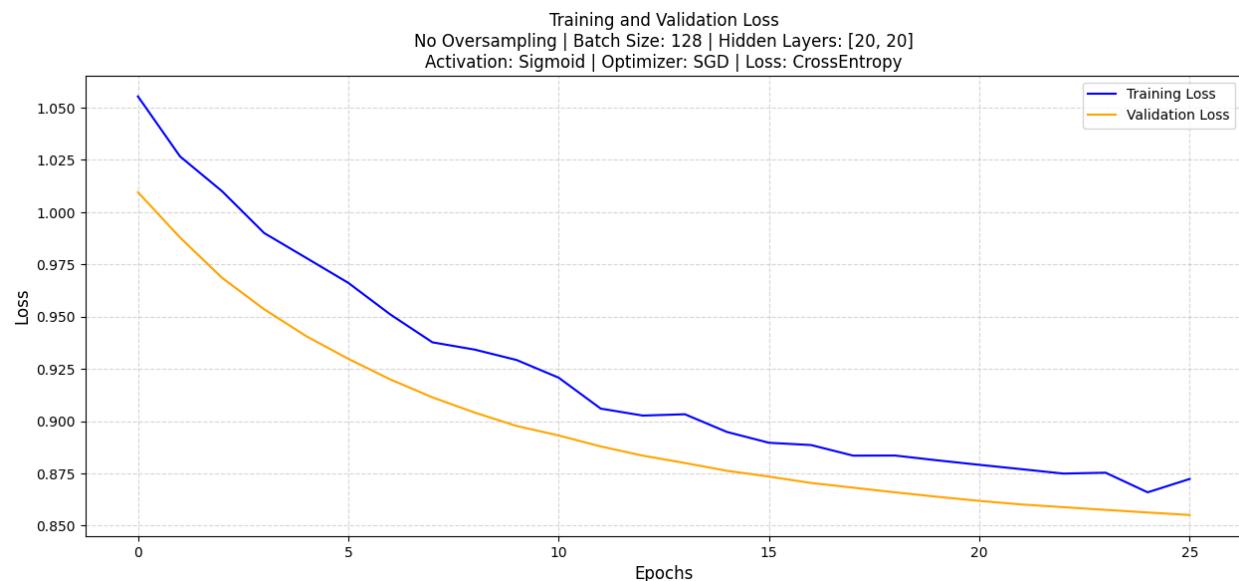
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



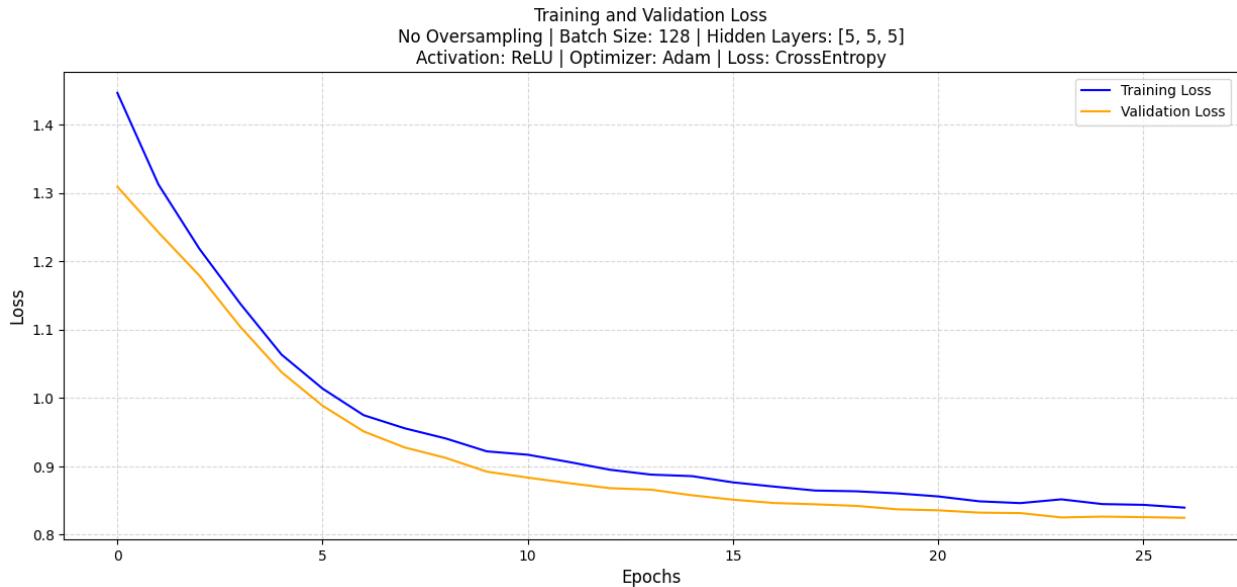
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



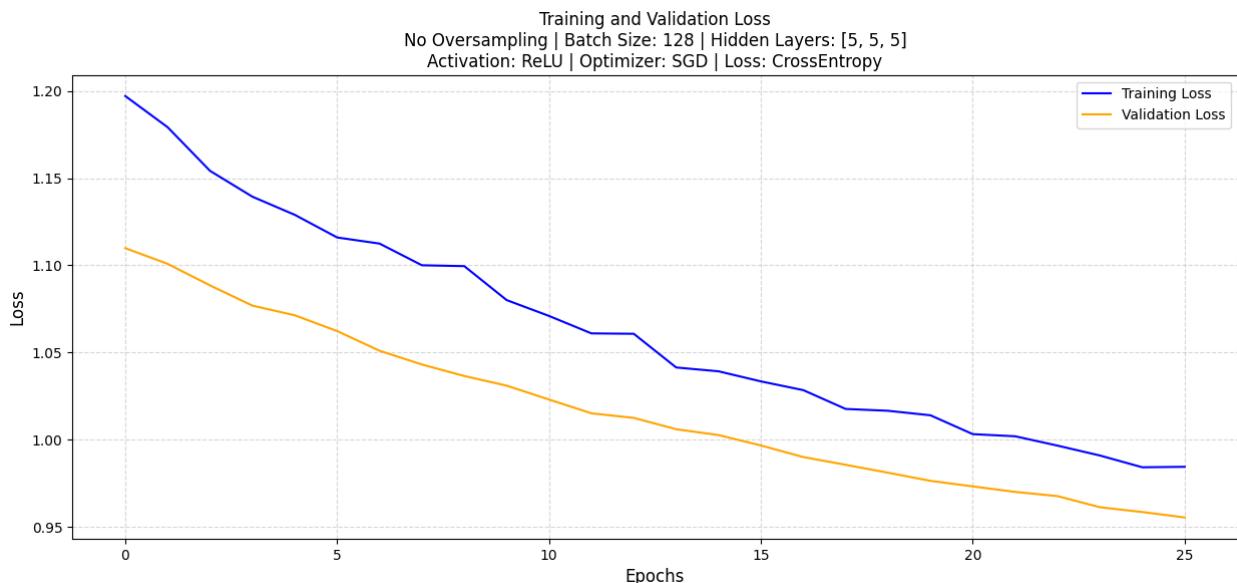
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



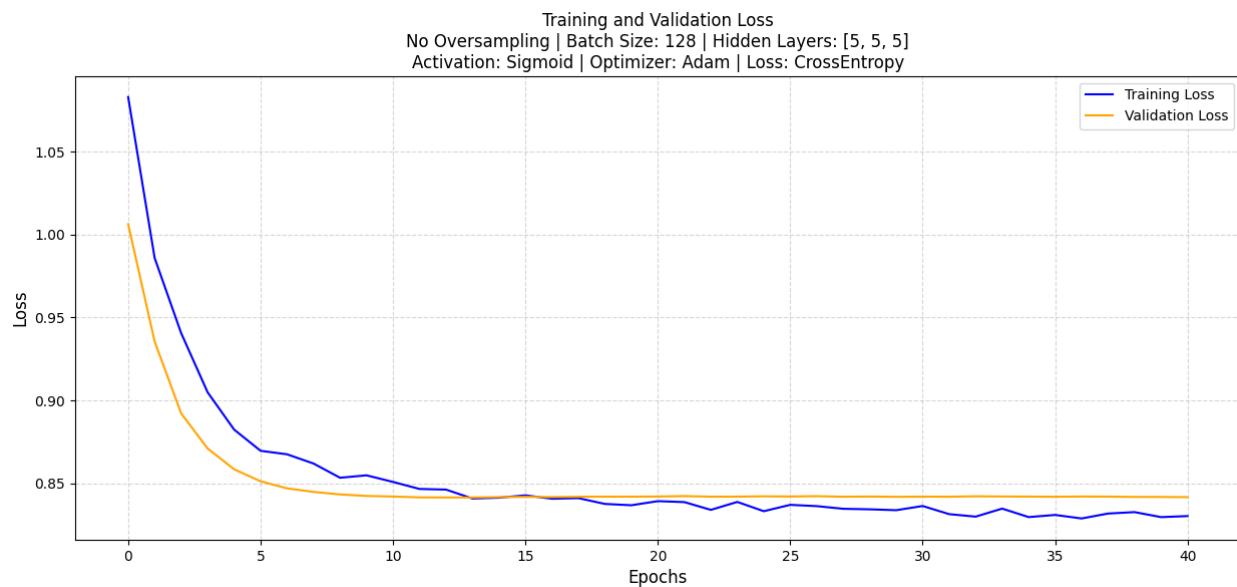
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



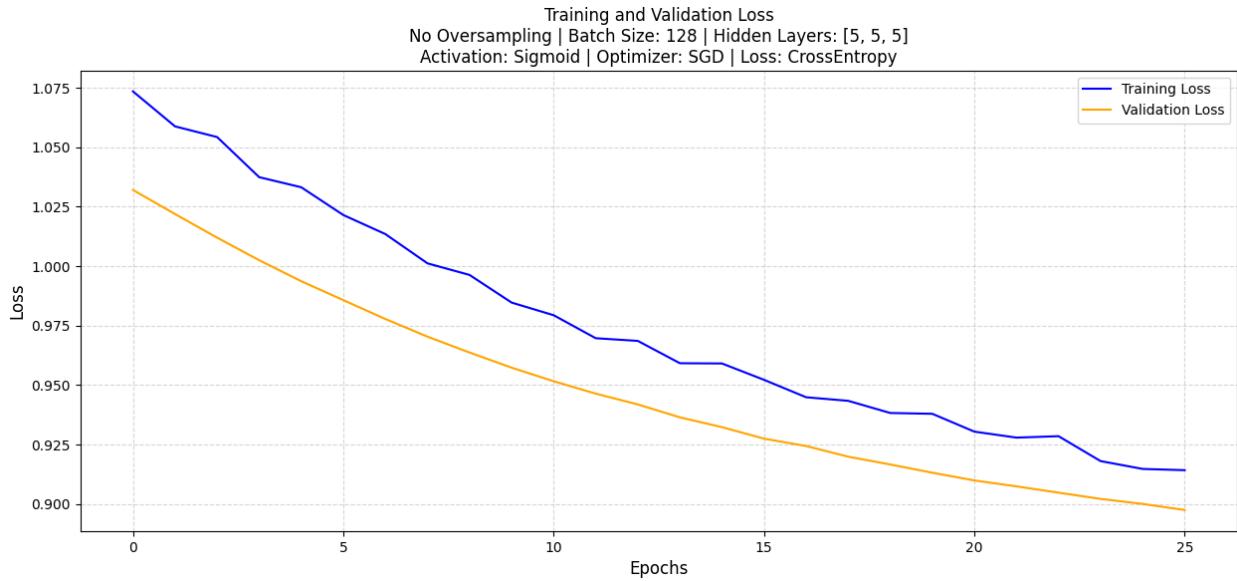
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



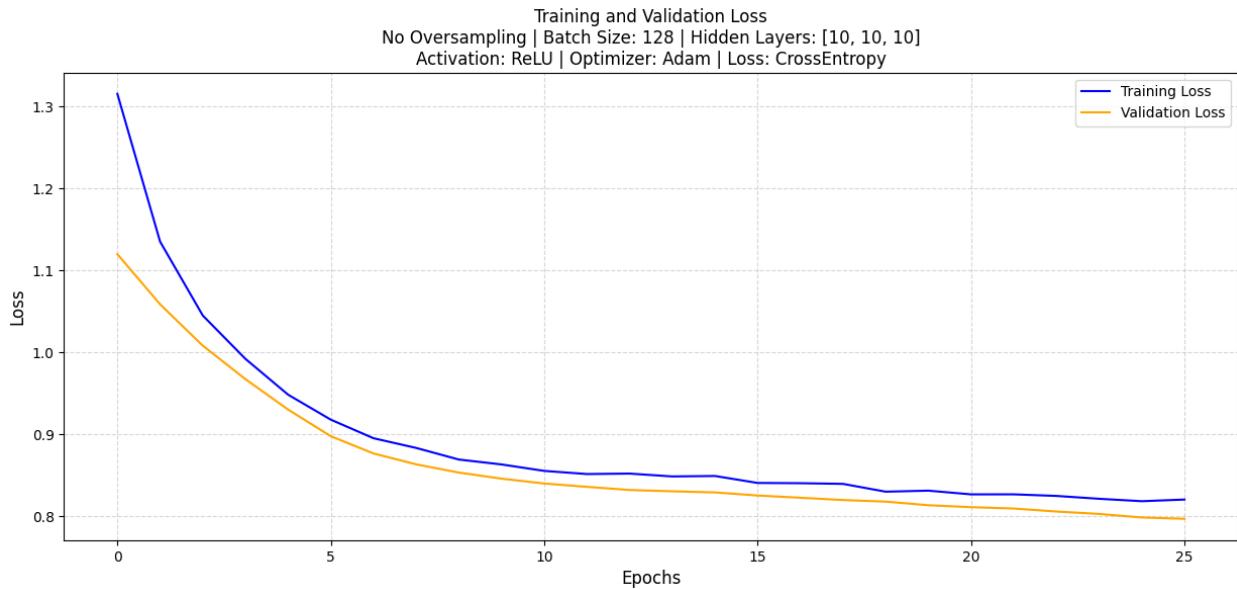
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



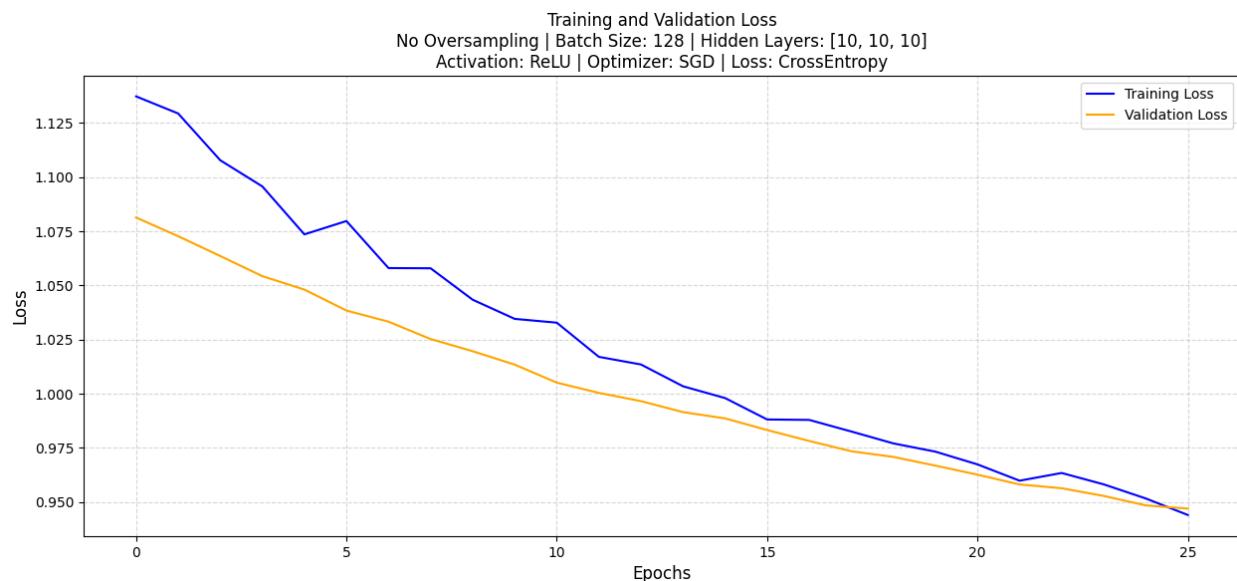
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```

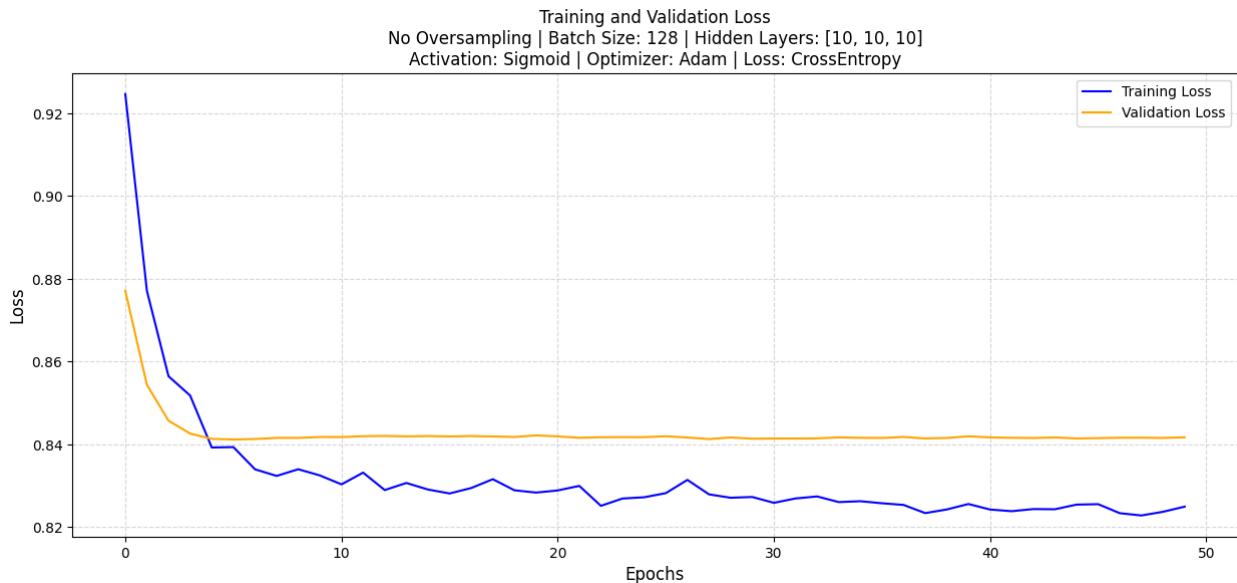


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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```

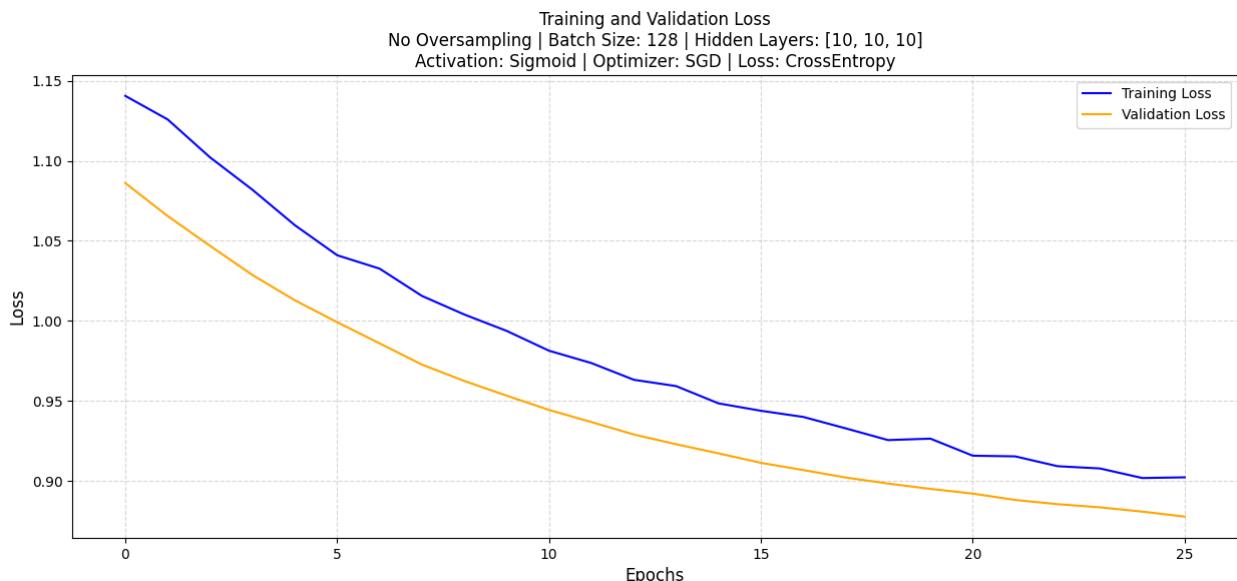


```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
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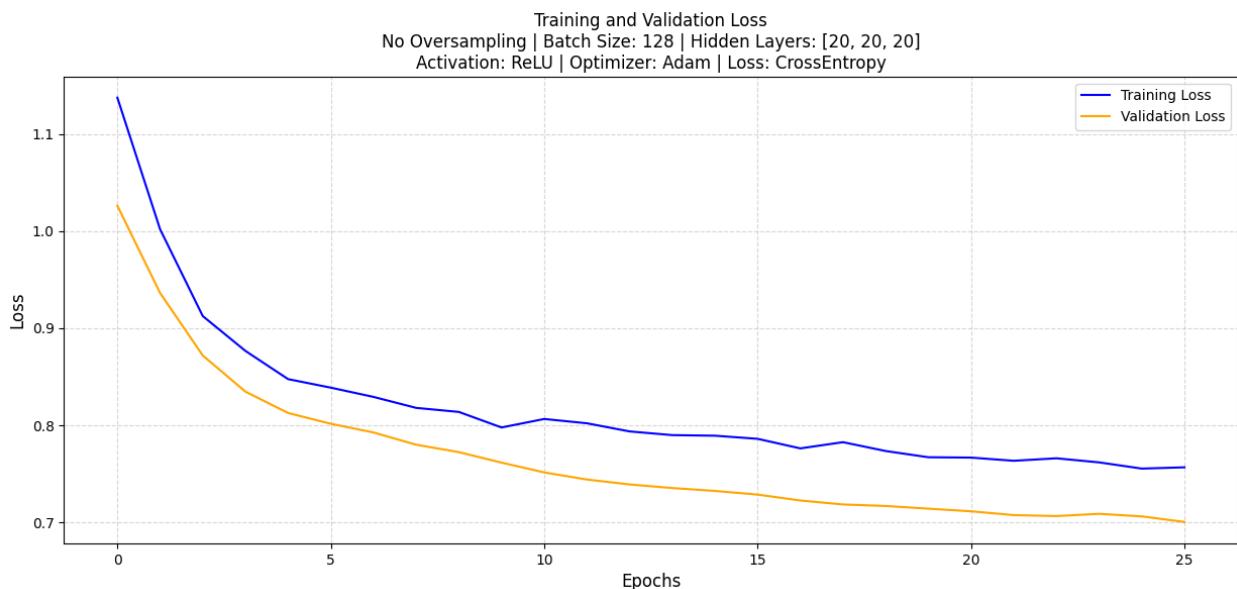
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



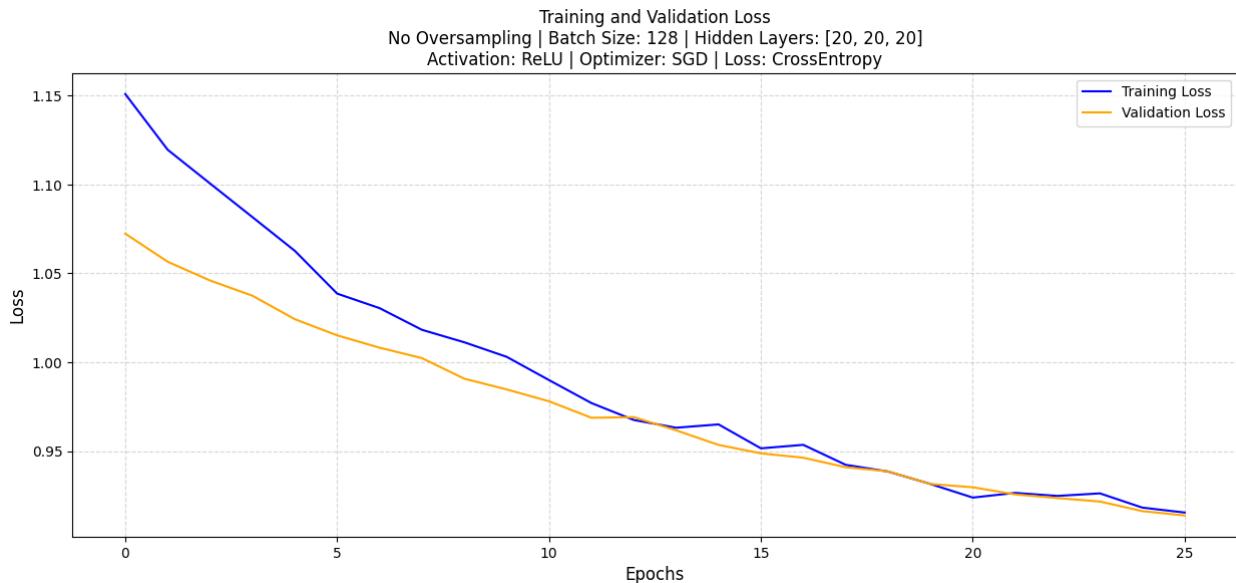
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



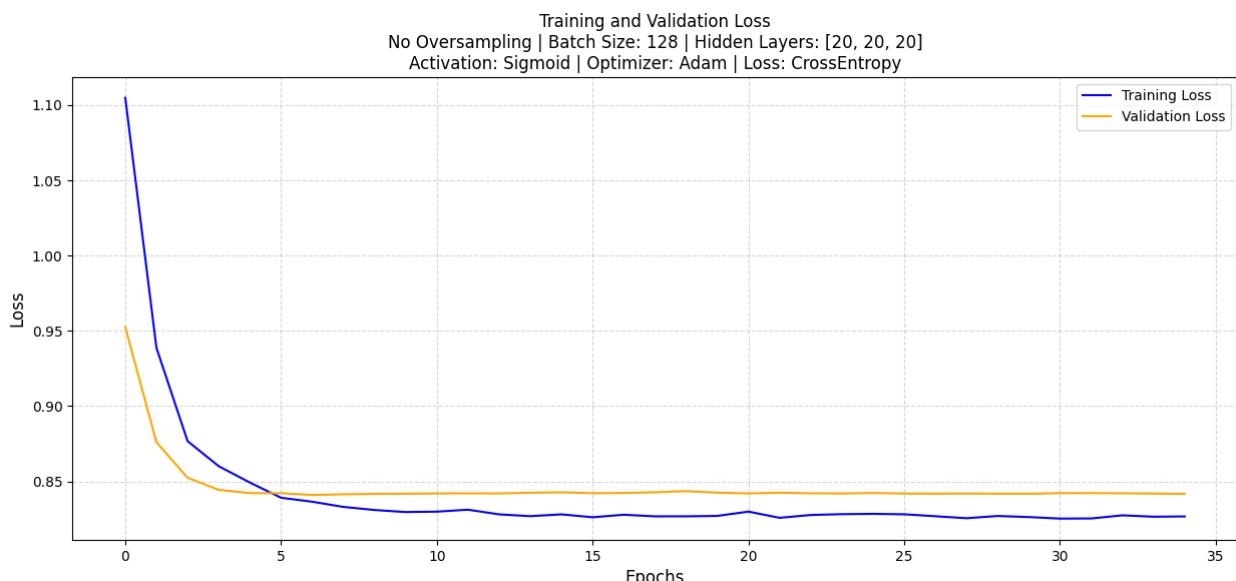
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



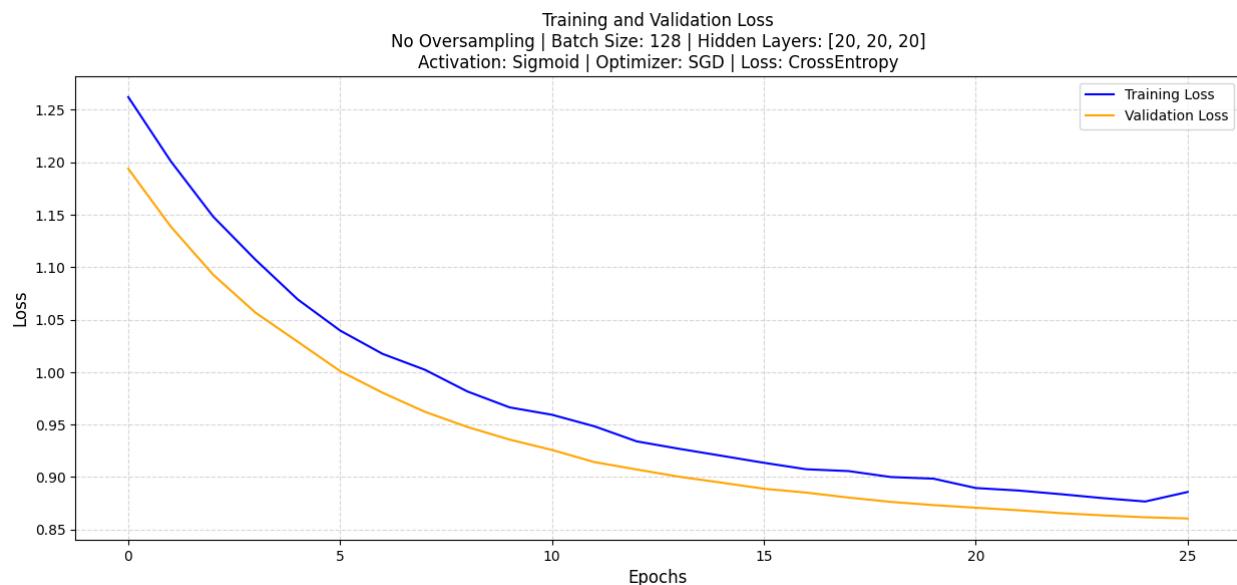
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```

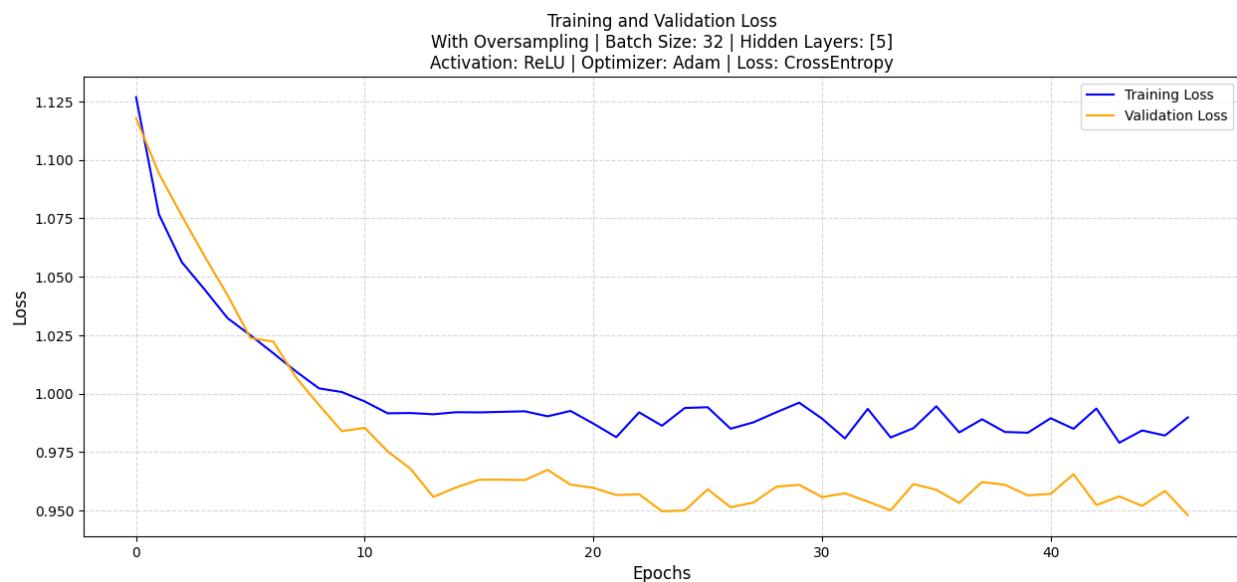


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```

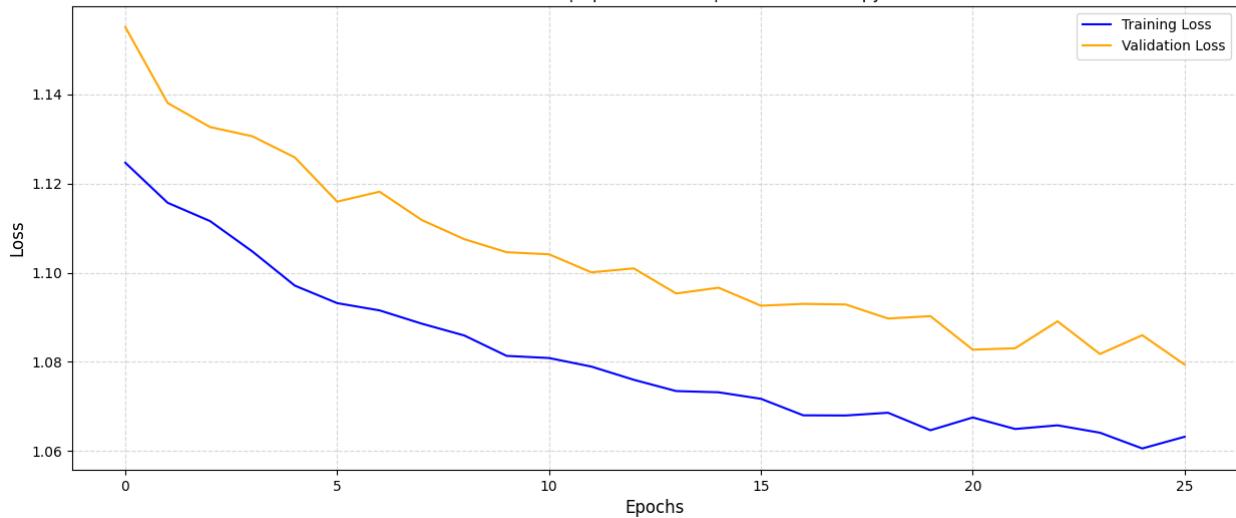


Early stopping triggered



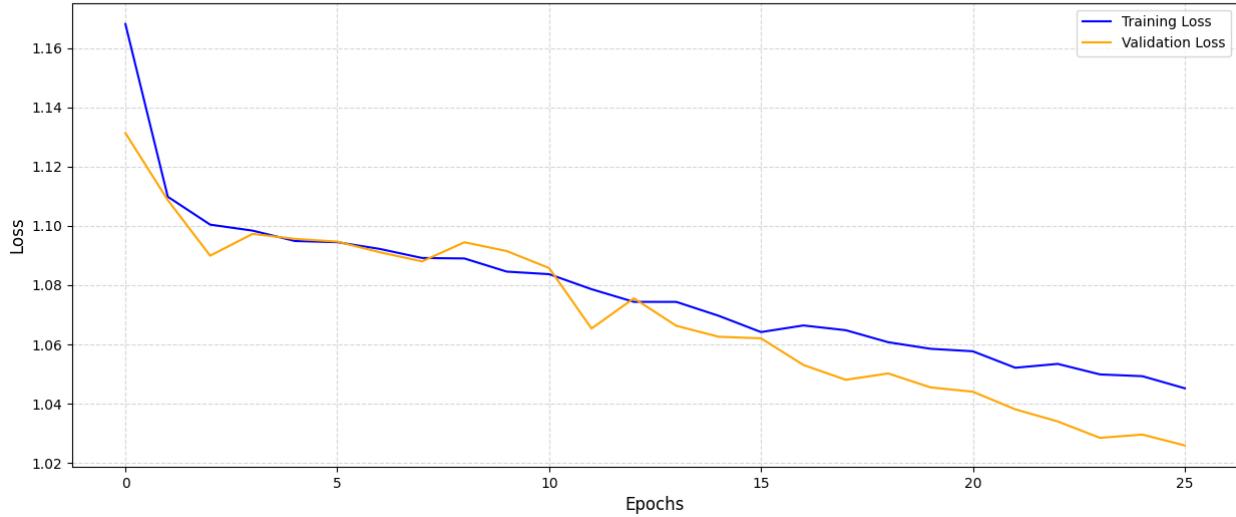
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

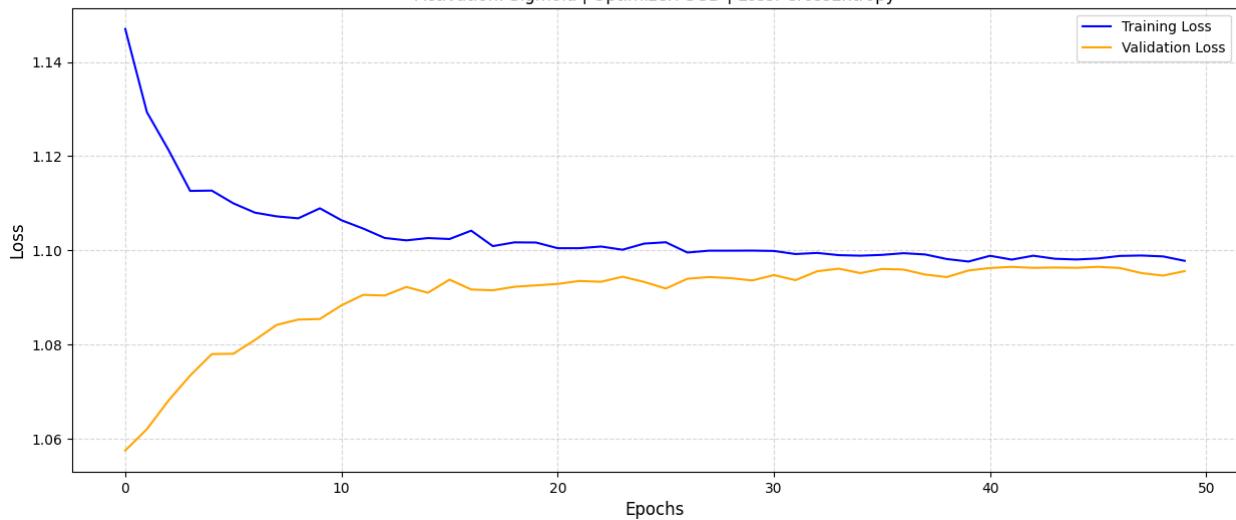


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy

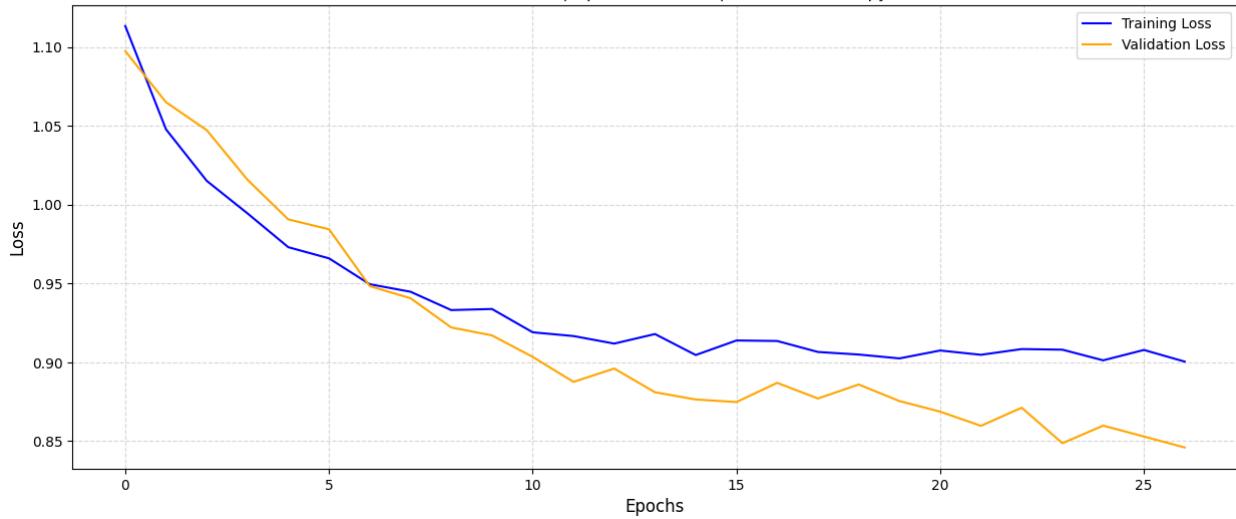


Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



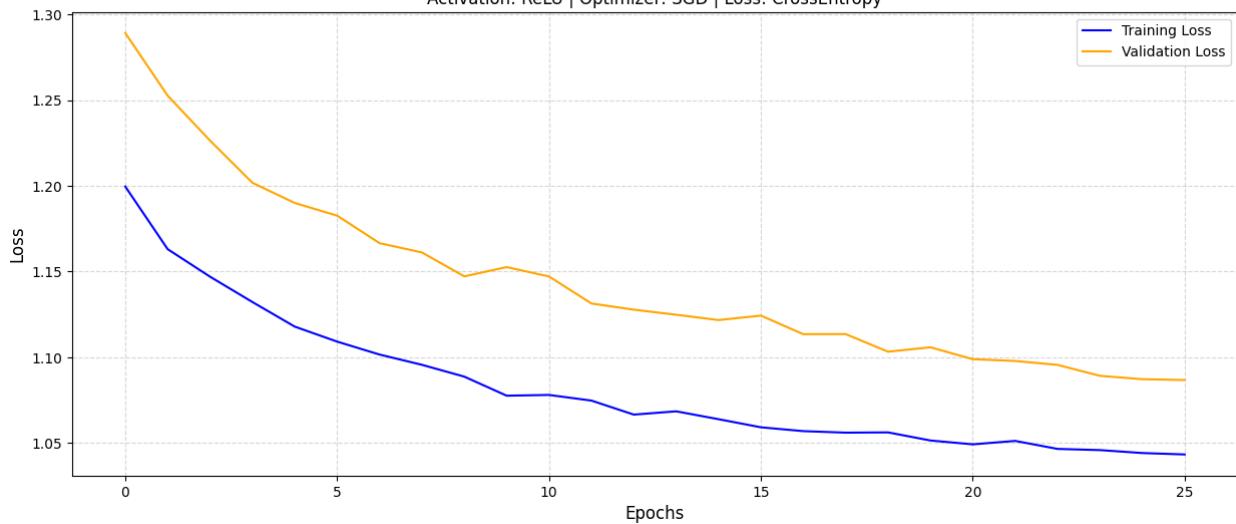
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



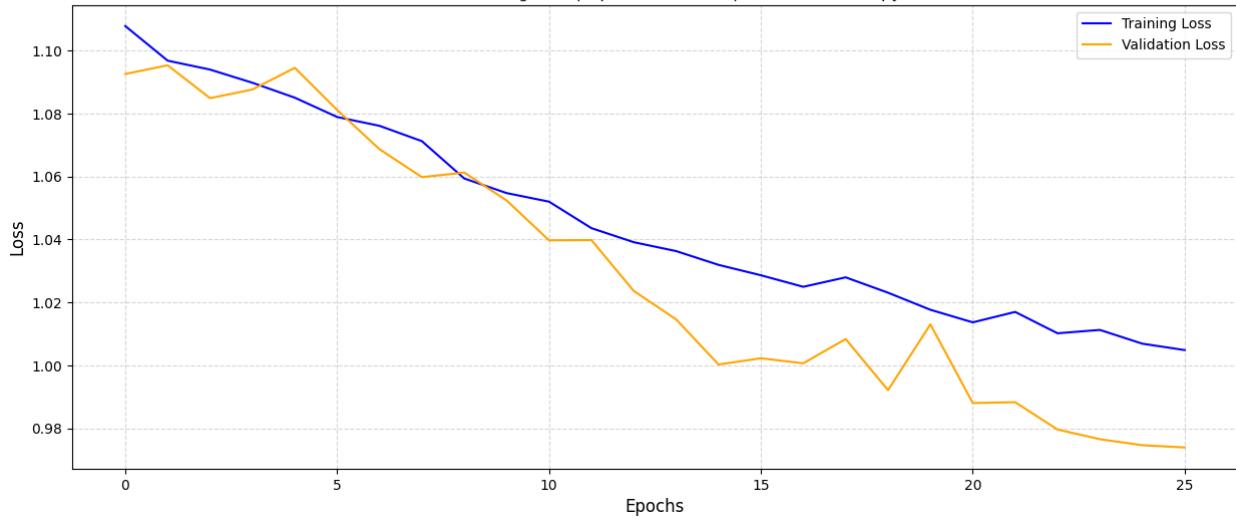
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



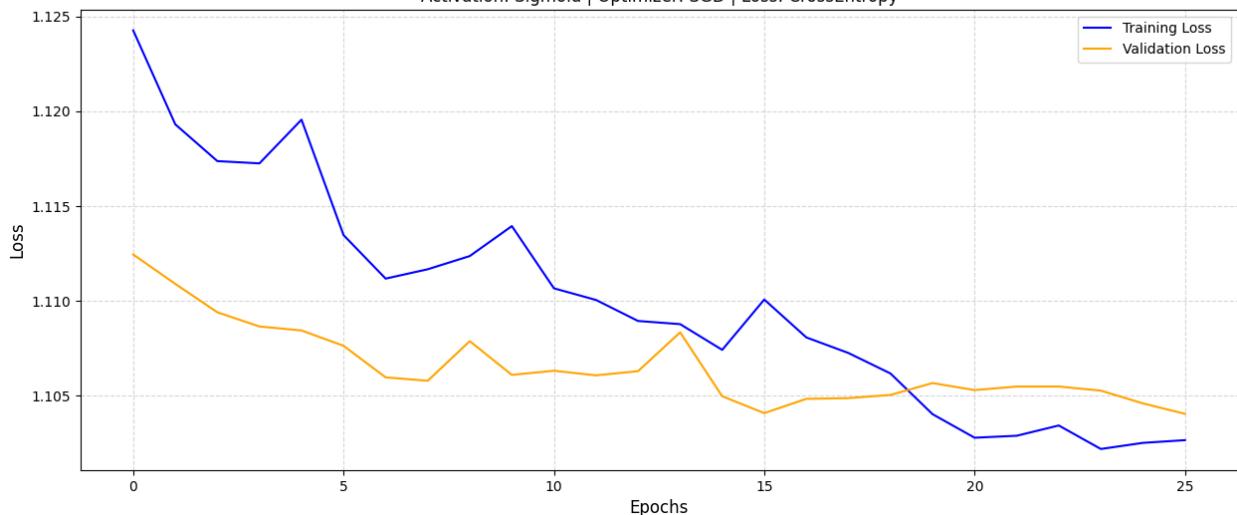
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



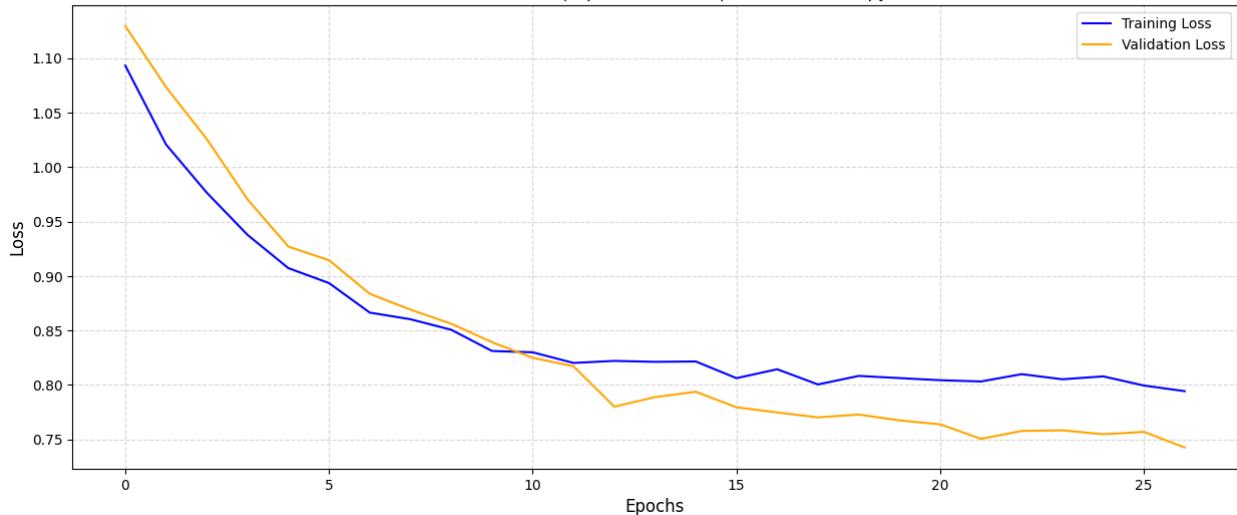
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

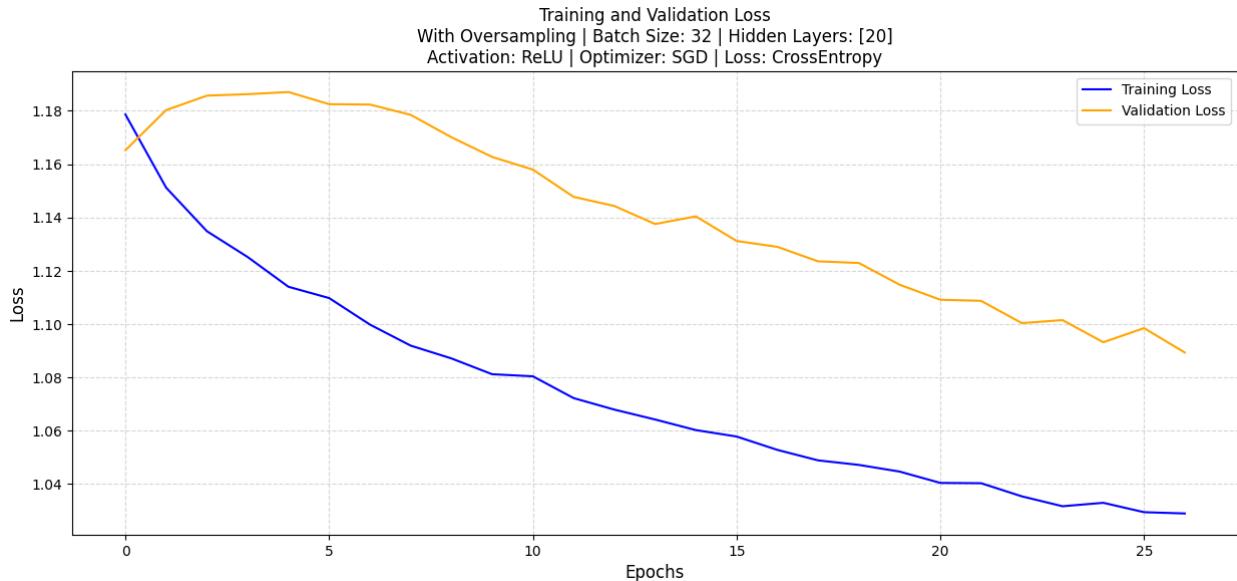


Early stopping triggered

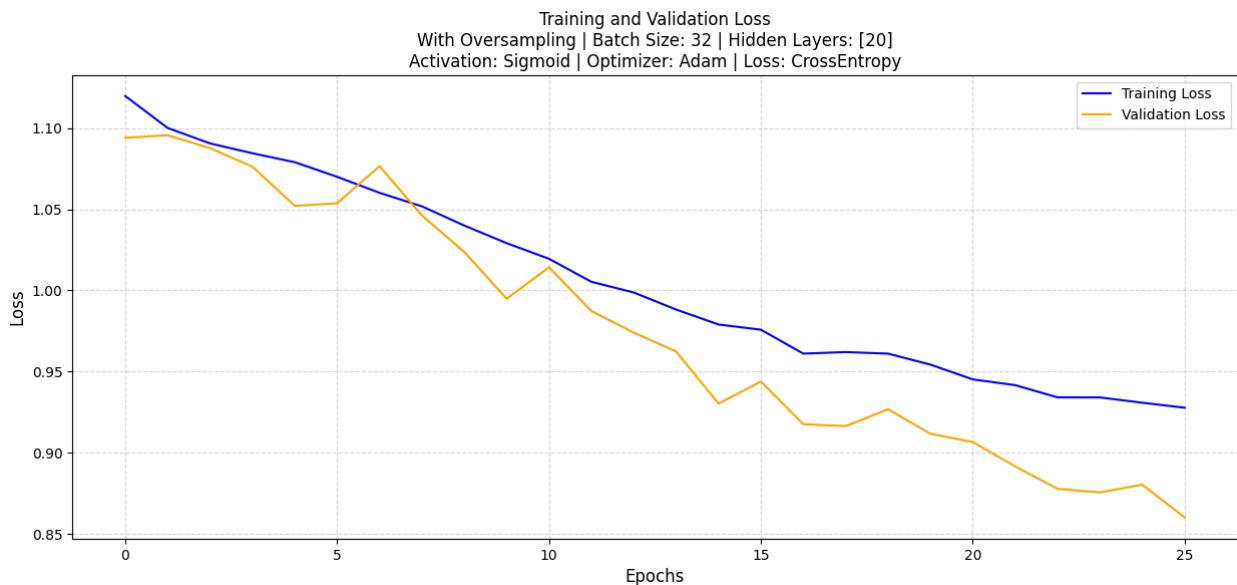
Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



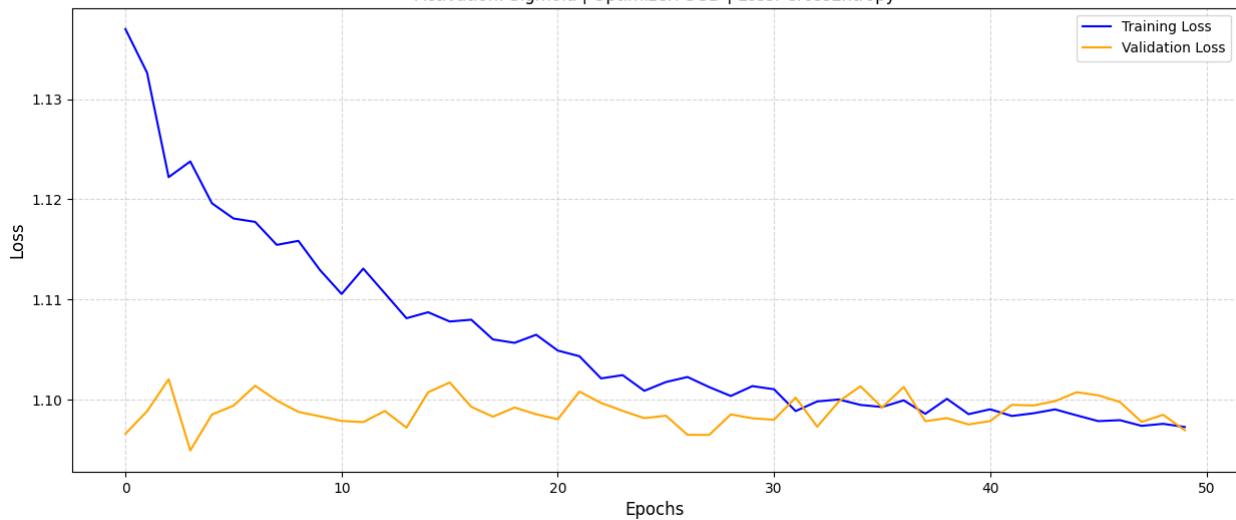
Early stopping triggered



Early stopping triggered

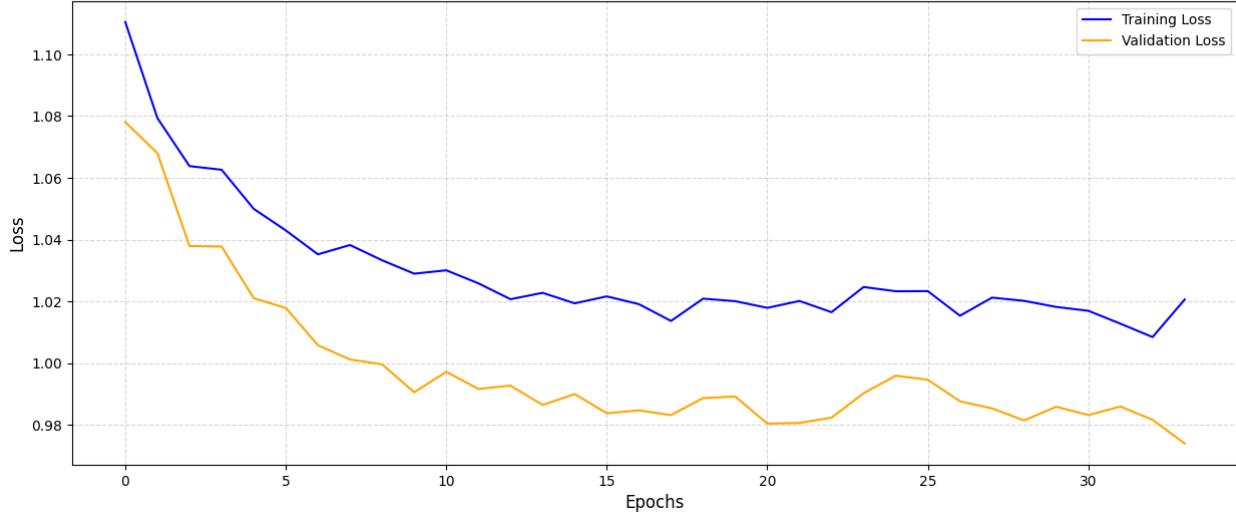


Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

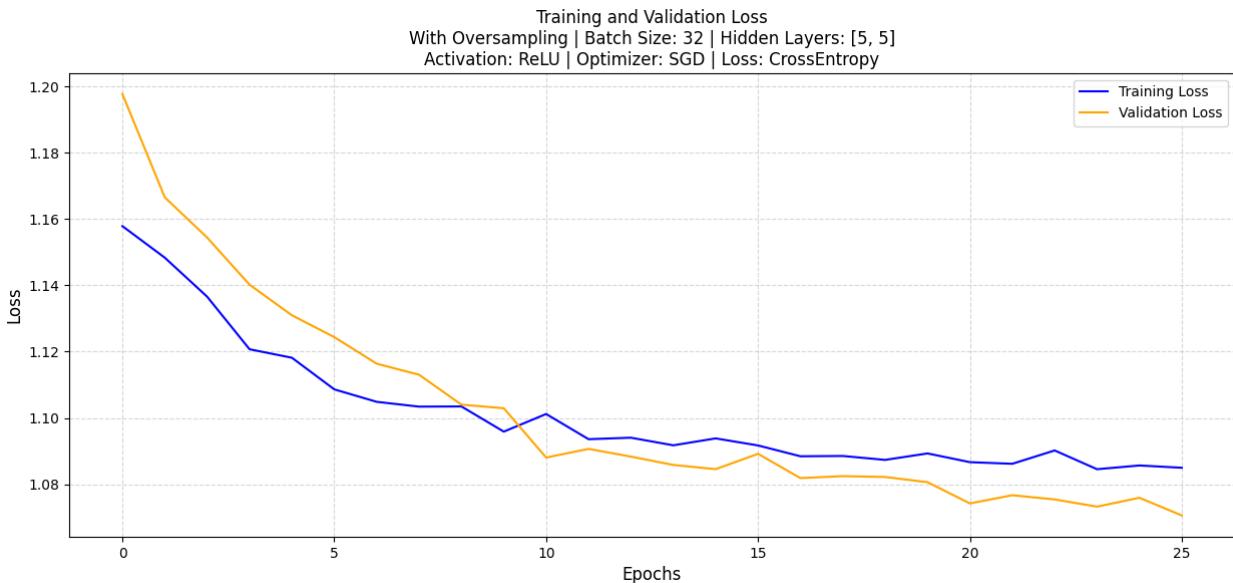


Early stopping triggered

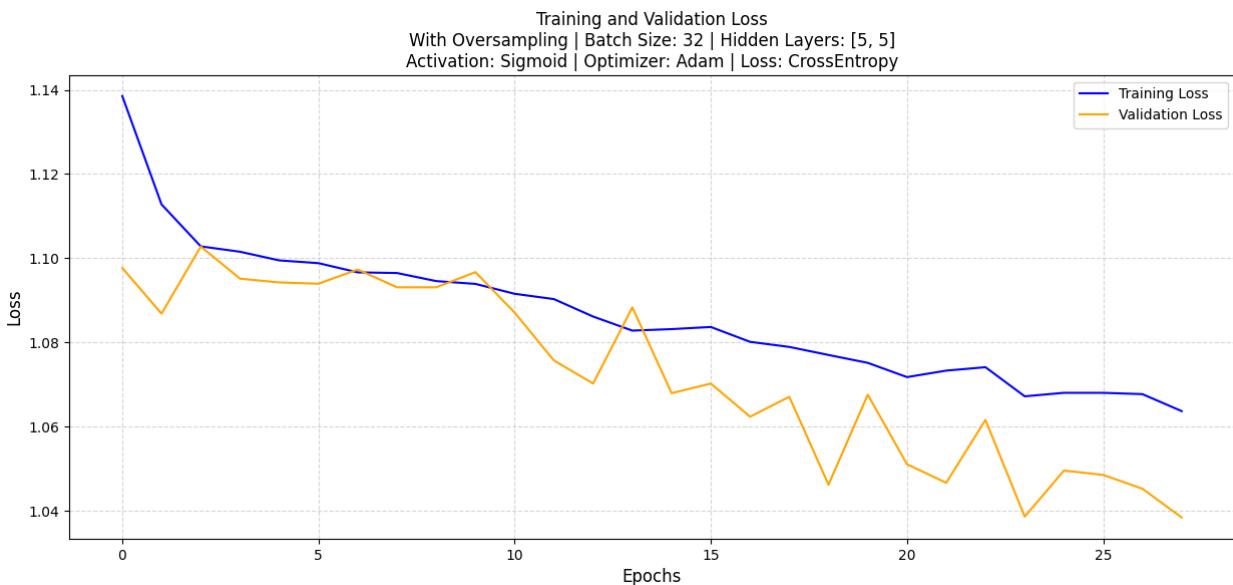
Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5, 5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



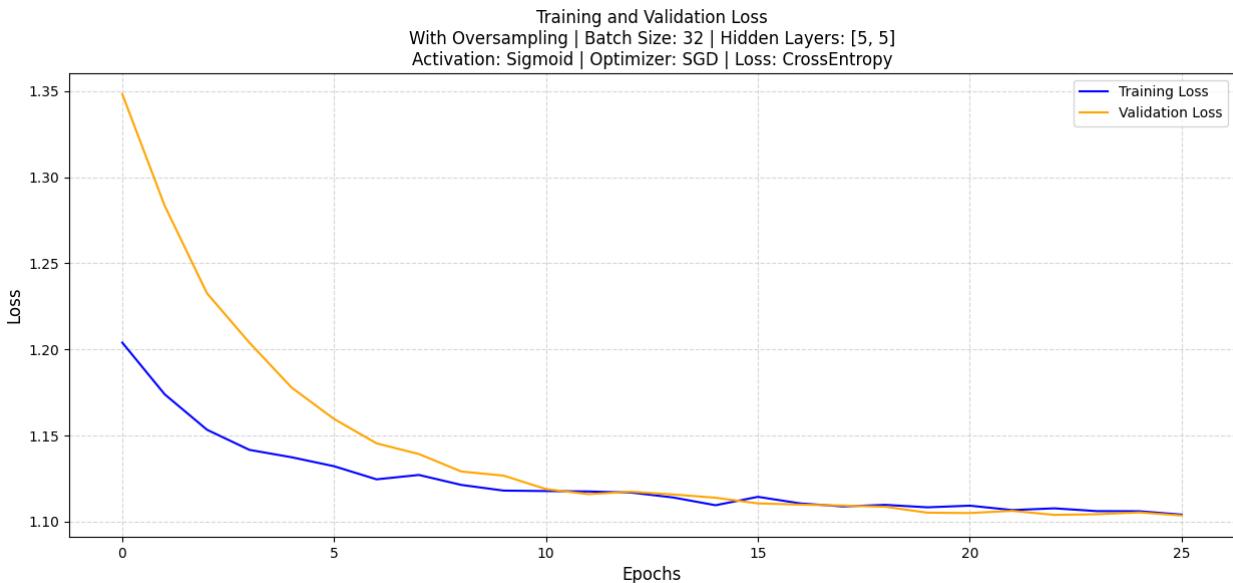
Early stopping triggered



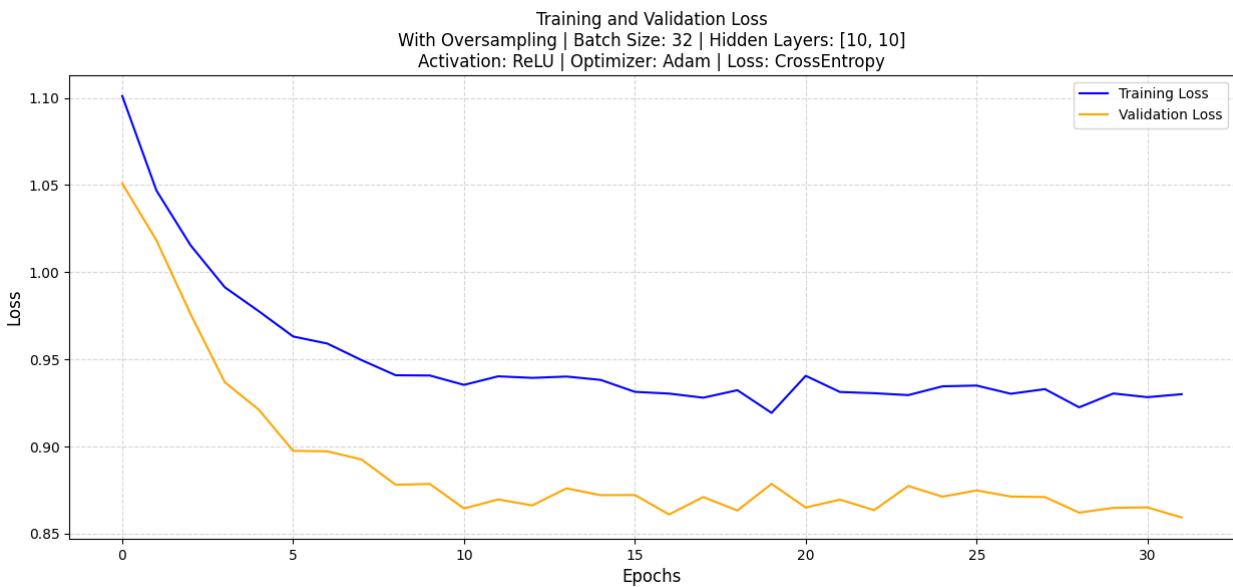
Early stopping triggered



Early stopping triggered

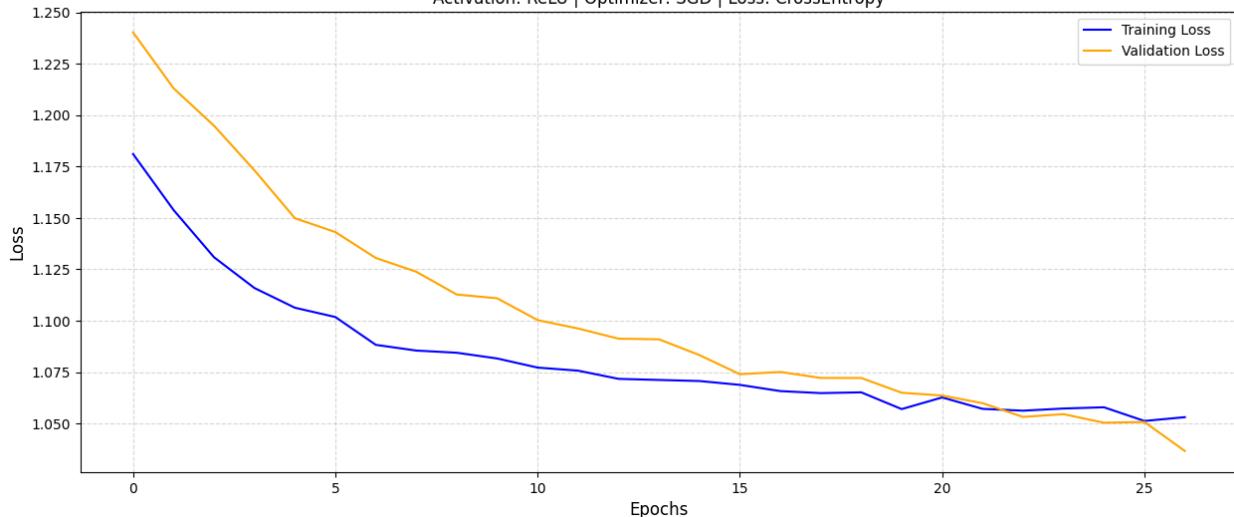


Early stopping triggered



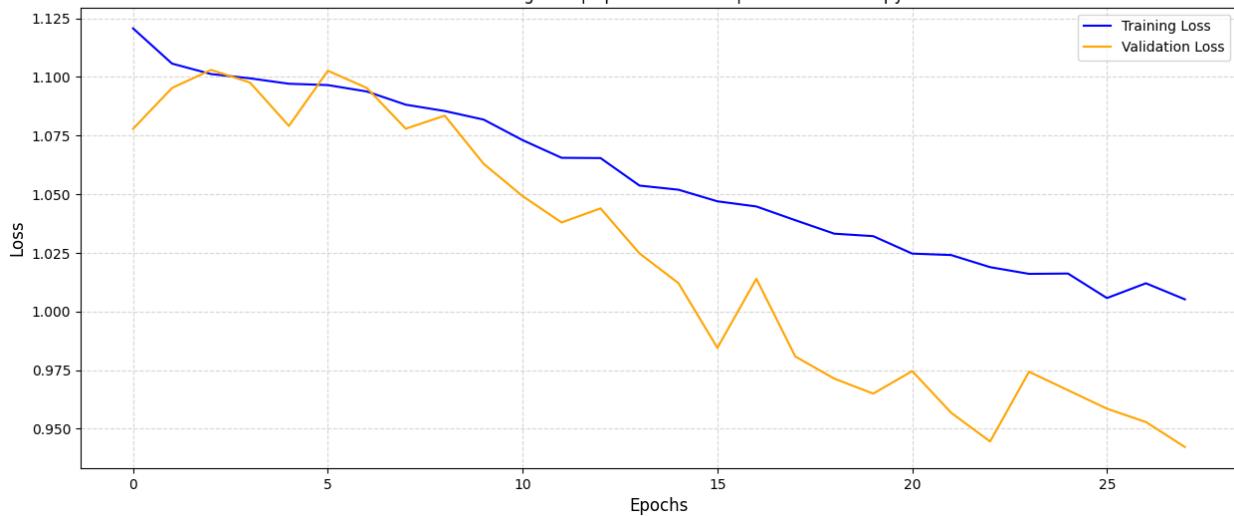
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10, 10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



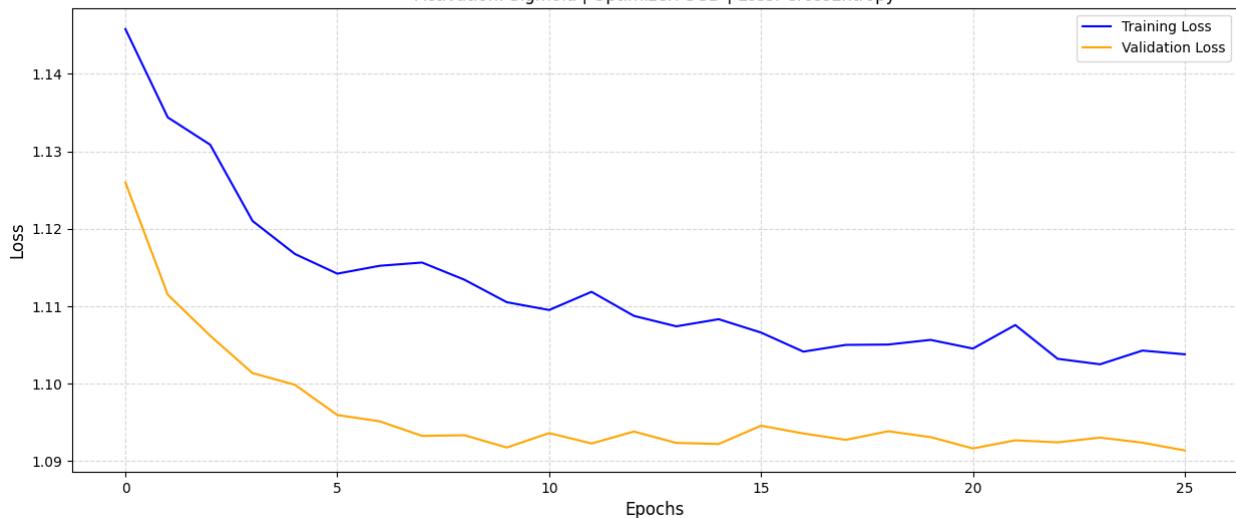
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10, 10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



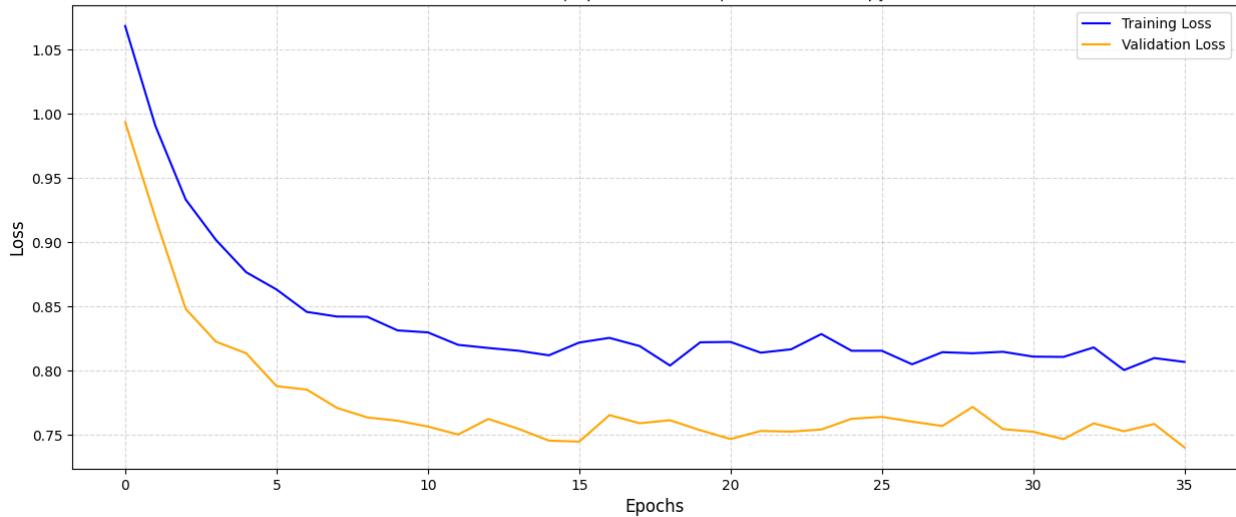
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10, 10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

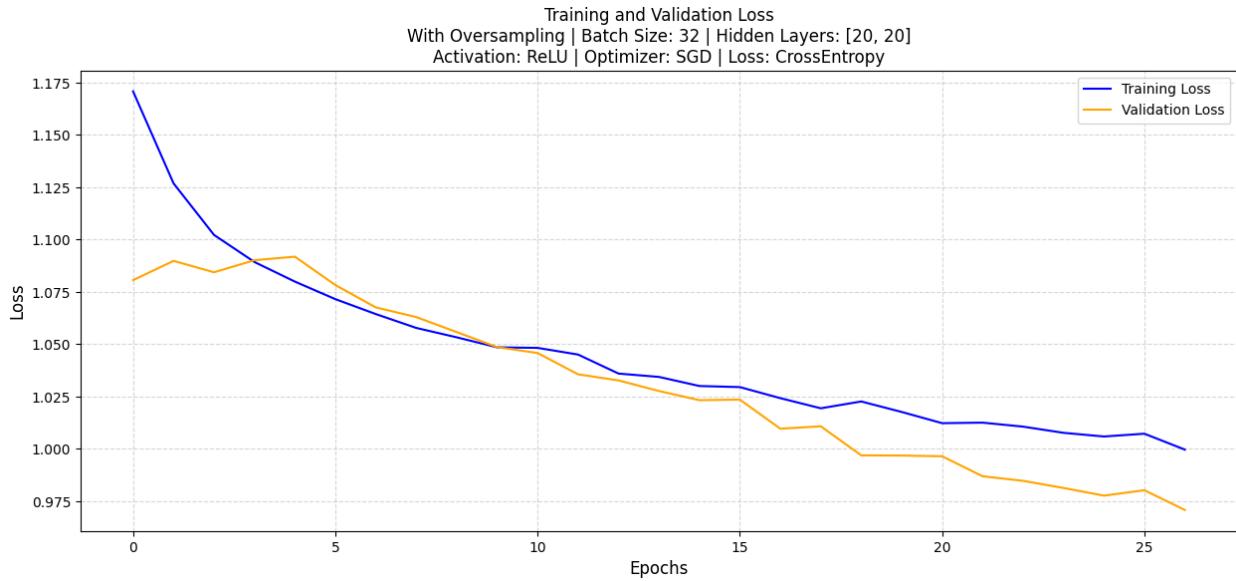


Early stopping triggered

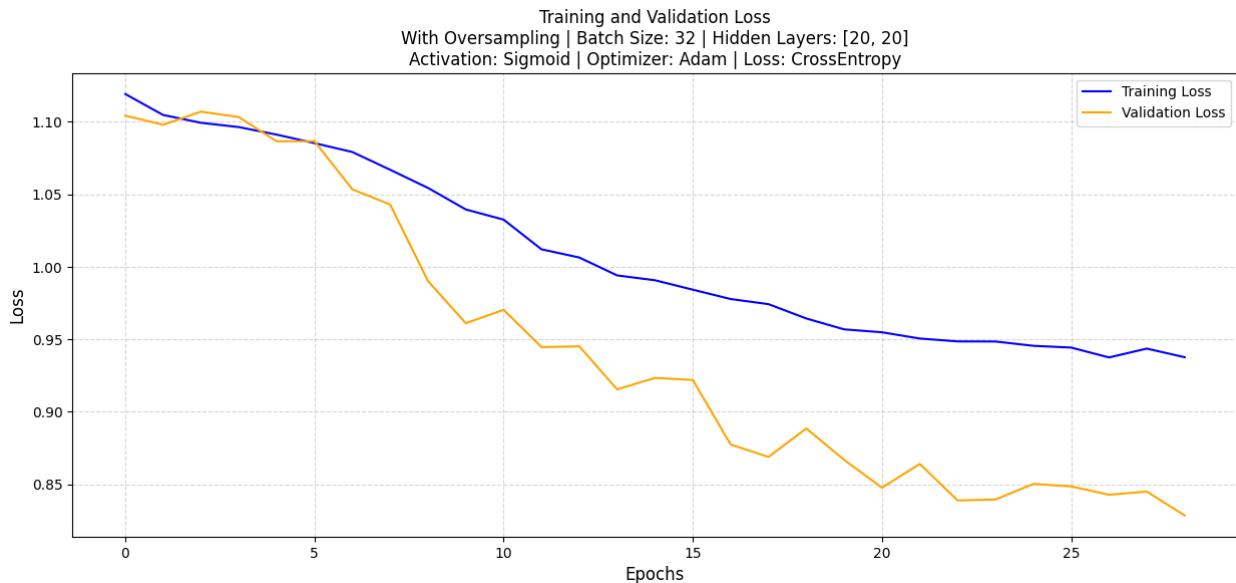
Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20, 20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered

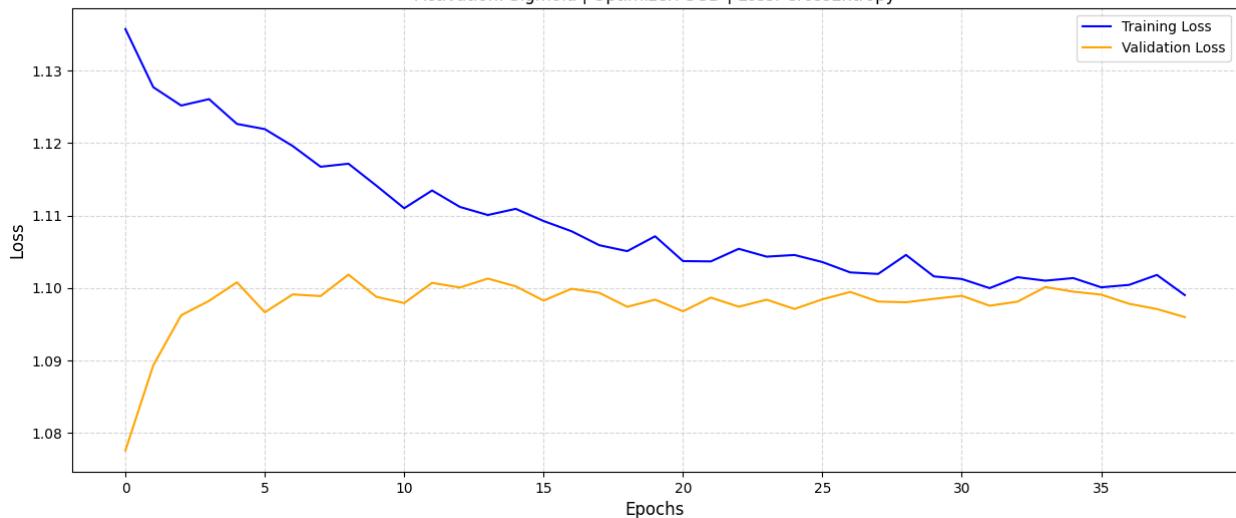


Early stopping triggered



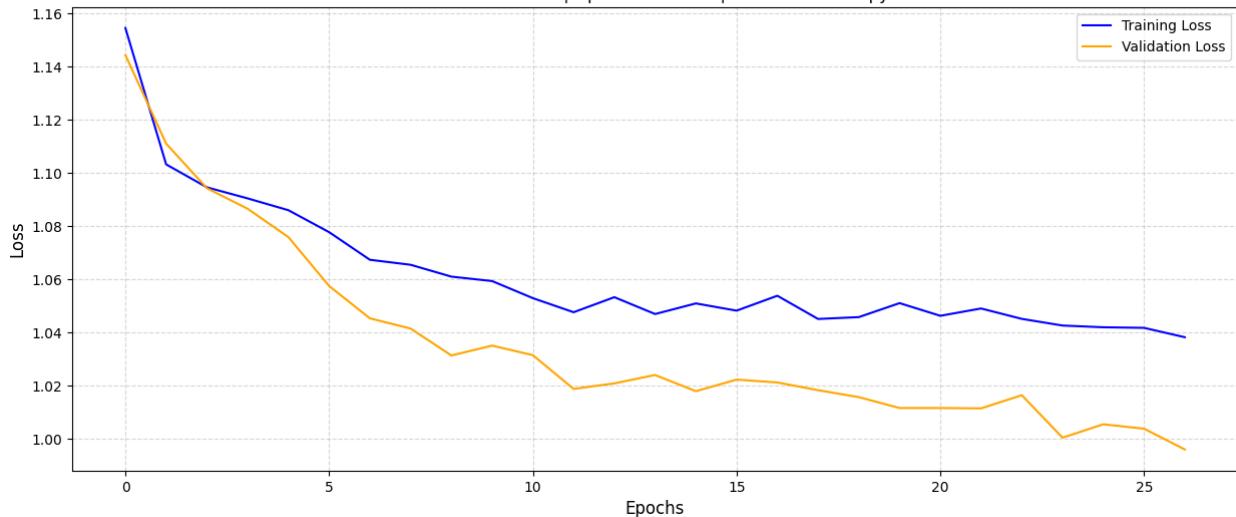
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20, 20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

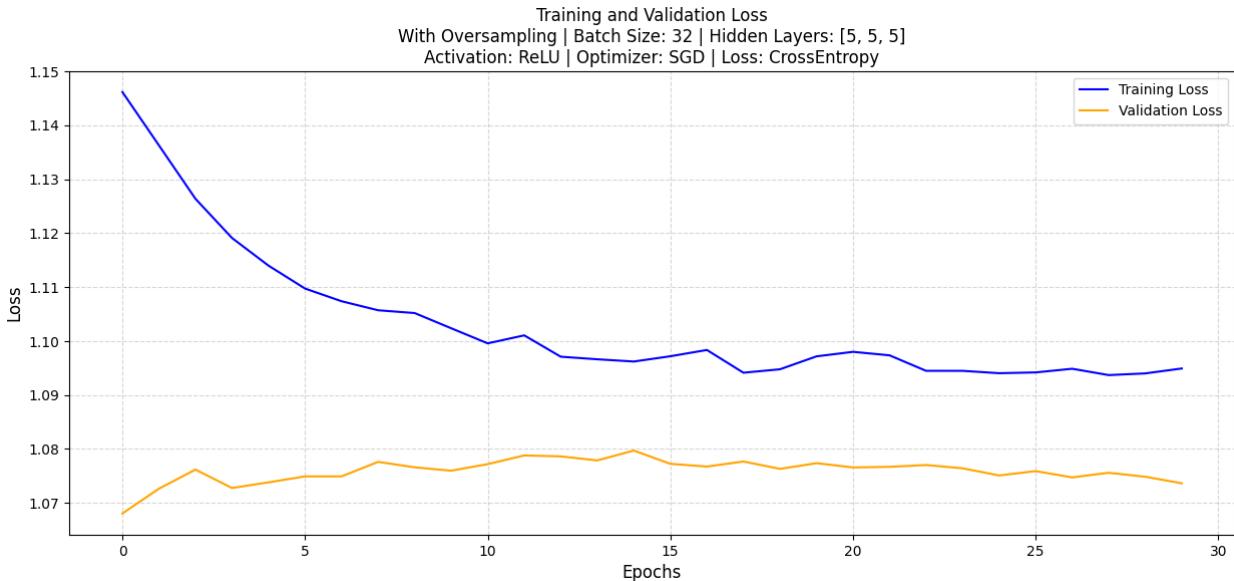


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5, 5, 5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered



Early stopping triggered

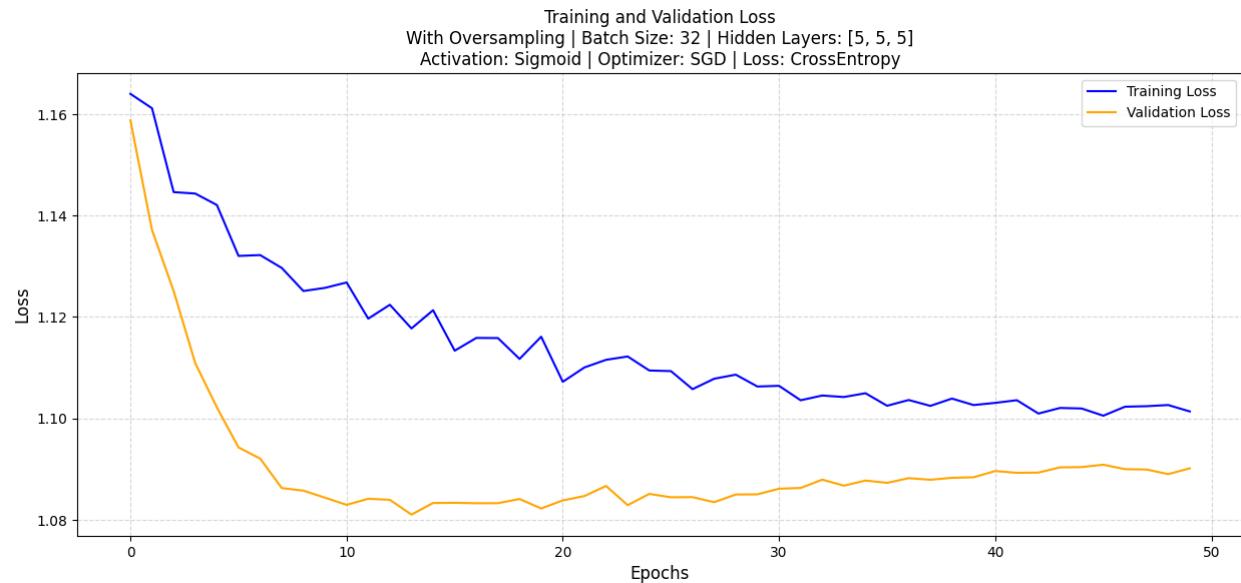
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
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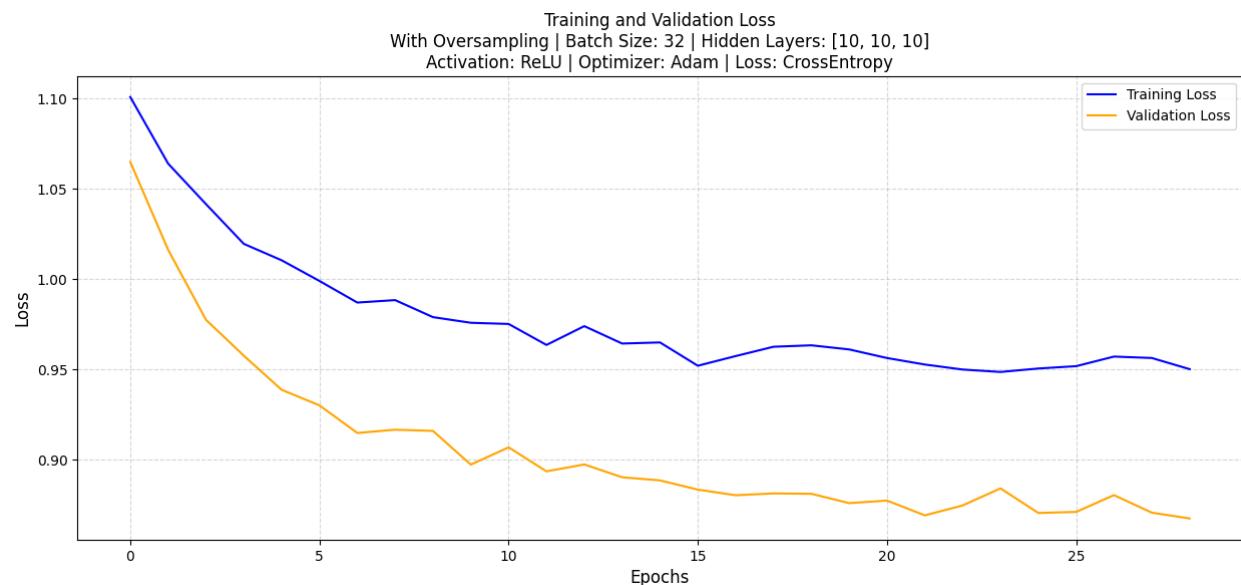
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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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```
in labels with no predicted samples. Use `zero_division` parameter to  
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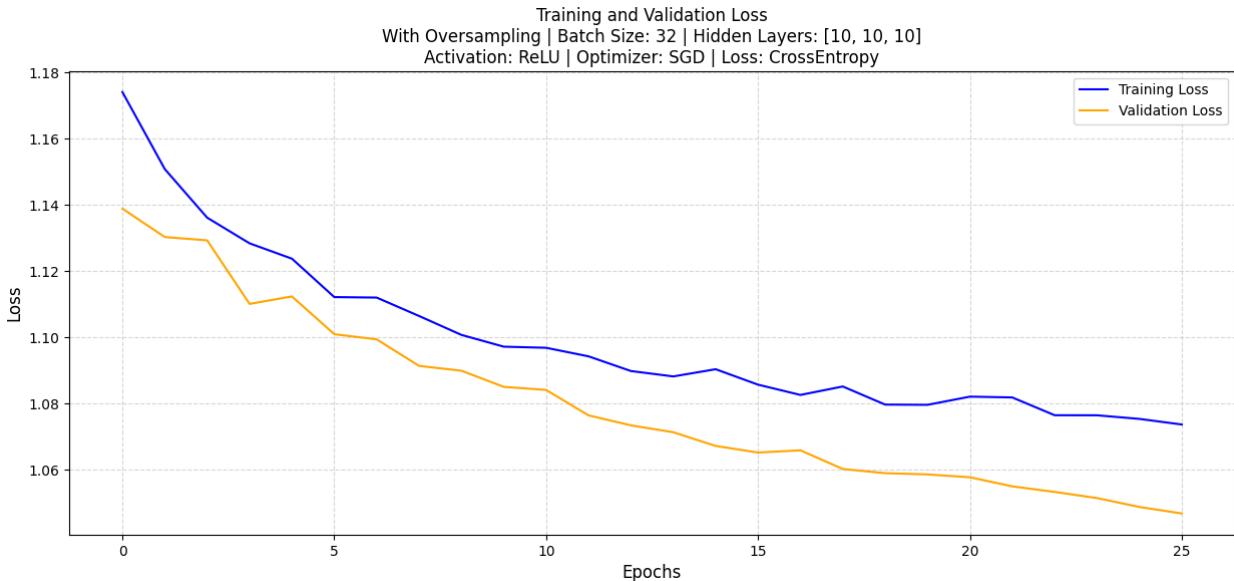
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_warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



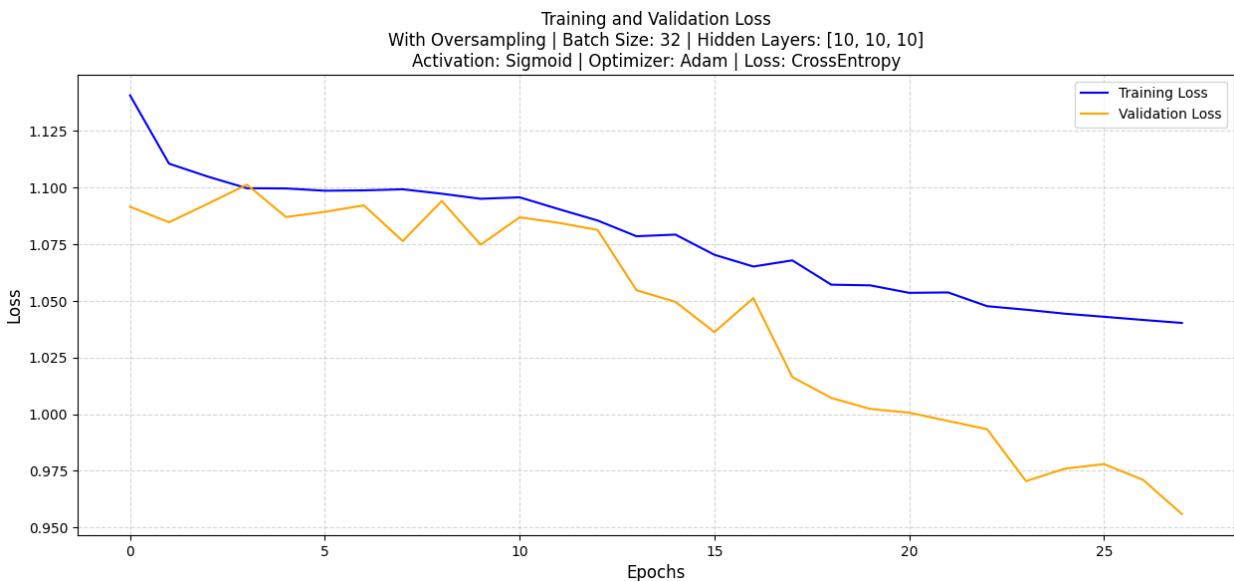
Early stopping triggered



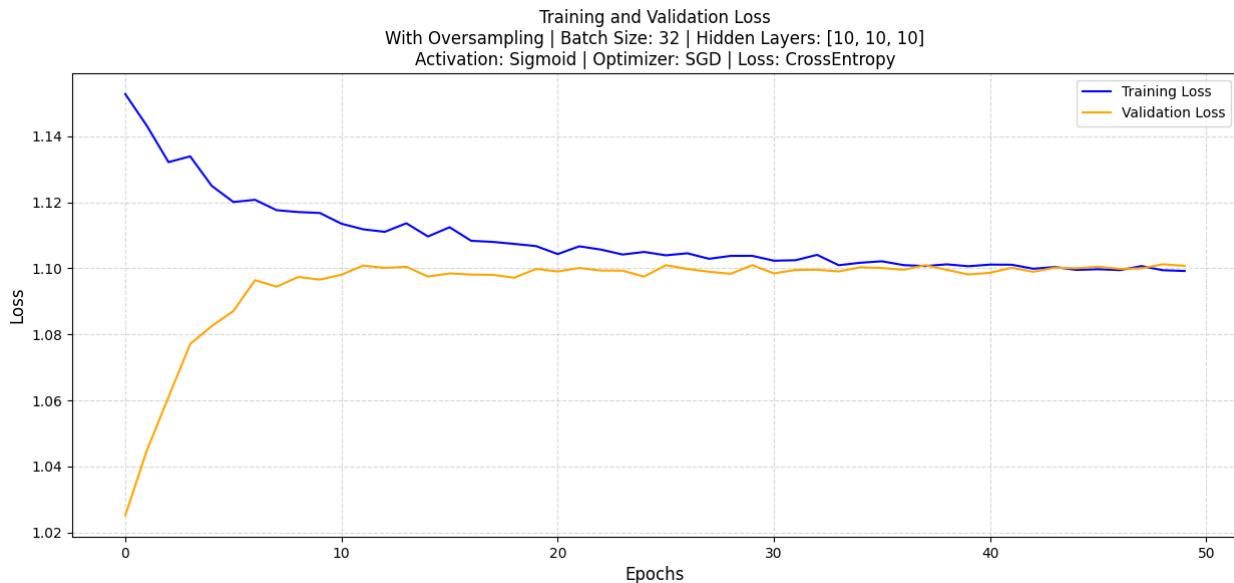
Early stopping triggered



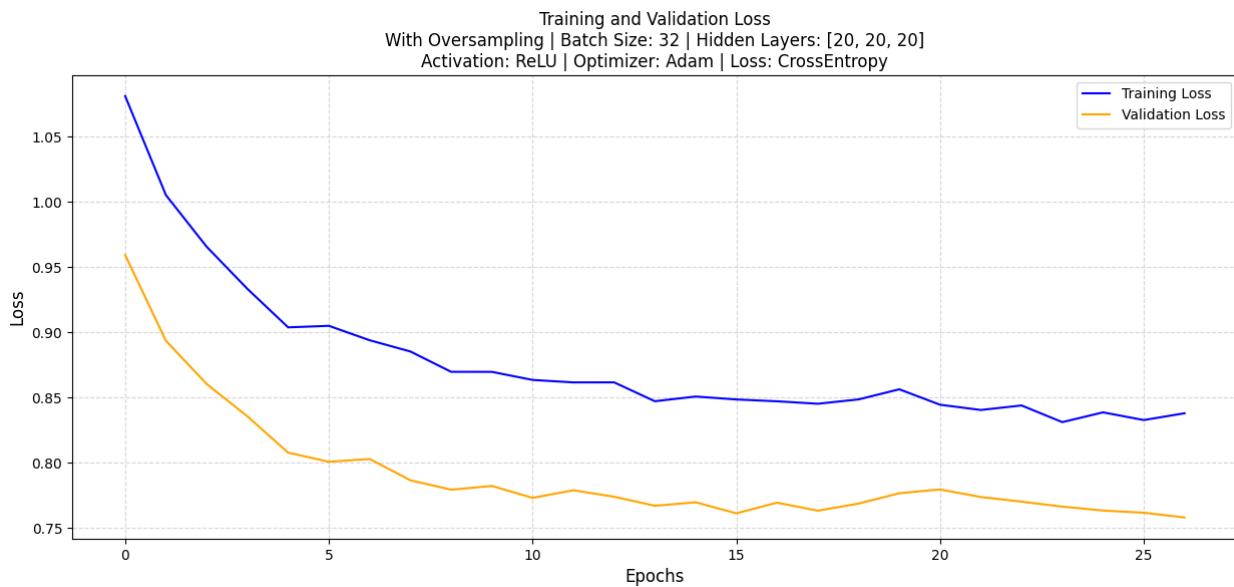
Early stopping triggered



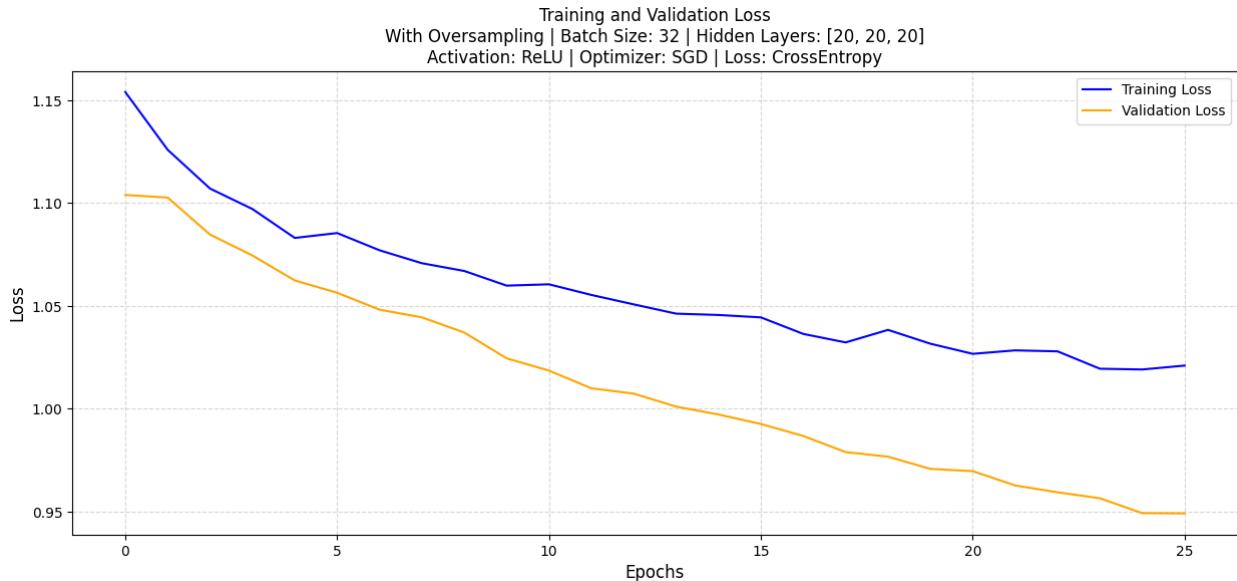
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



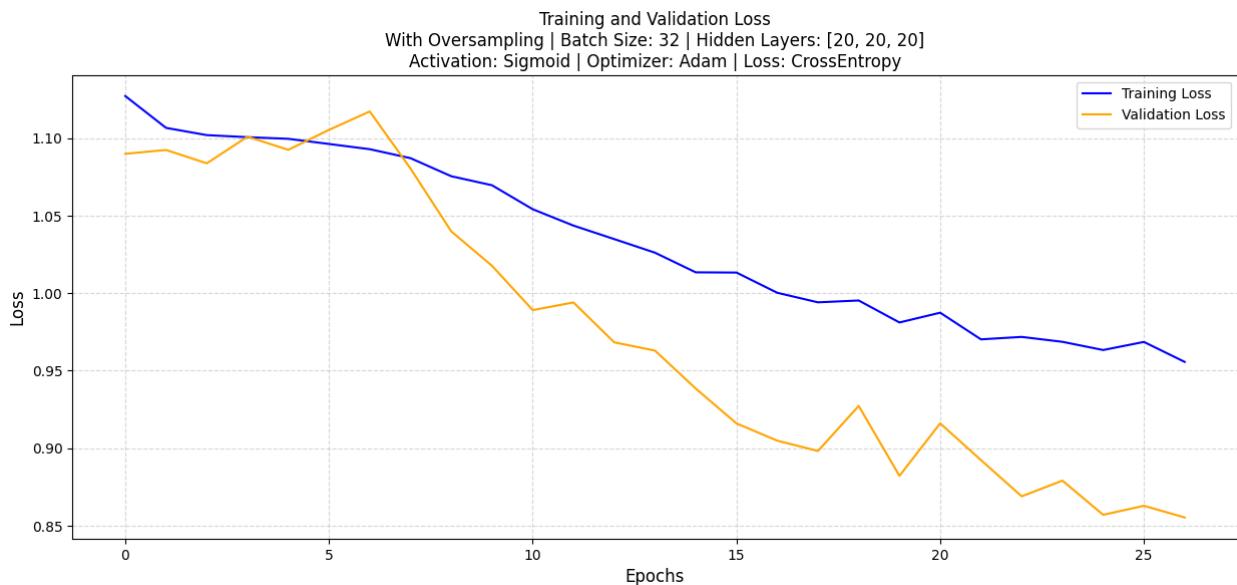
Early stopping triggered



Early stopping triggered

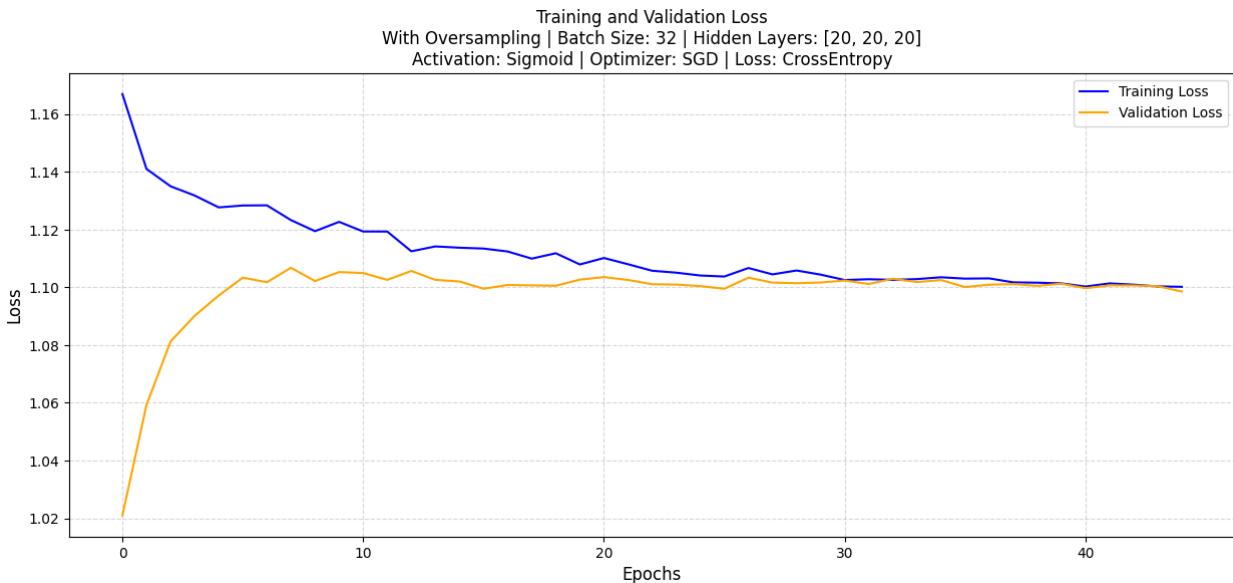


Early stopping triggered

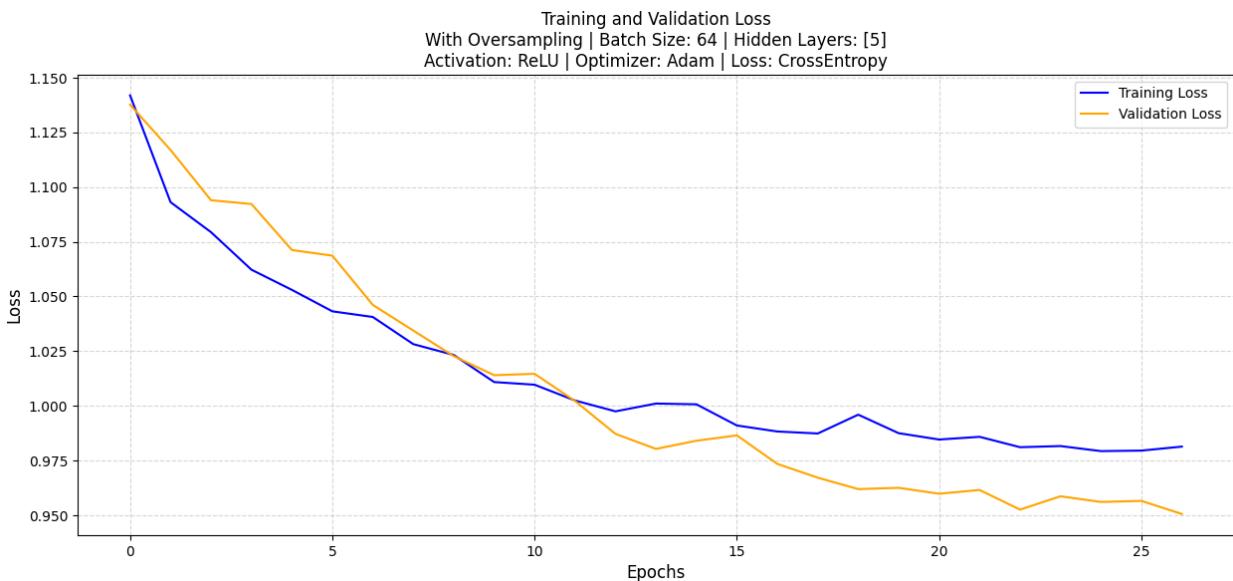


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
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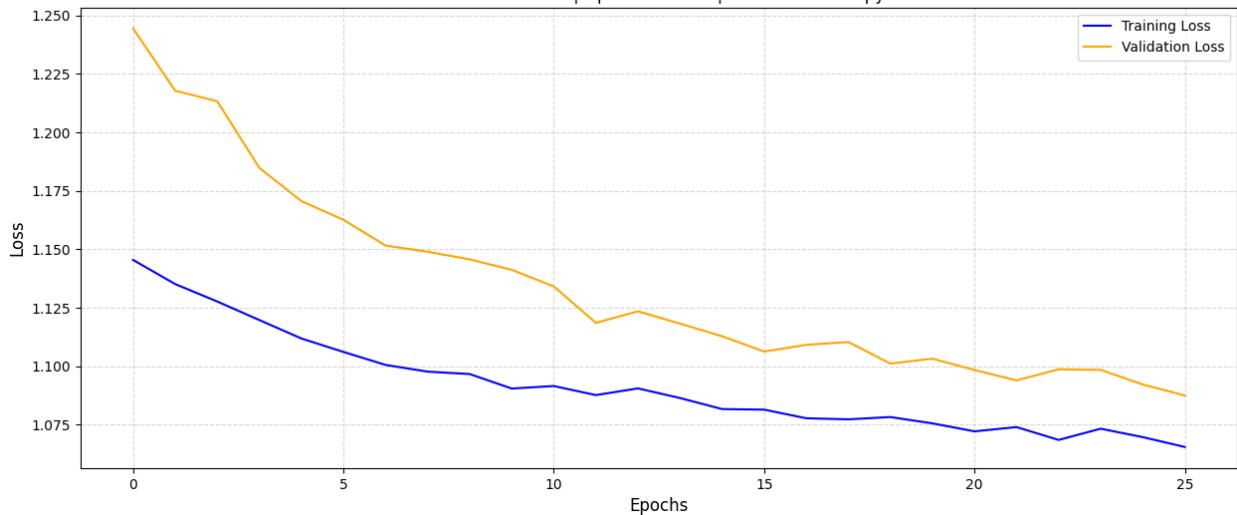


Early stopping triggered



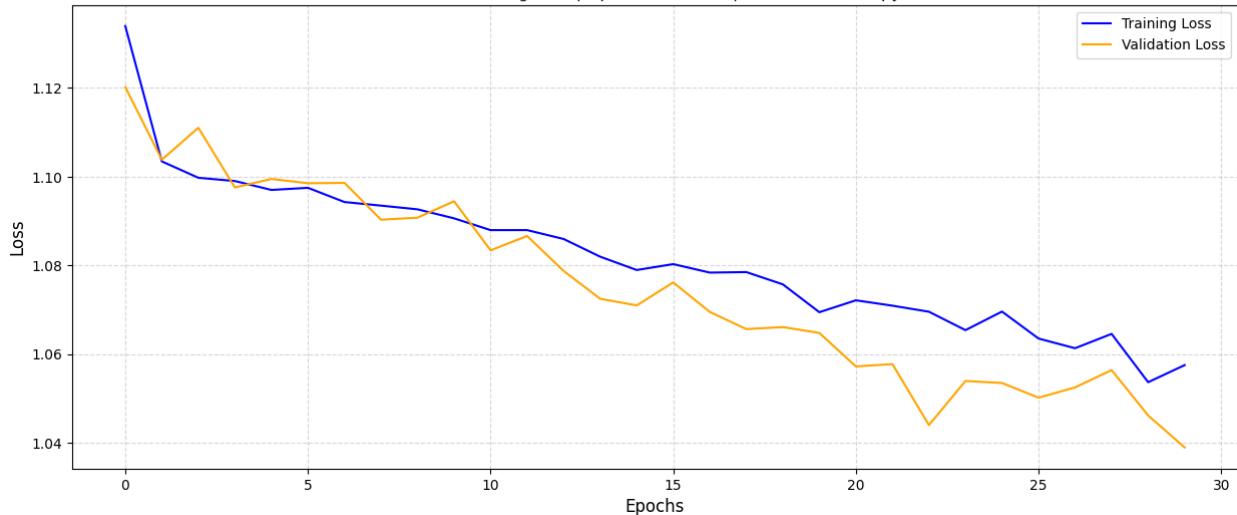
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



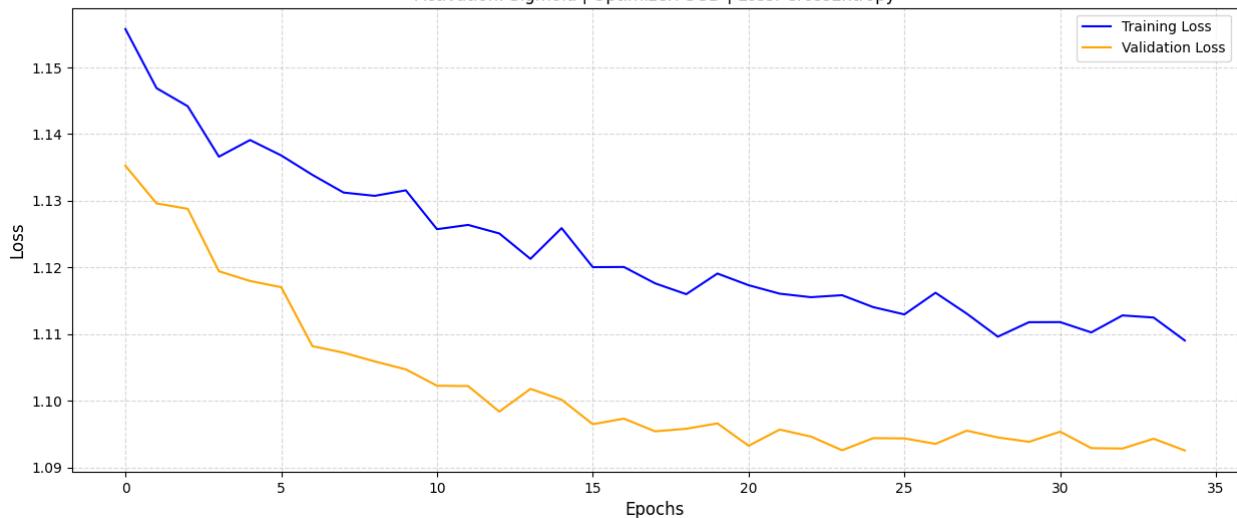
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



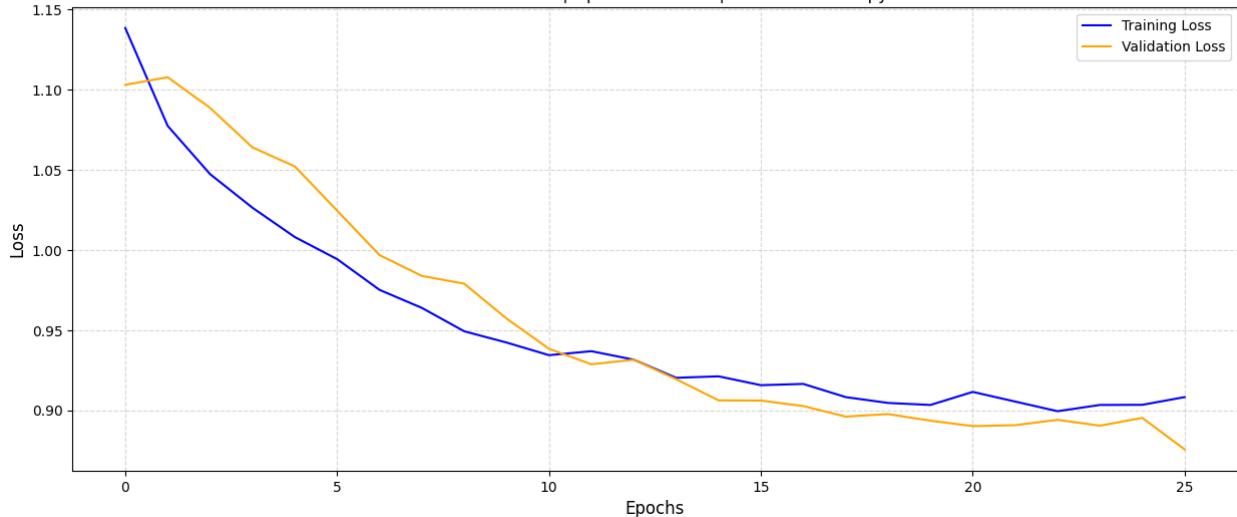
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



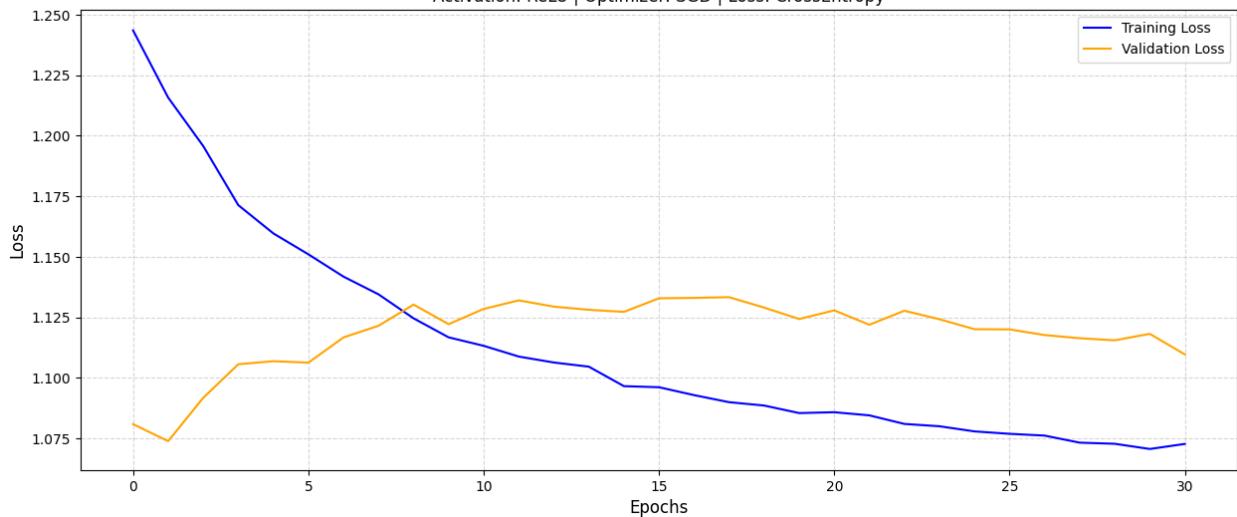
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



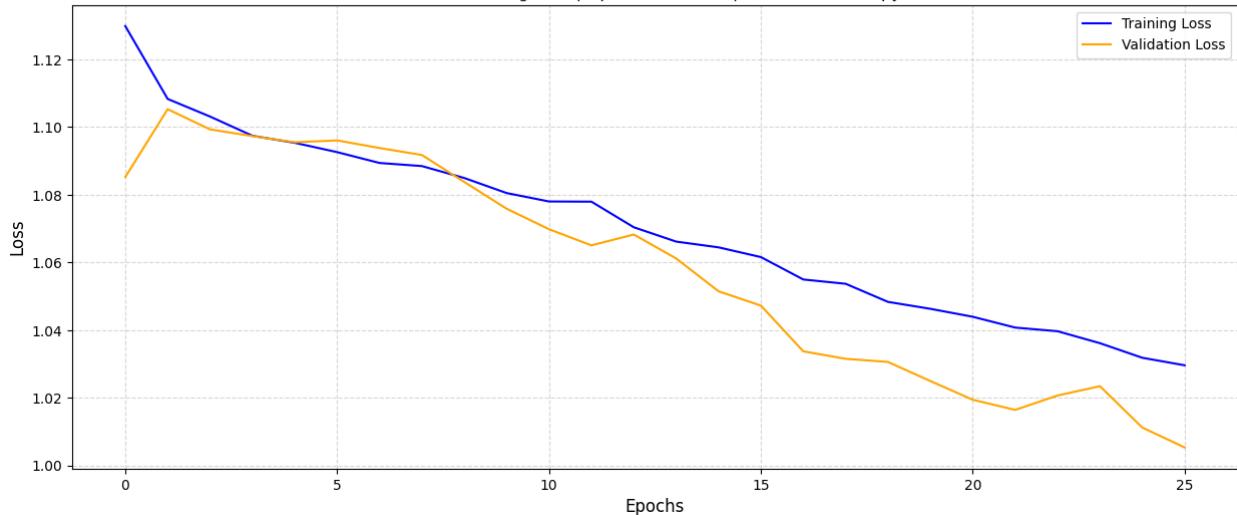
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

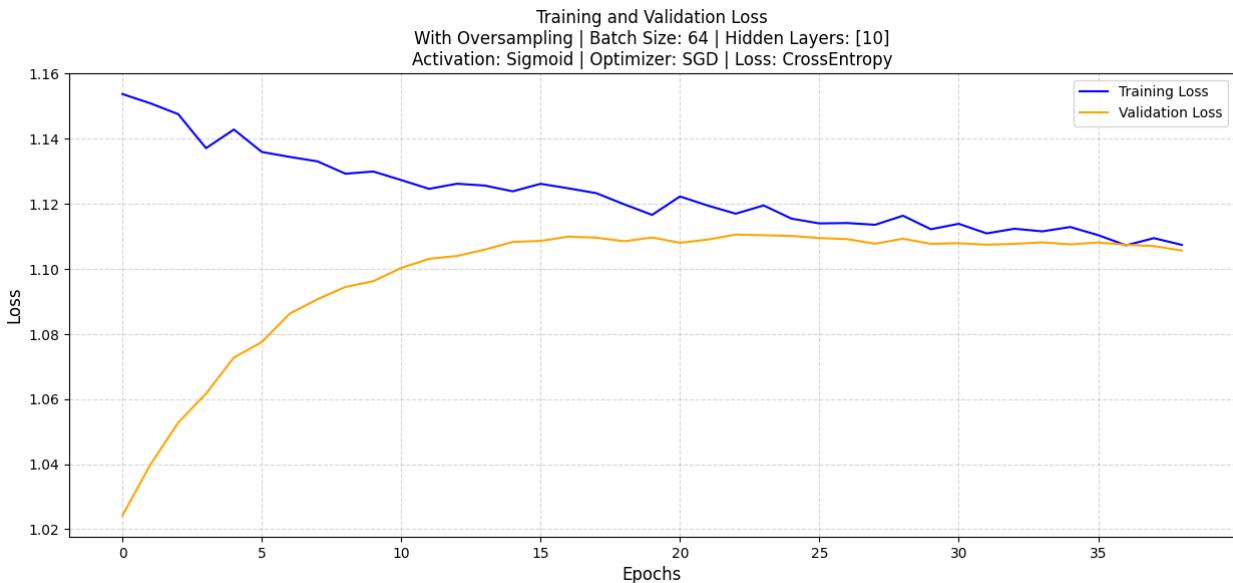


Early stopping triggered

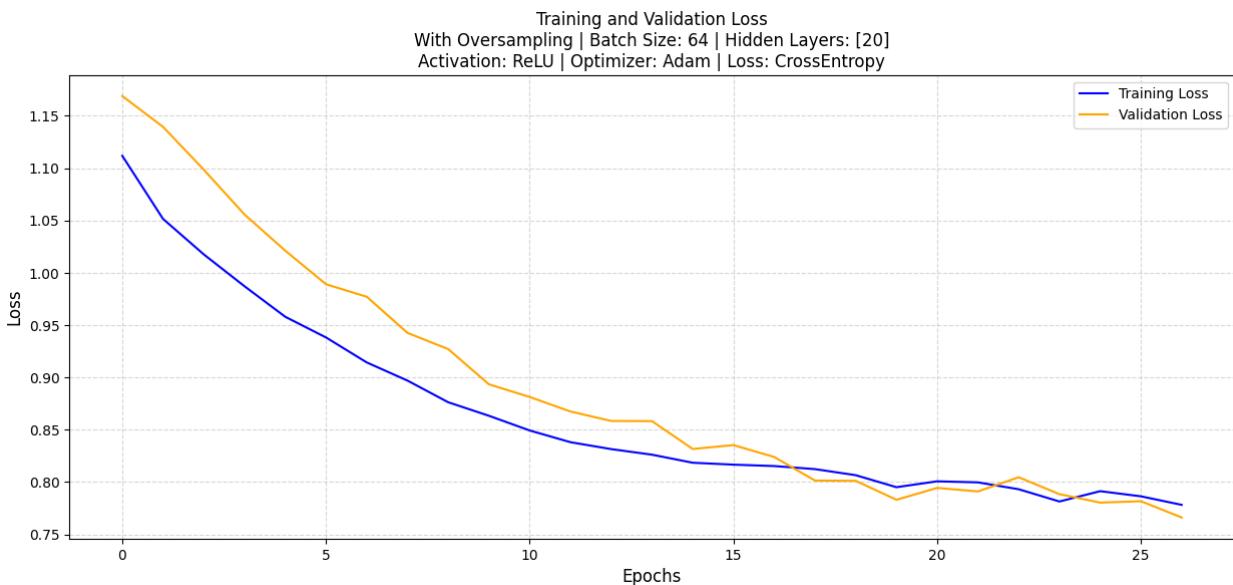
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered

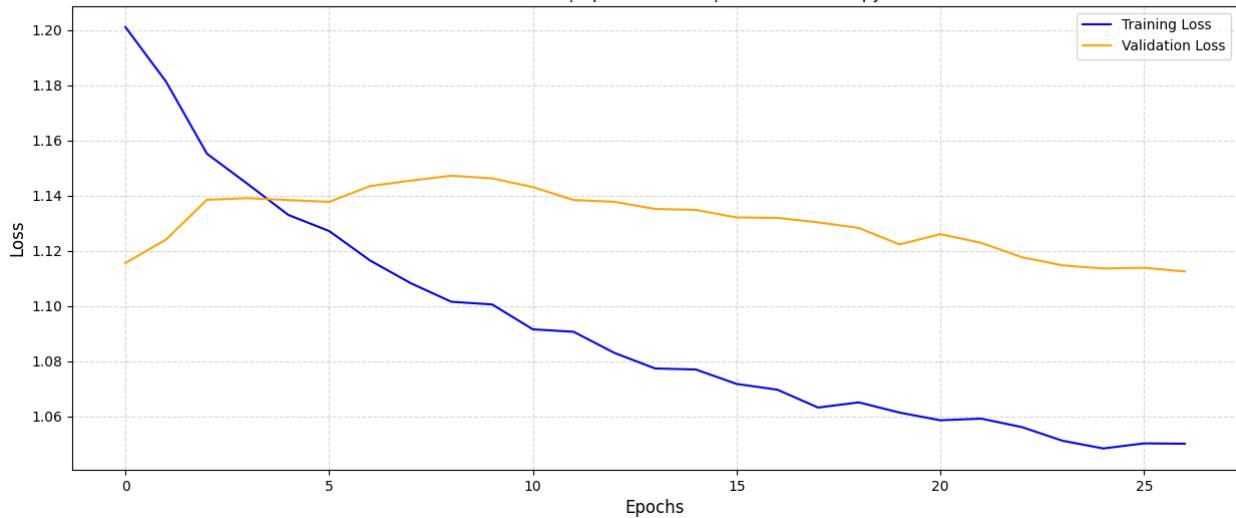


Early stopping triggered



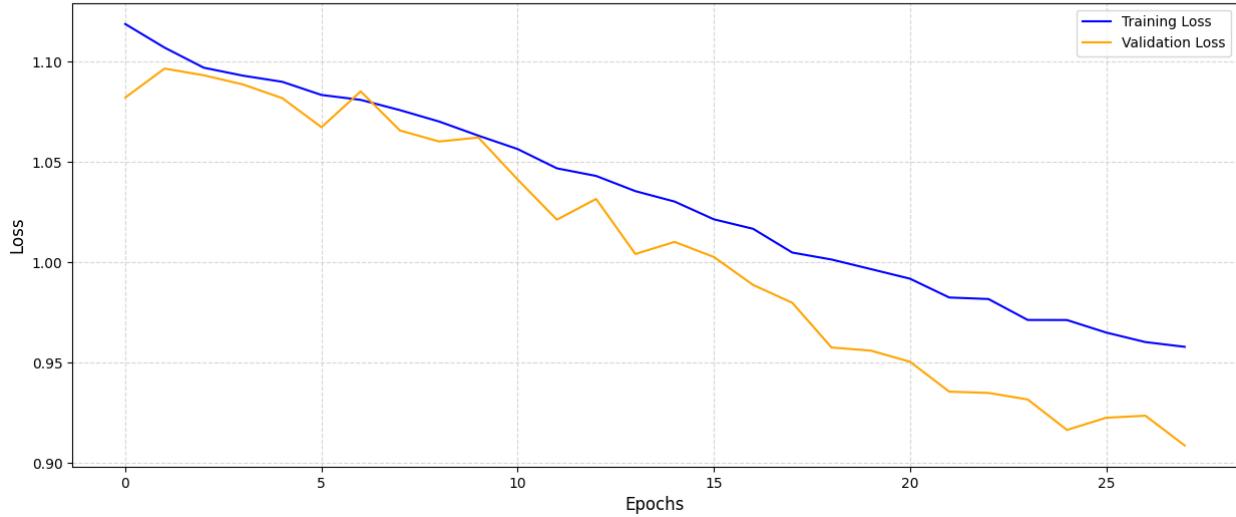
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



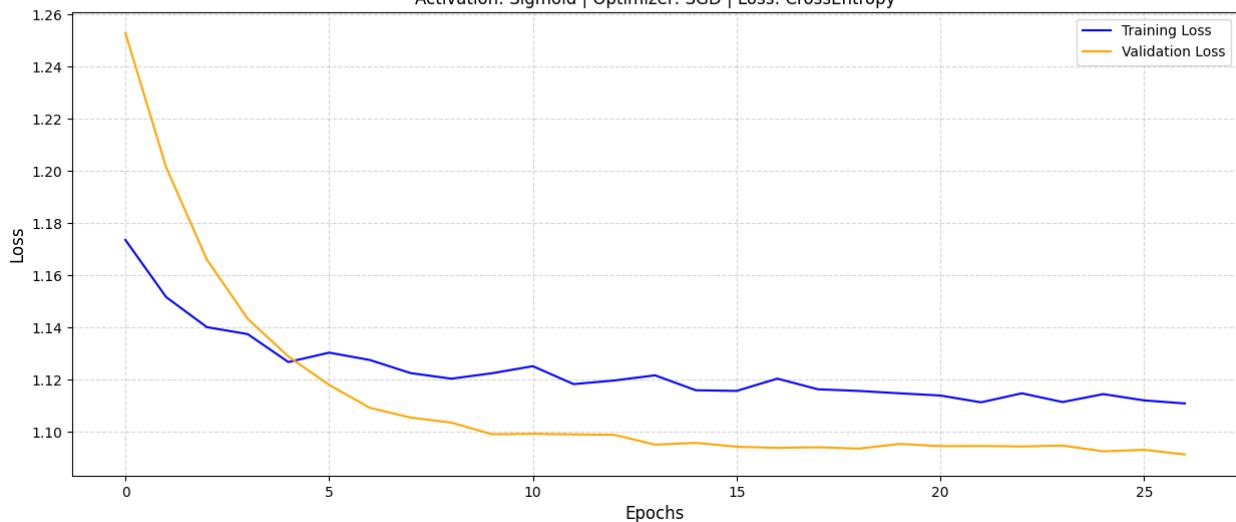
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



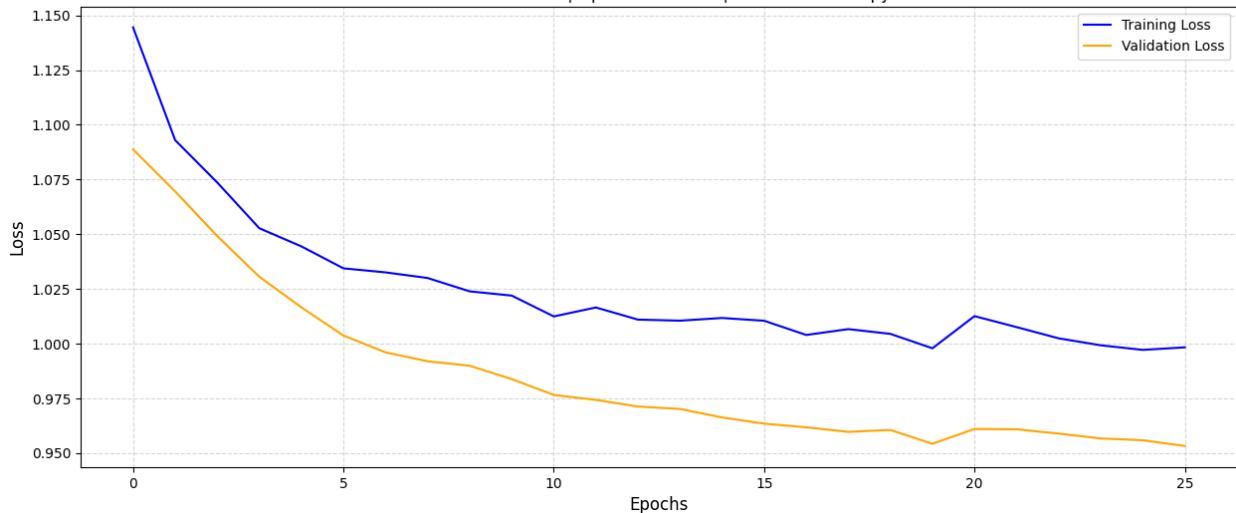
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

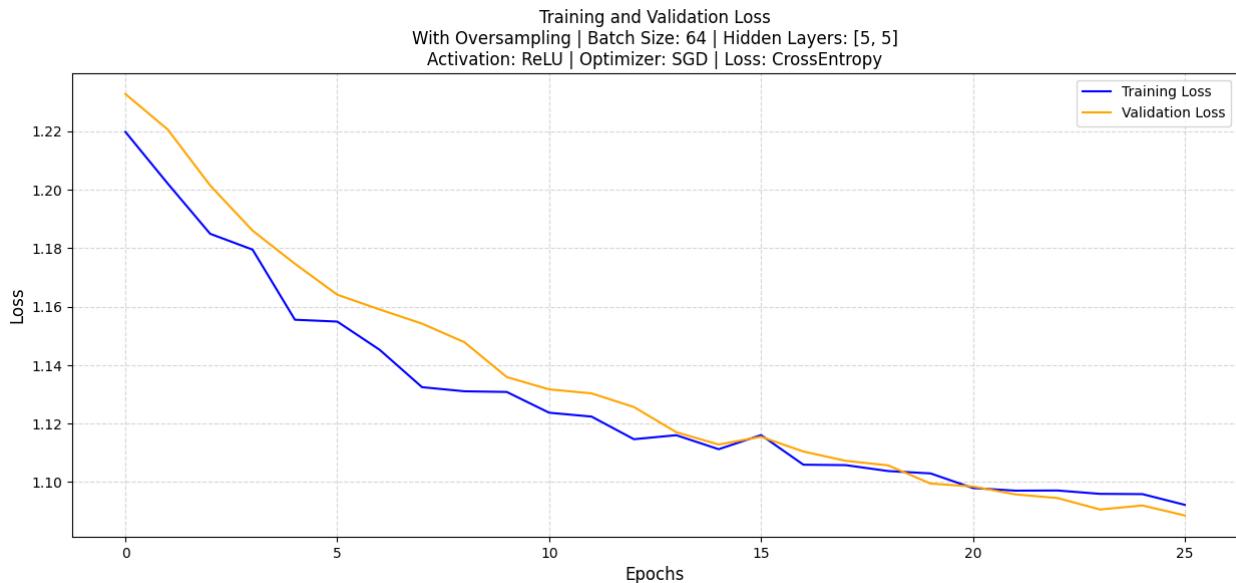


Early stopping triggered

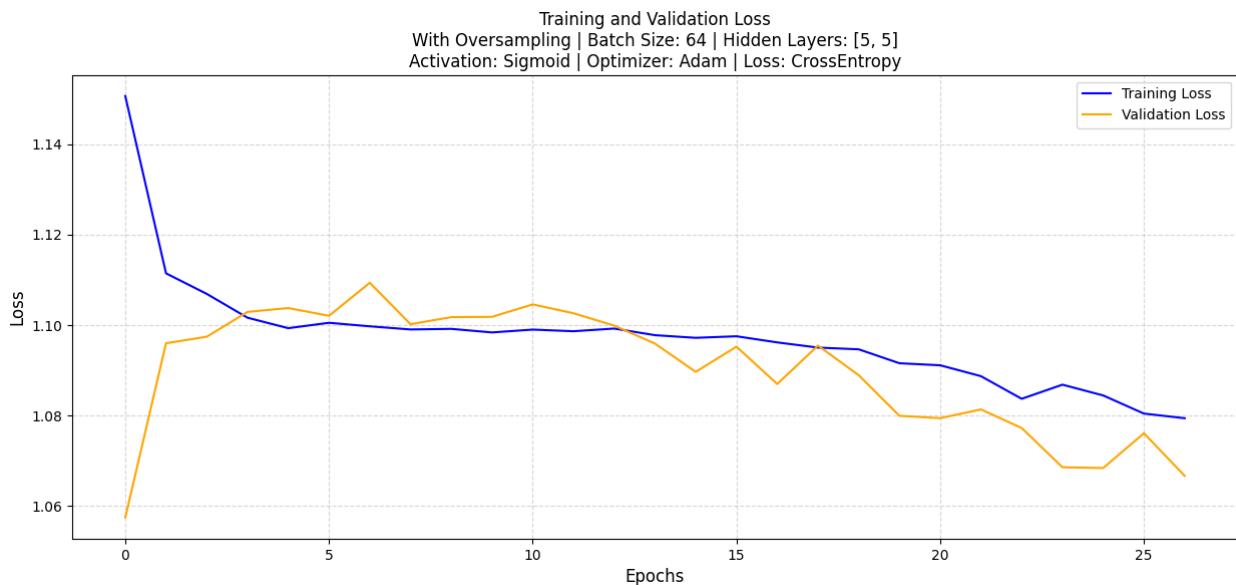
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5, 5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered

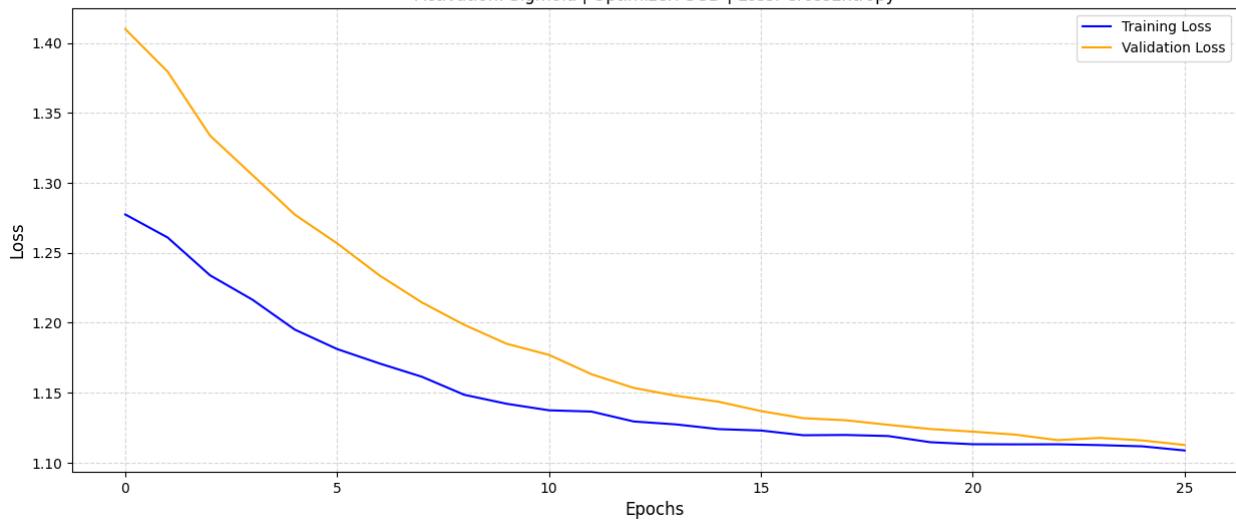


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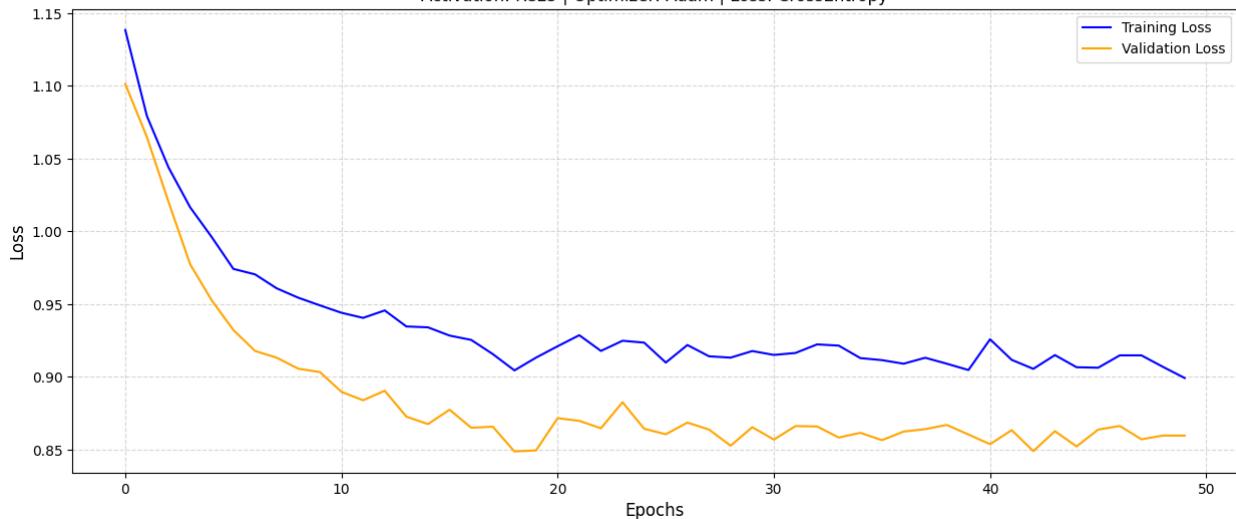


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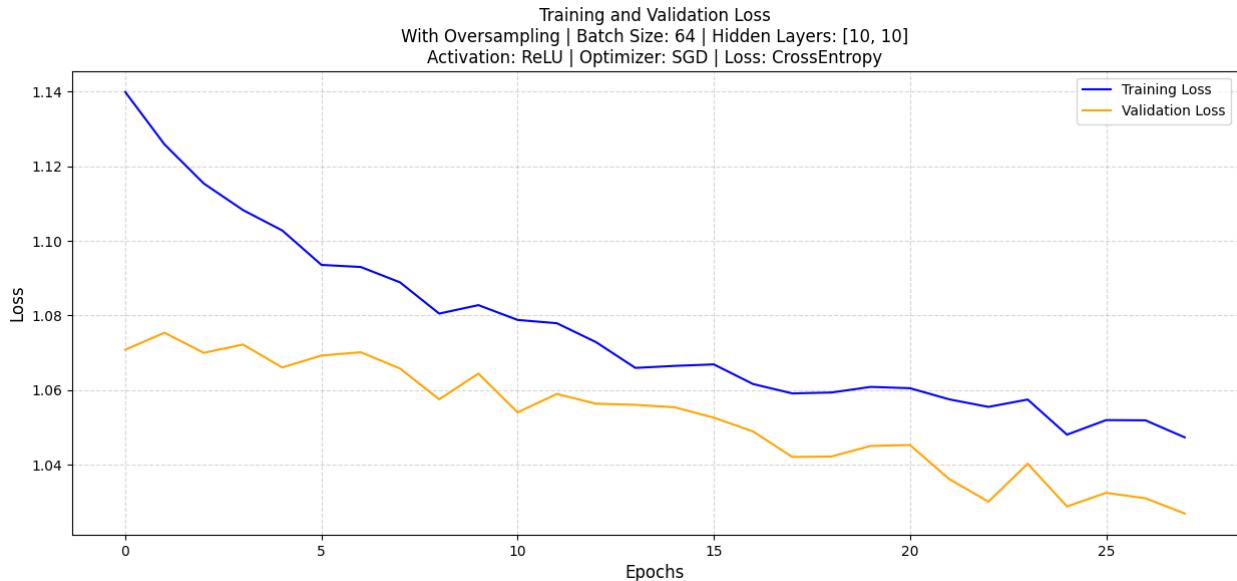
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5, 5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



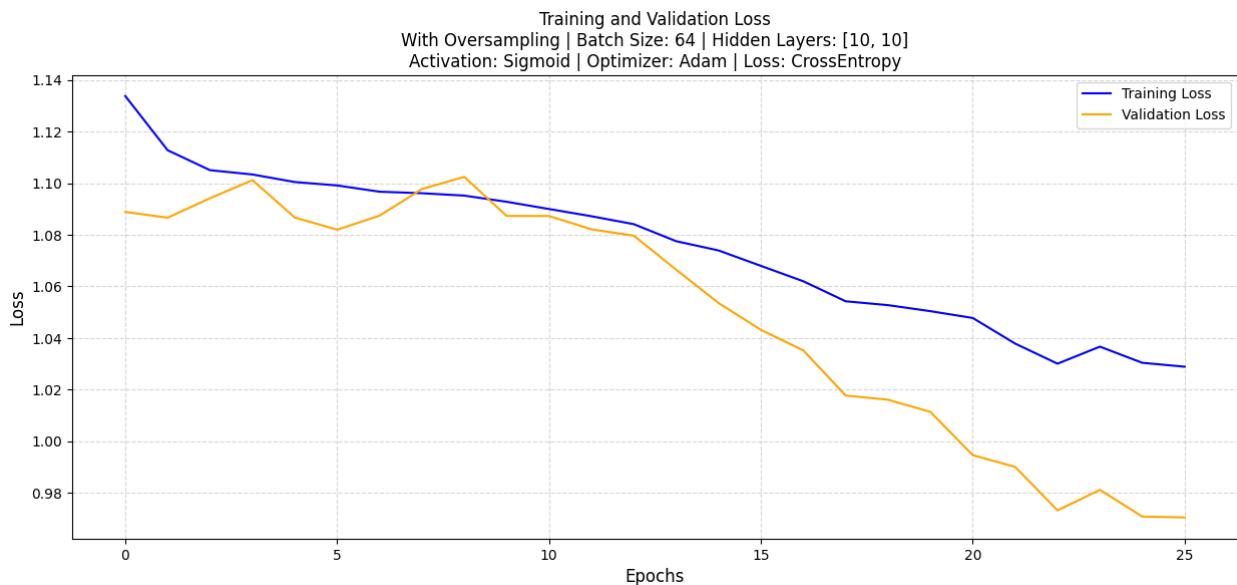
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10, 10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



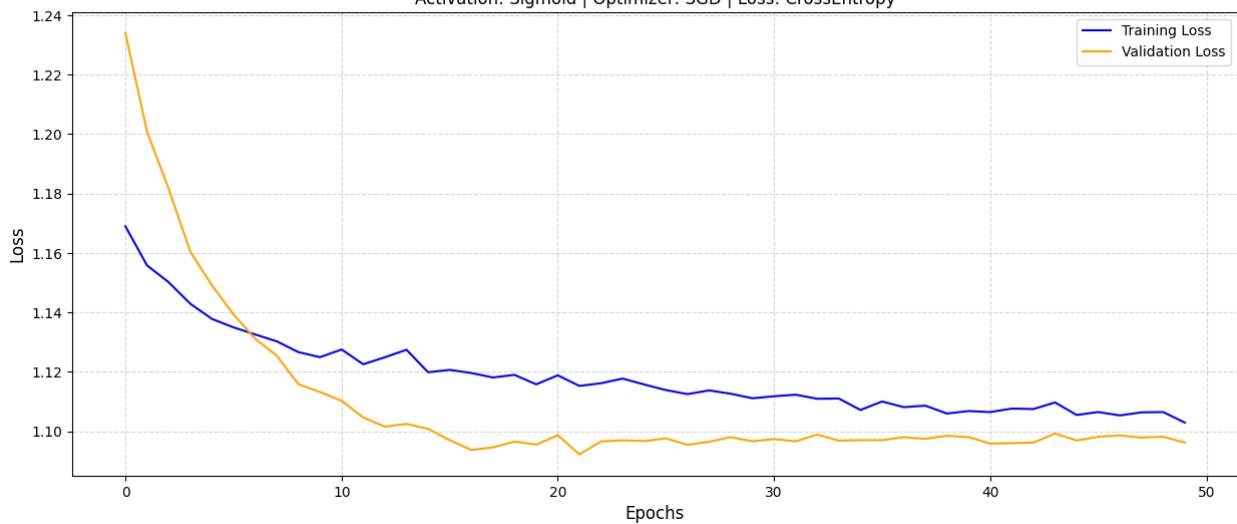
Early stopping triggered



Early stopping triggered

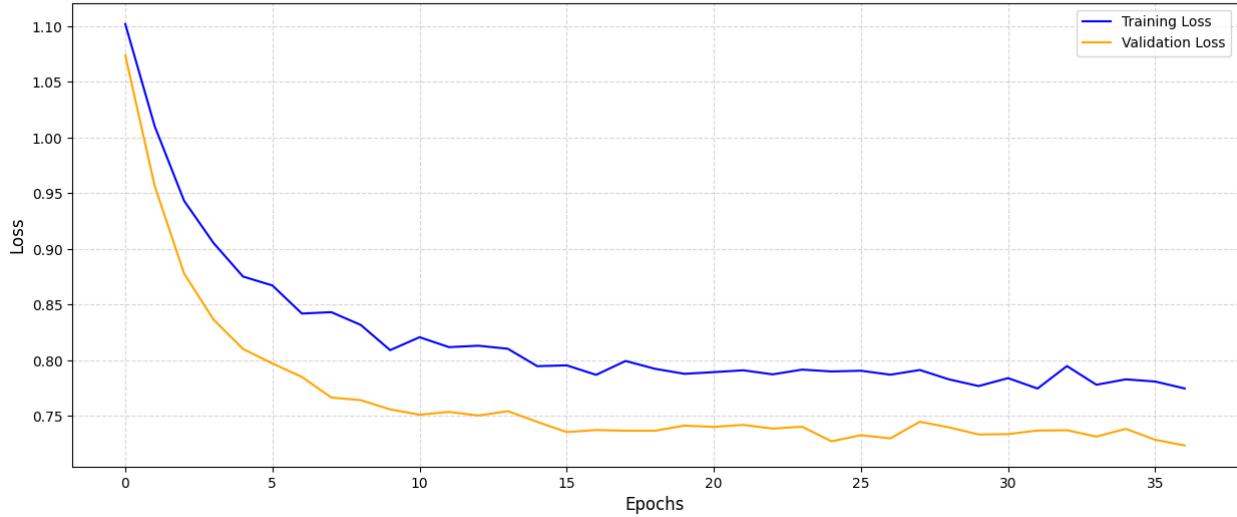


Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10, 10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



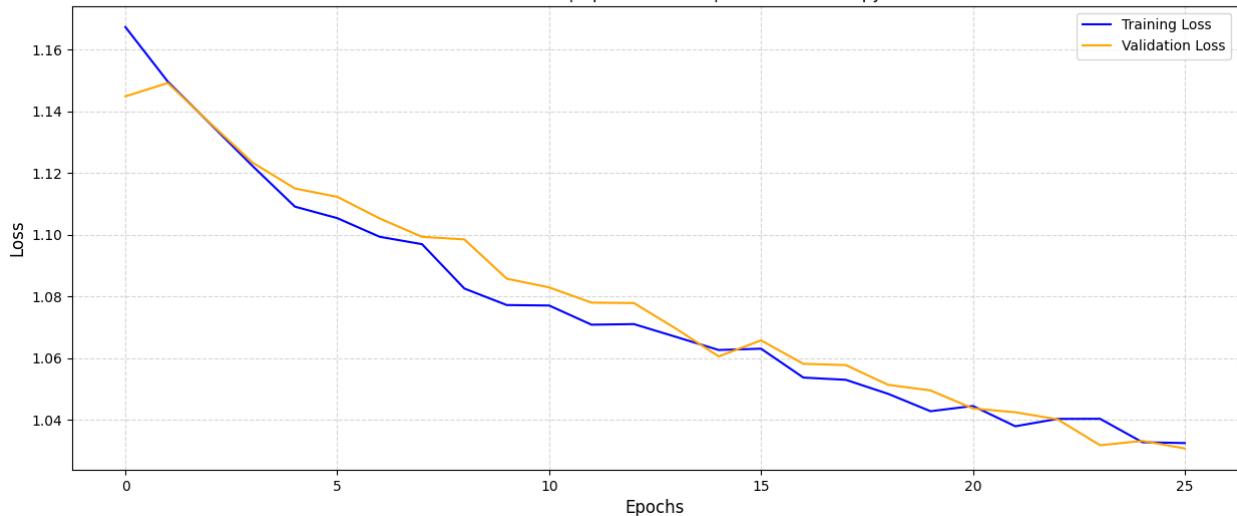
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Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20, 20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



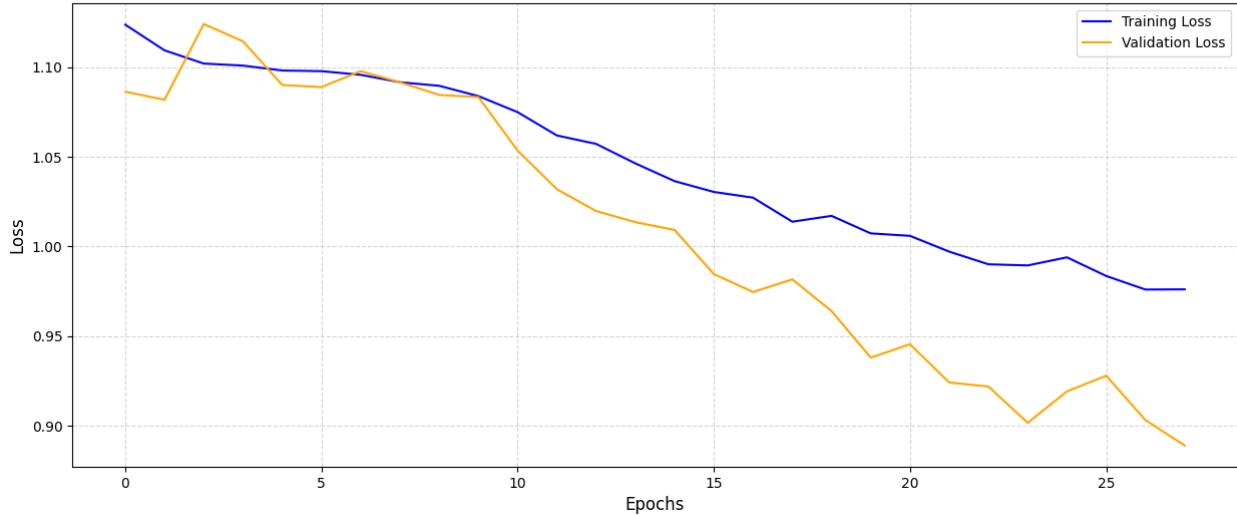
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Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20, 20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



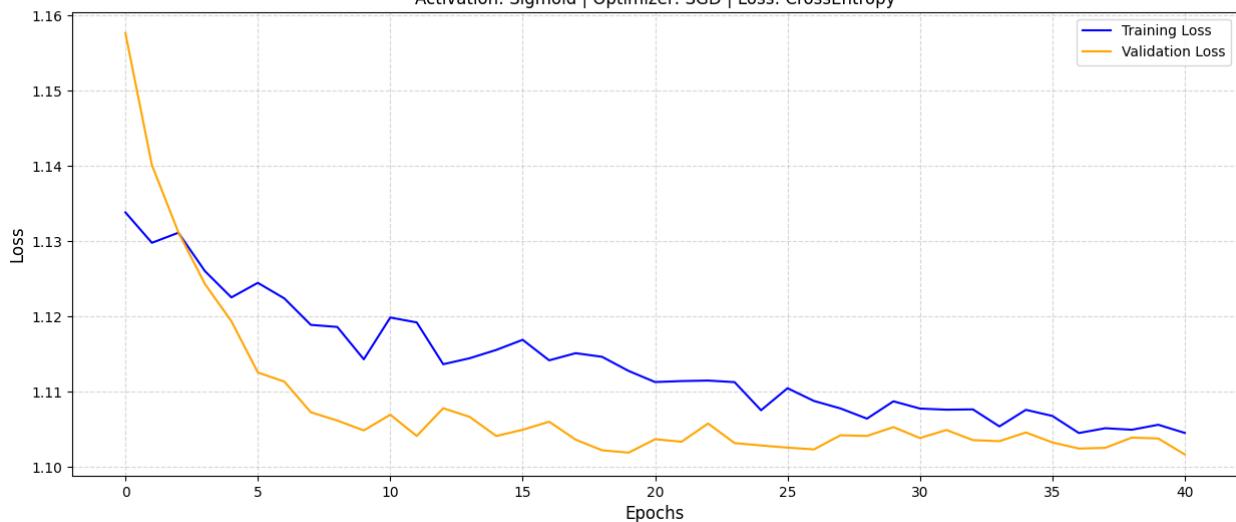
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20, 20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



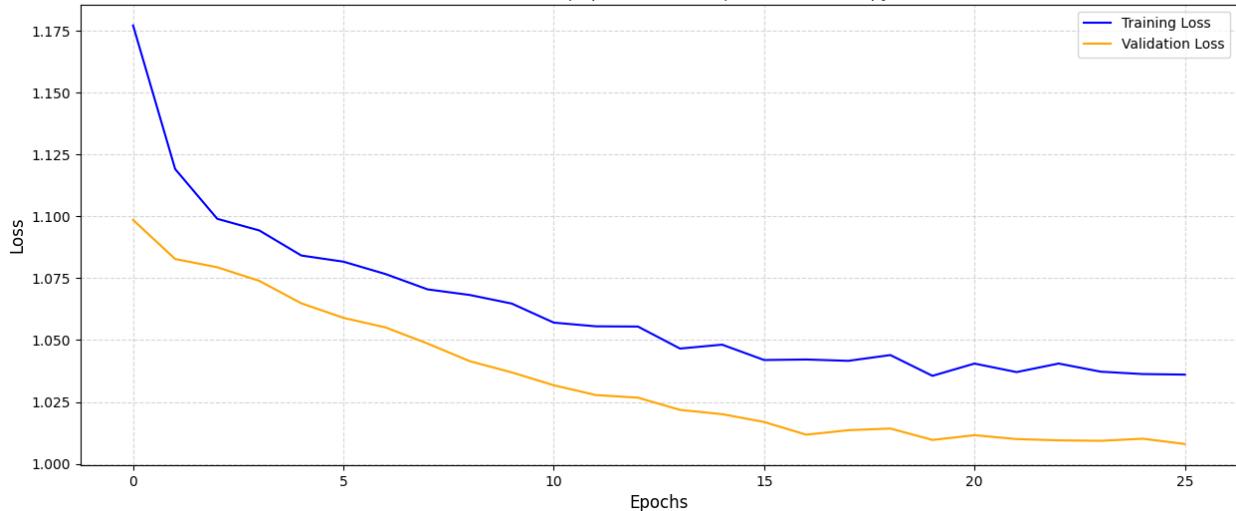
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20, 20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

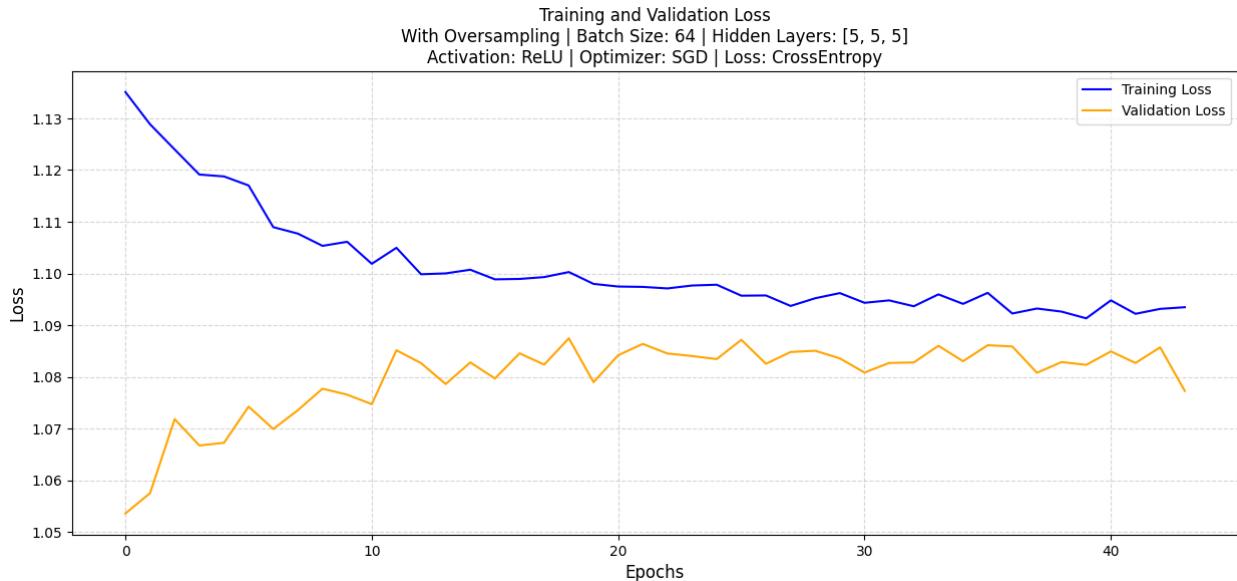


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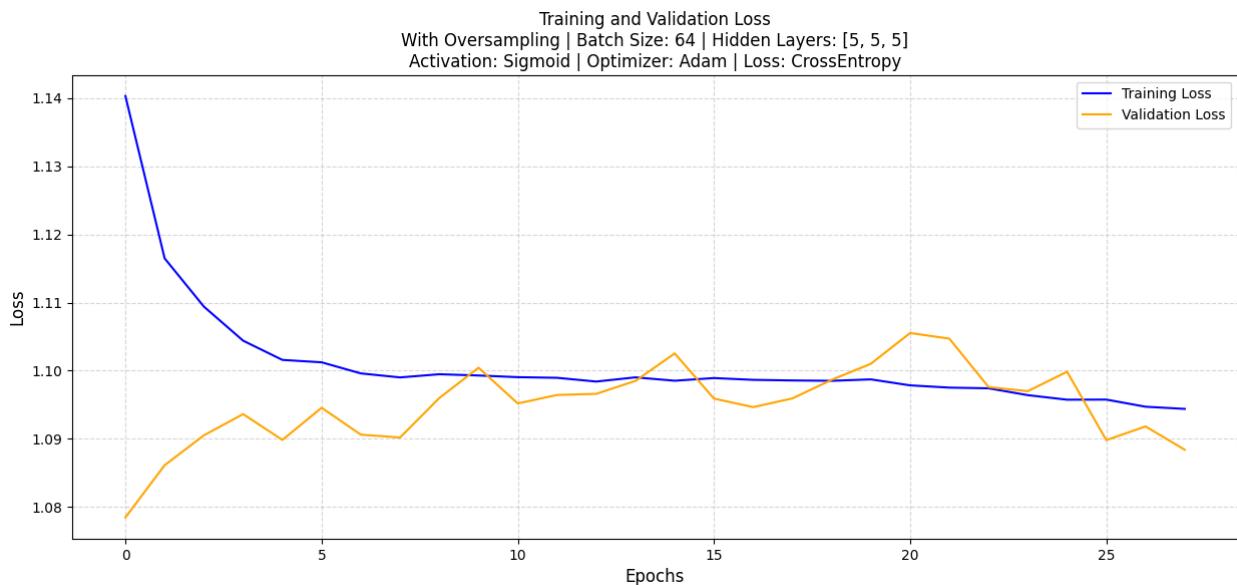
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5, 5, 5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered



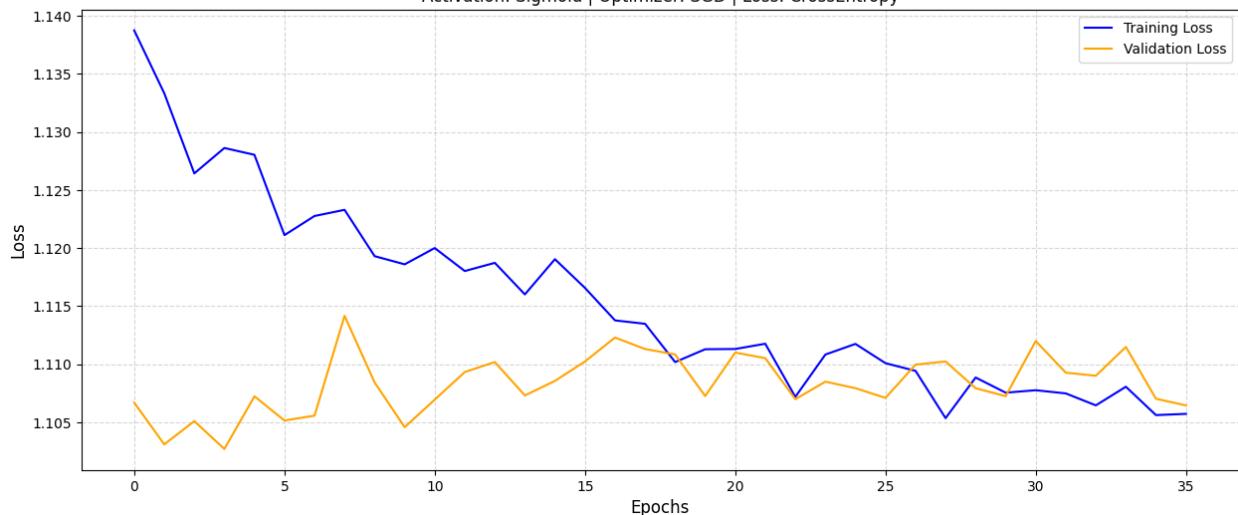
Early stopping triggered



Early stopping triggered

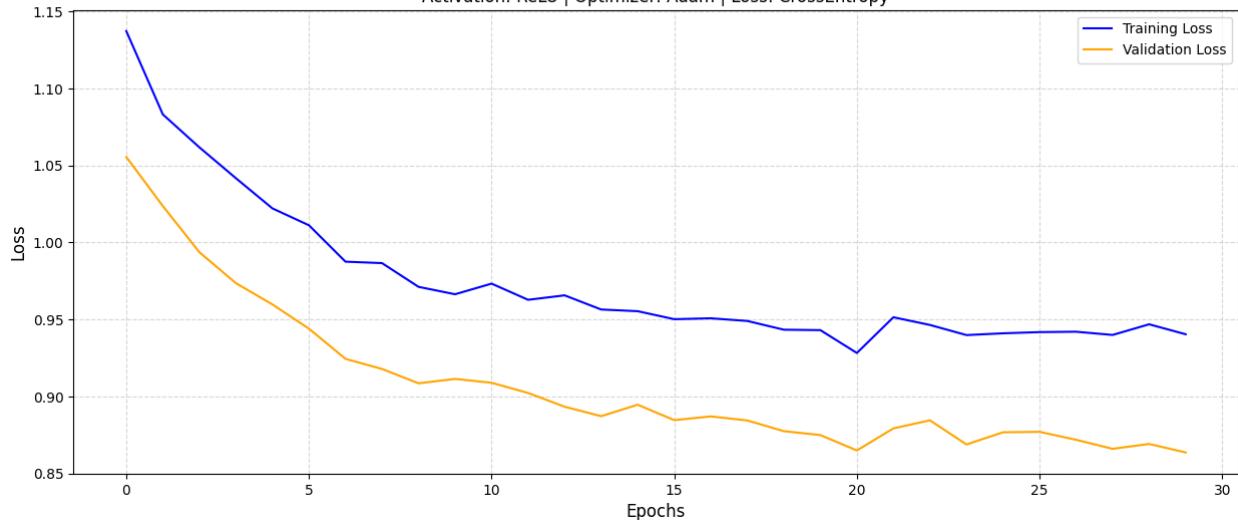
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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
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len(result))
```

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5, 5, 5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

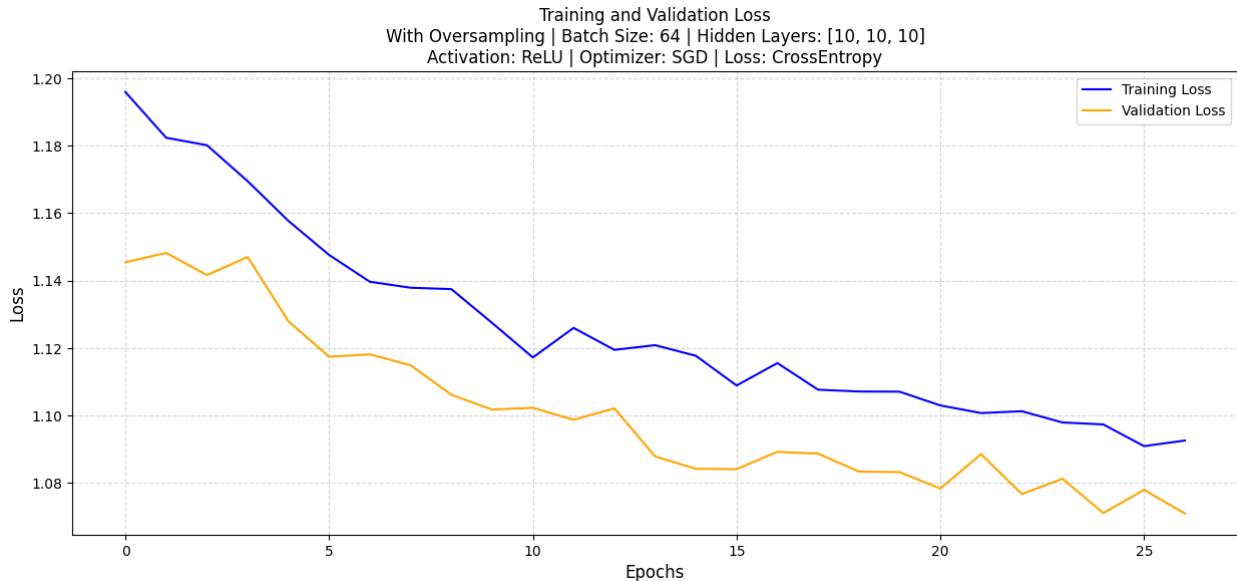


Early stopping triggered

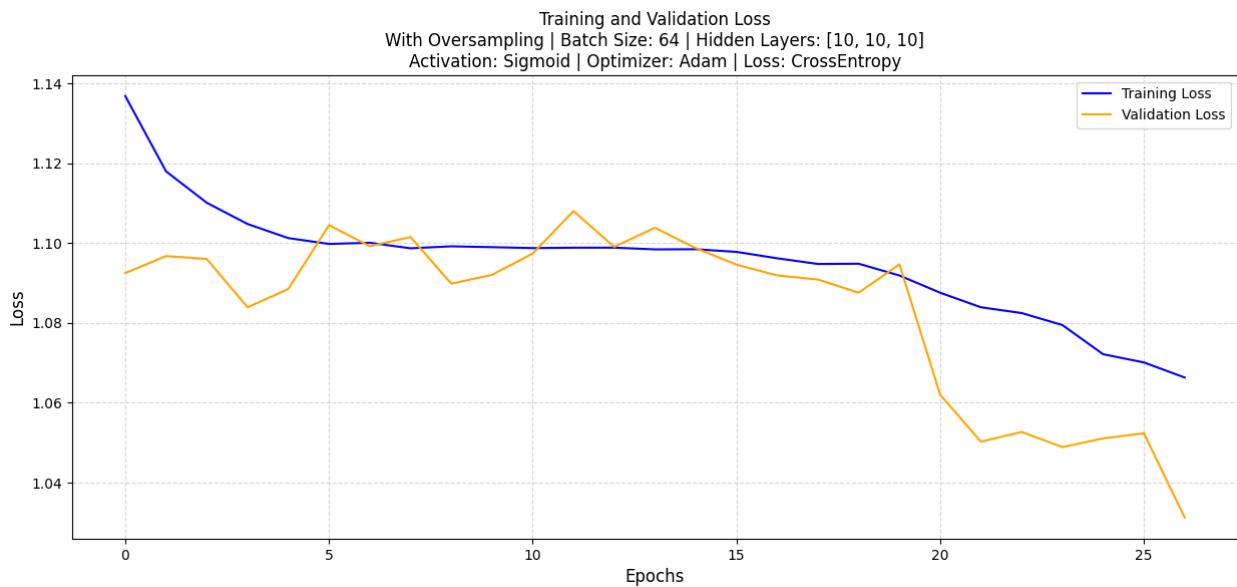
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10, 10, 10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy

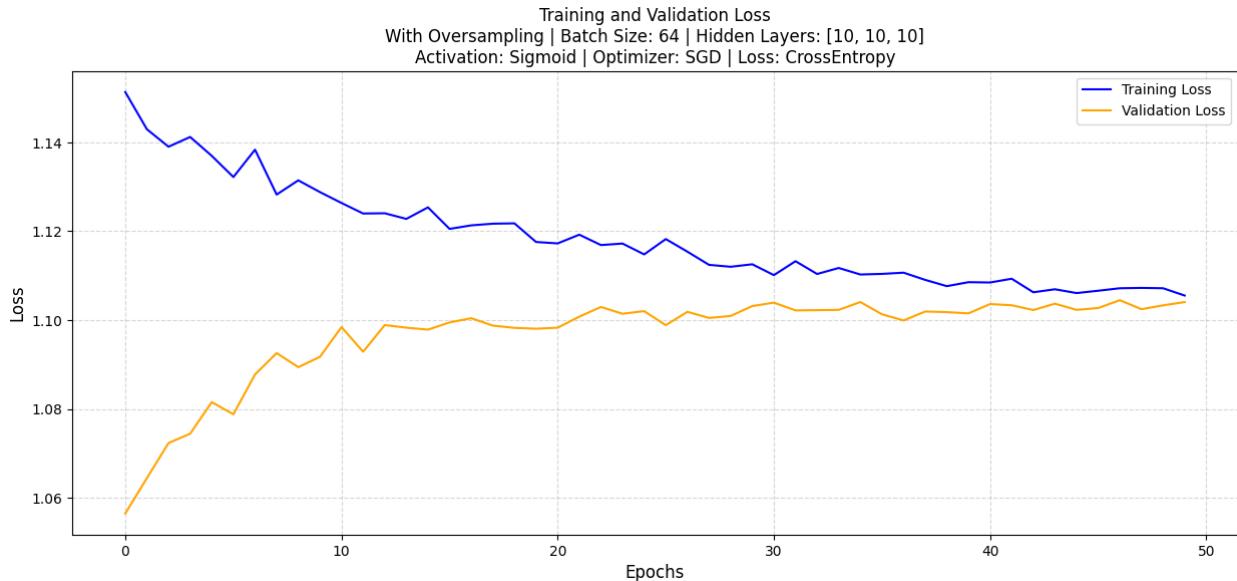


Early stopping triggered

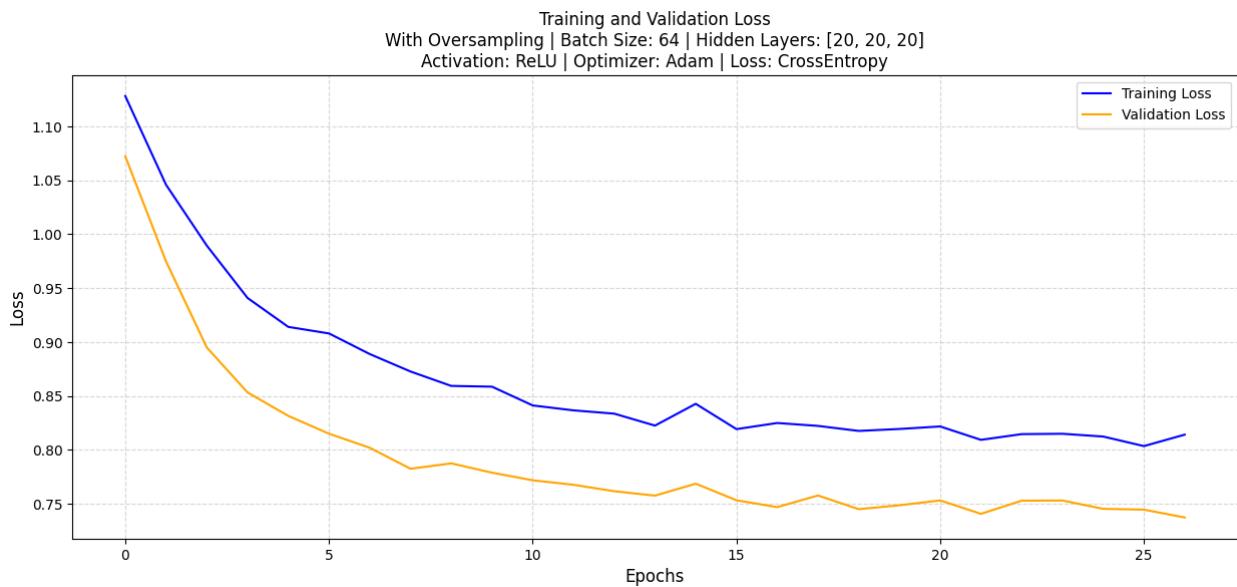


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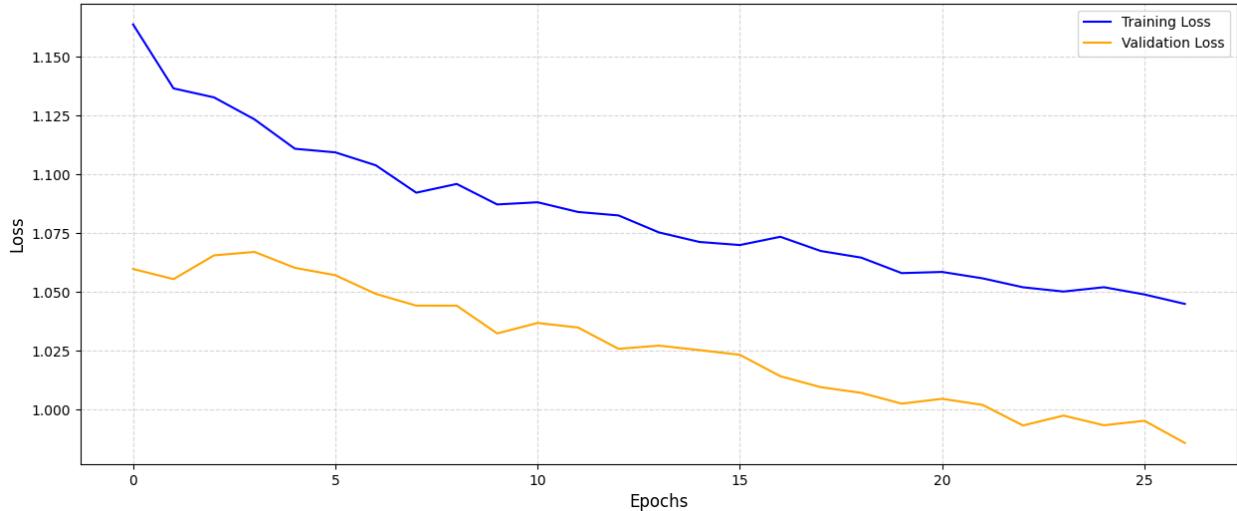


Early stopping triggered



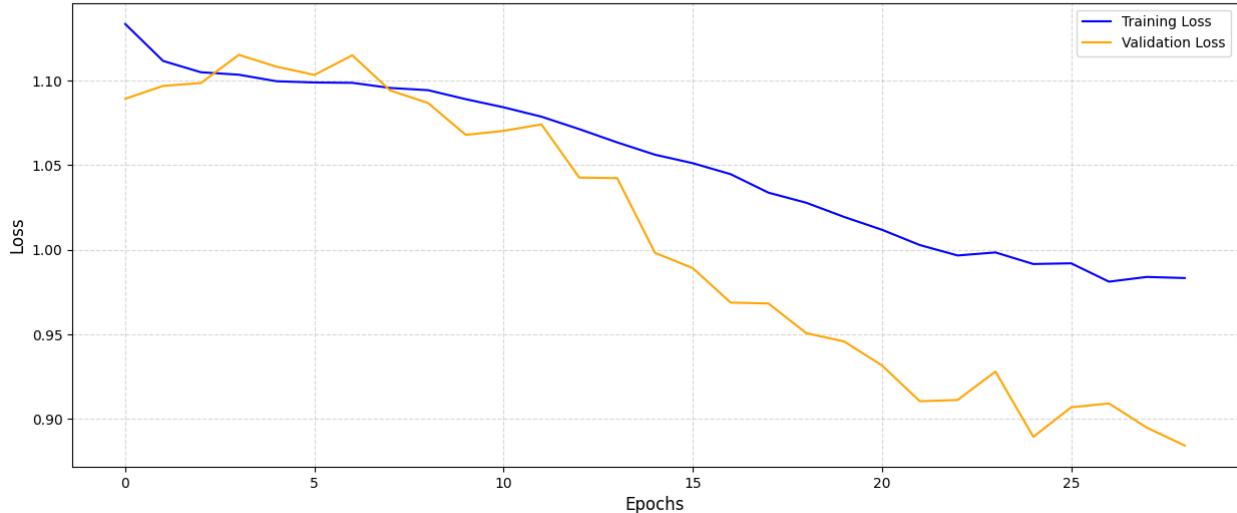
Early stopping triggered

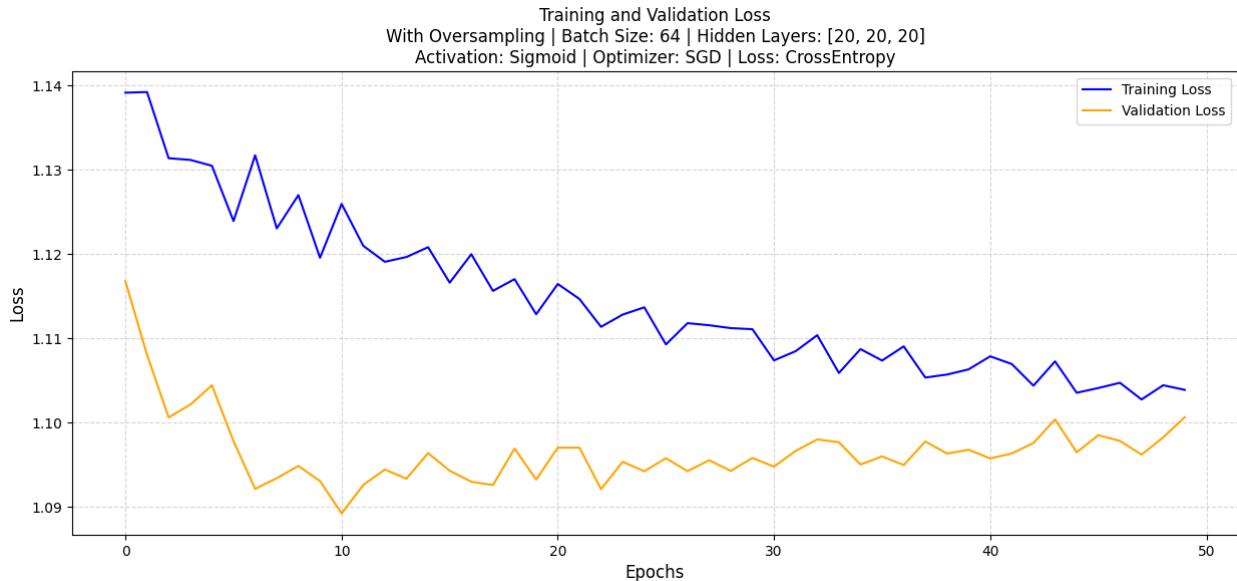
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20, 20, 20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



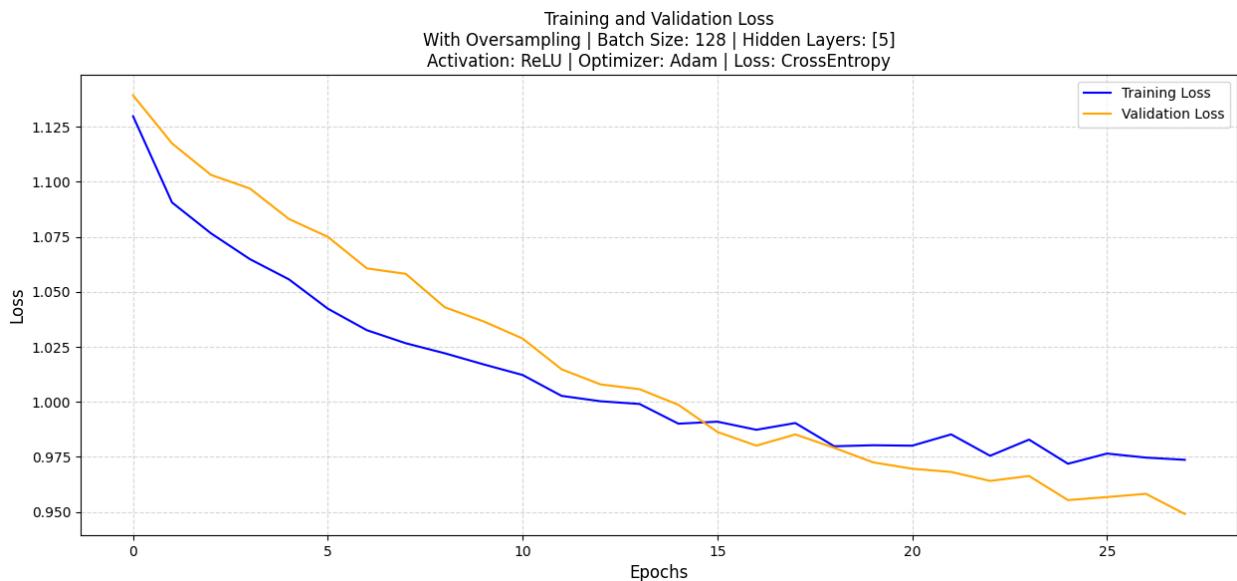
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20, 20, 20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



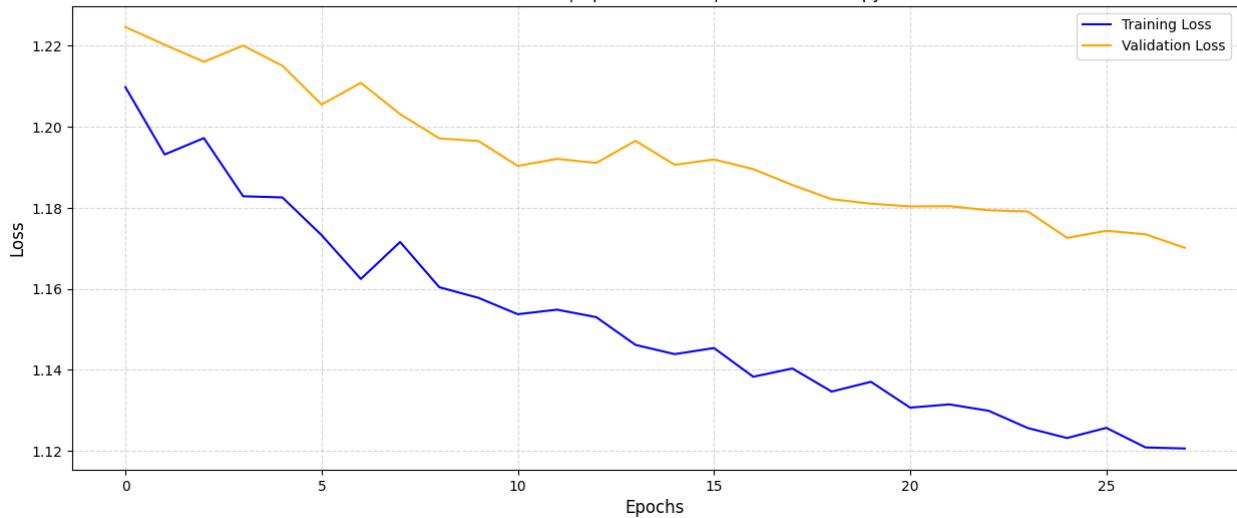


Early stopping triggered



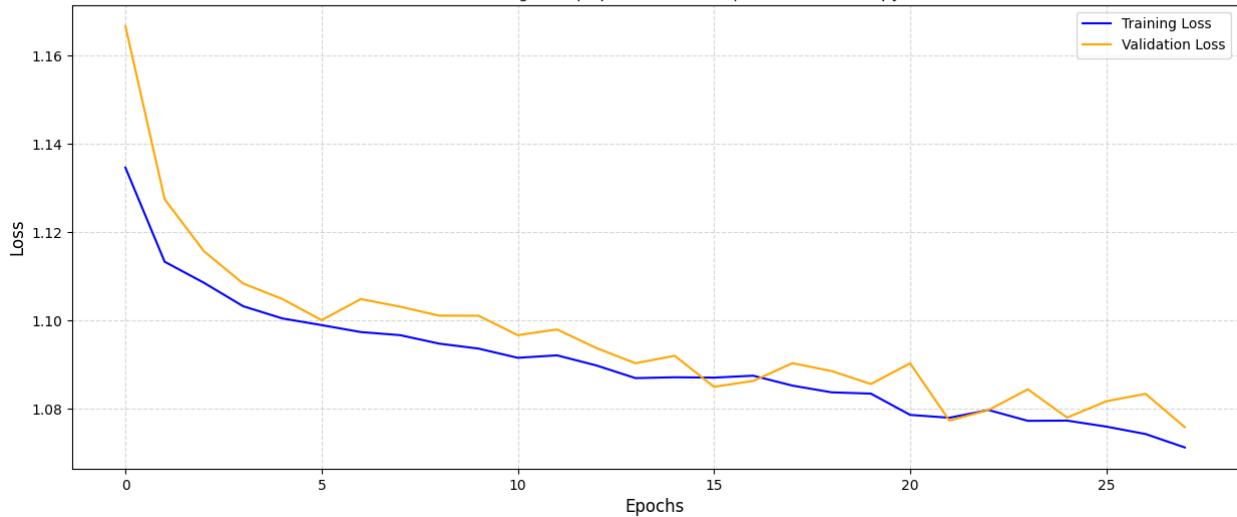
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [5]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

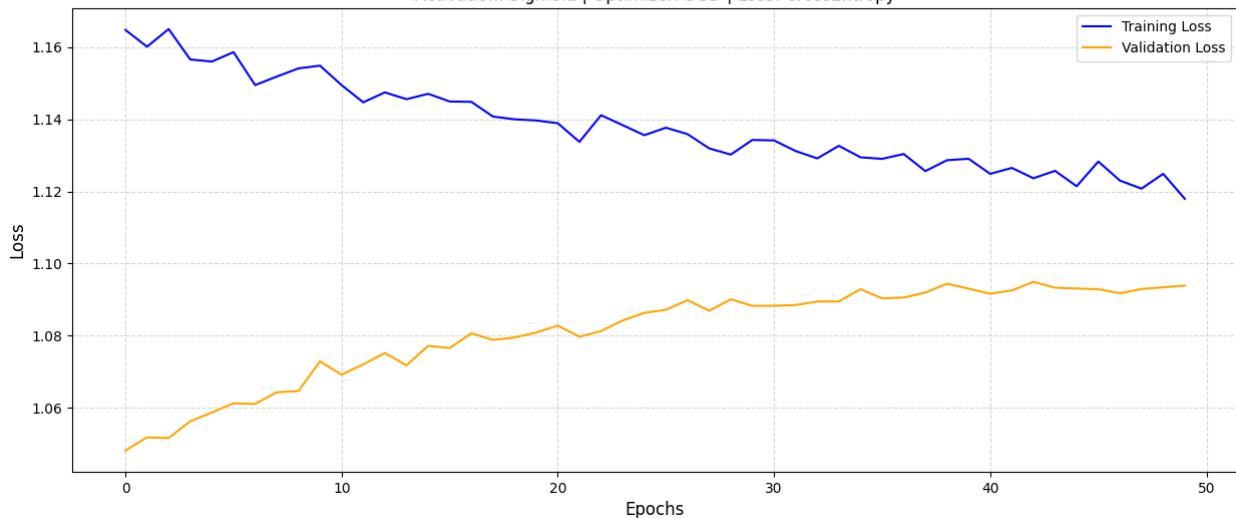


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy

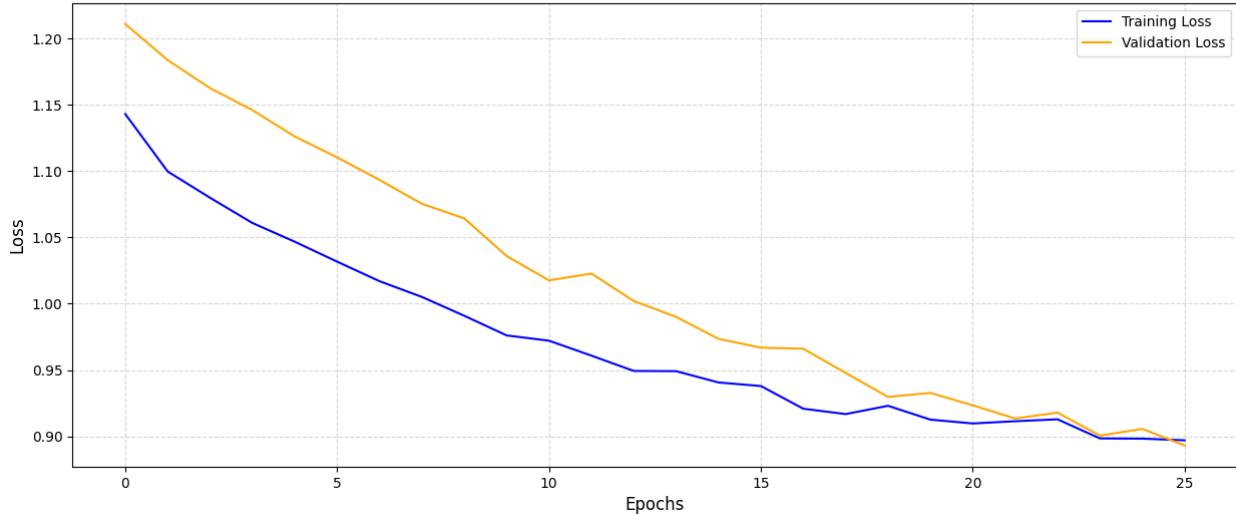


Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



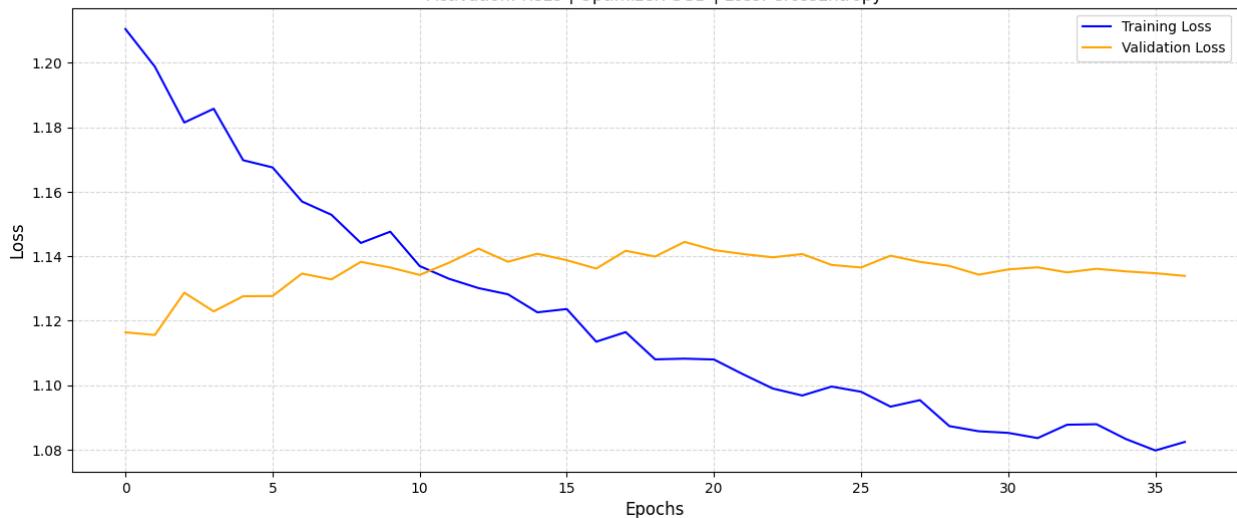
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



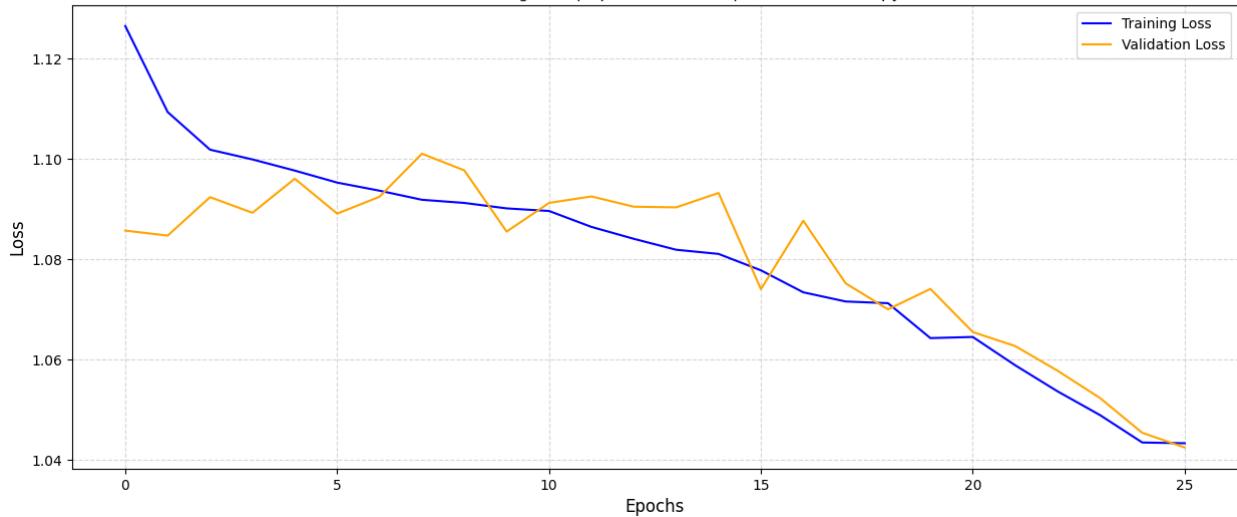
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

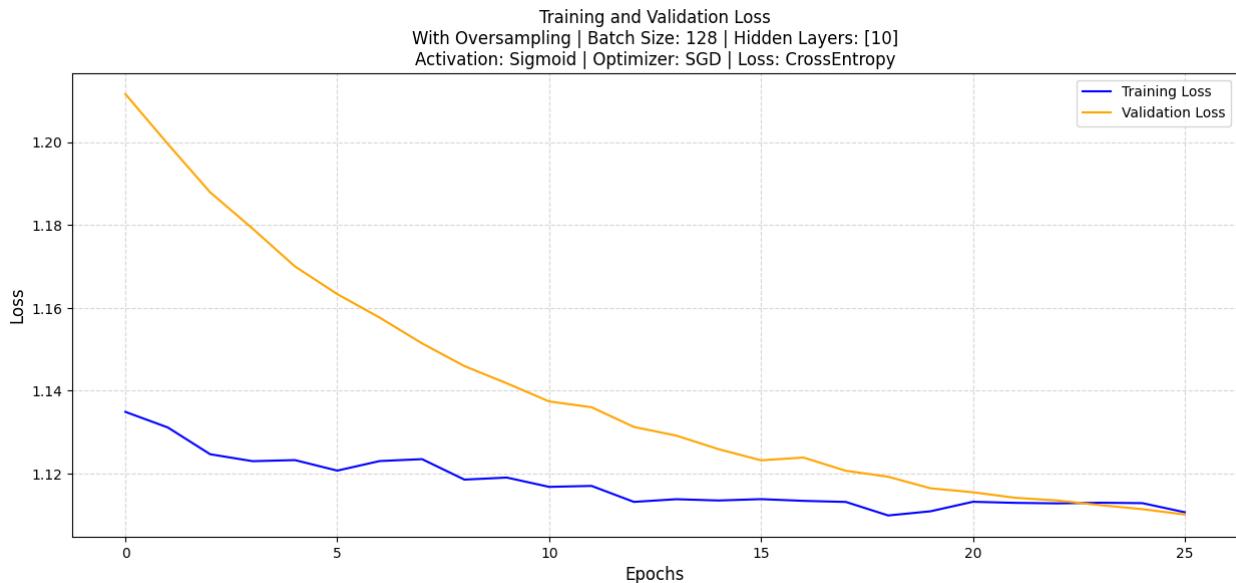


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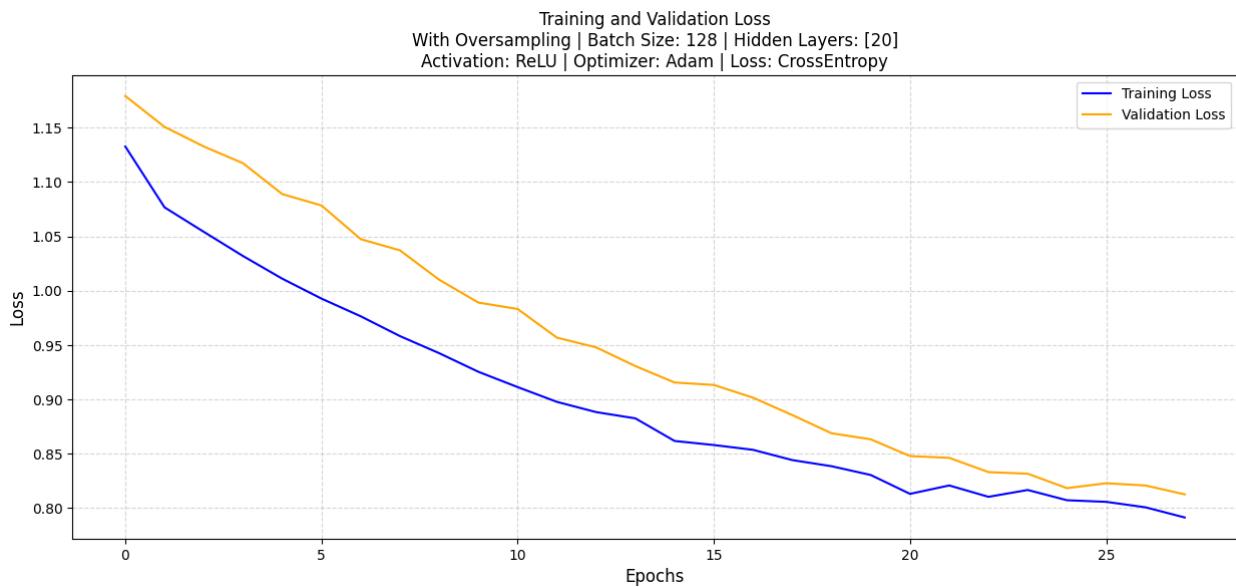
Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered

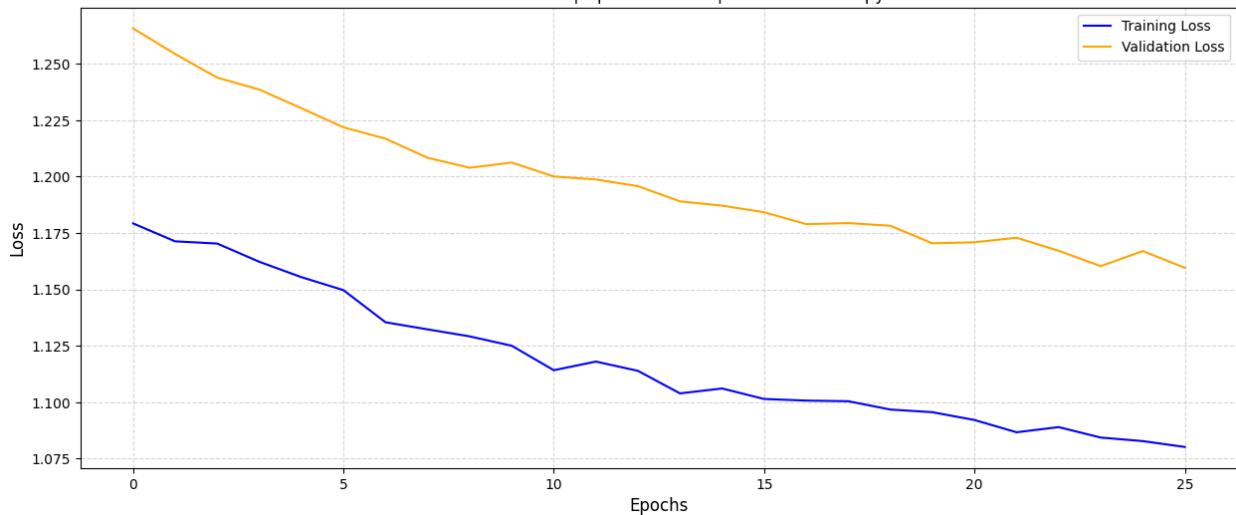


Early stopping triggered



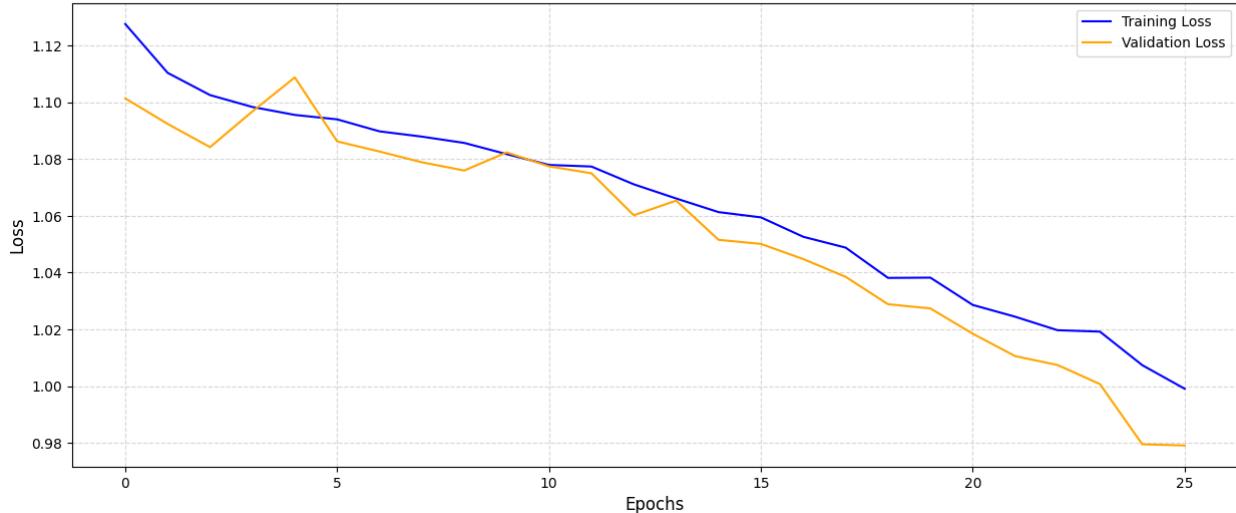
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

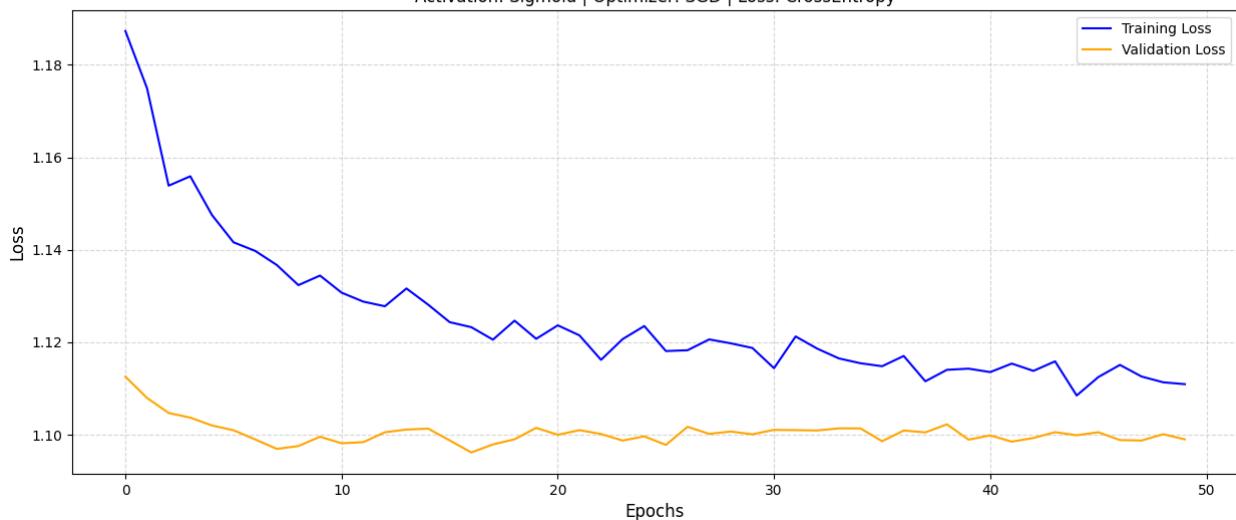


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy

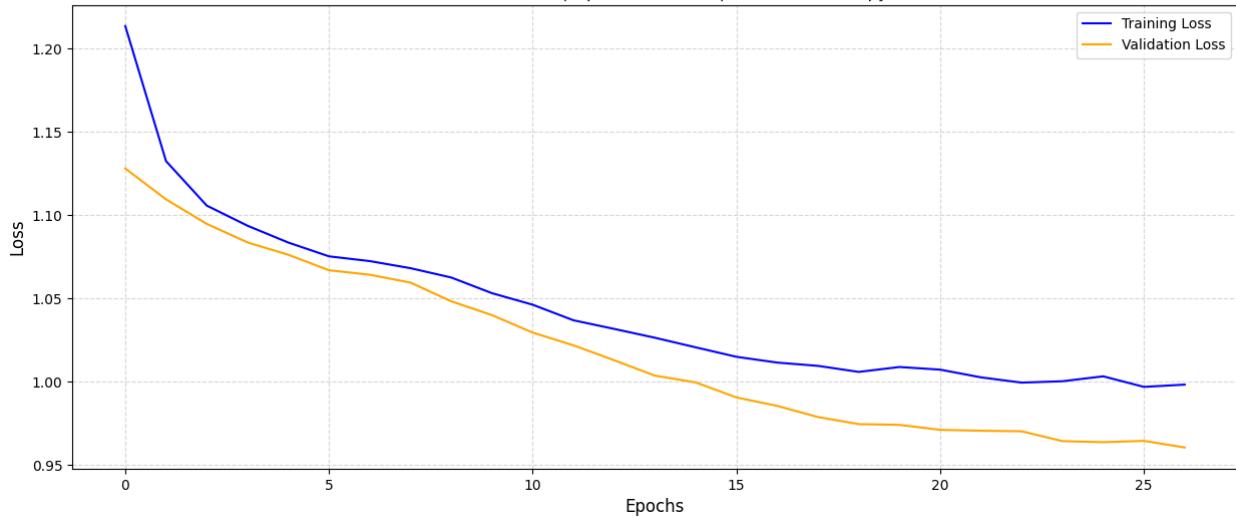


Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

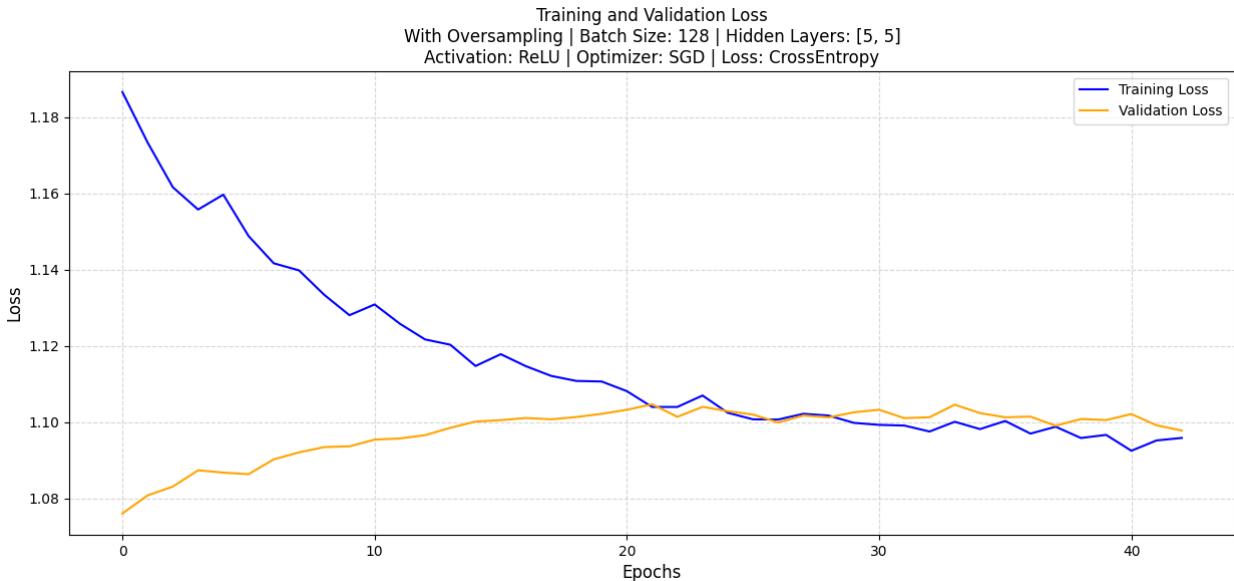


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [5, 5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy

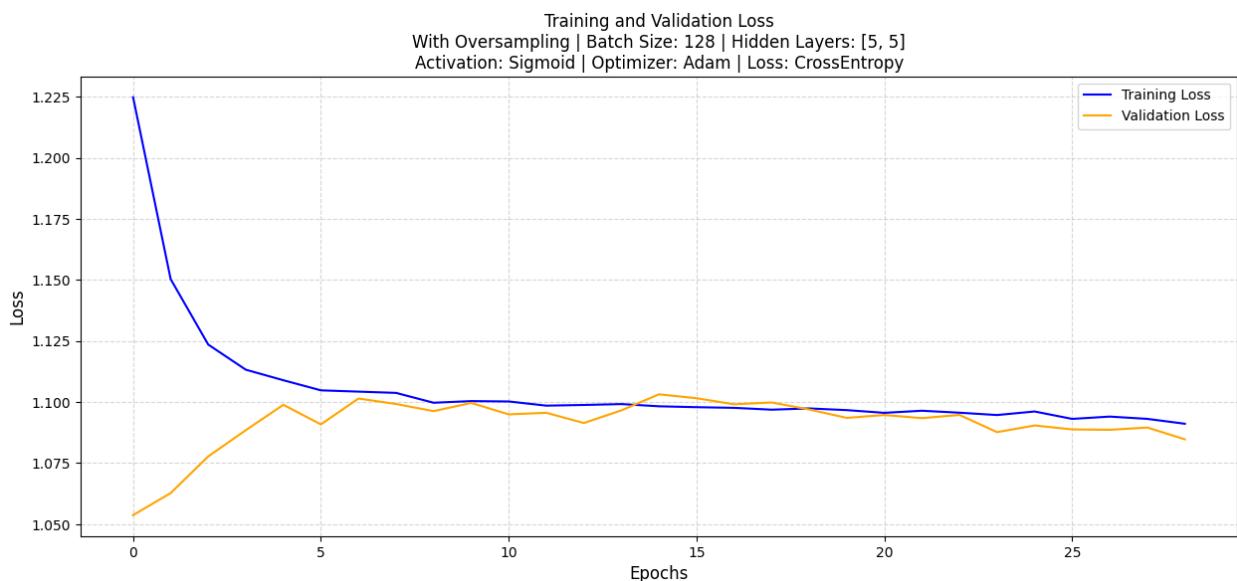


Early stopping triggered



Early stopping triggered

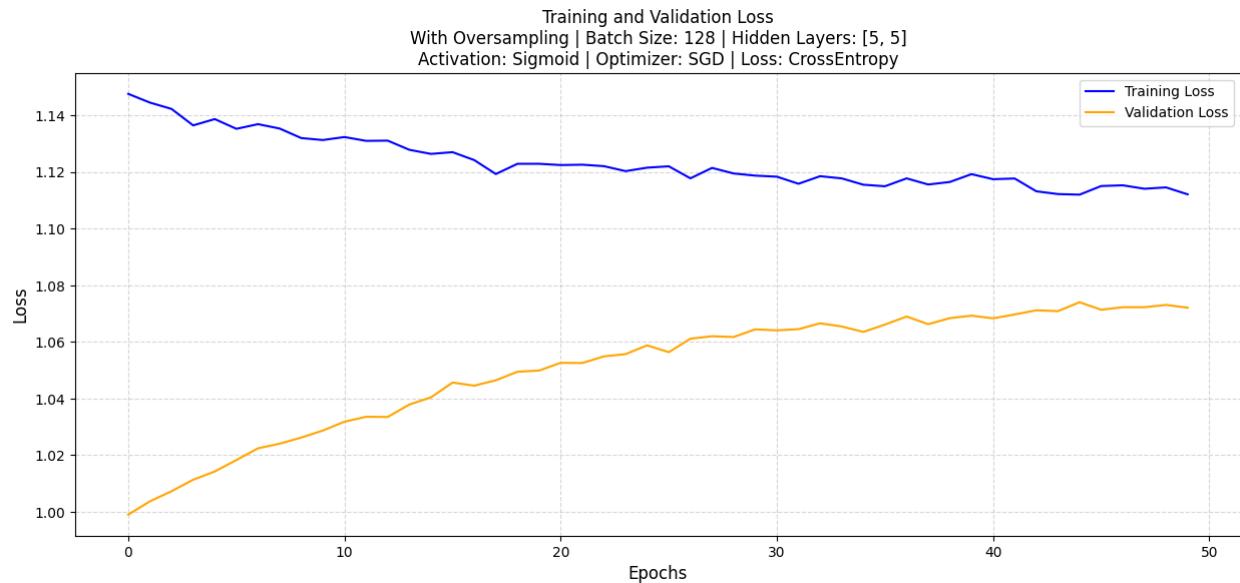
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



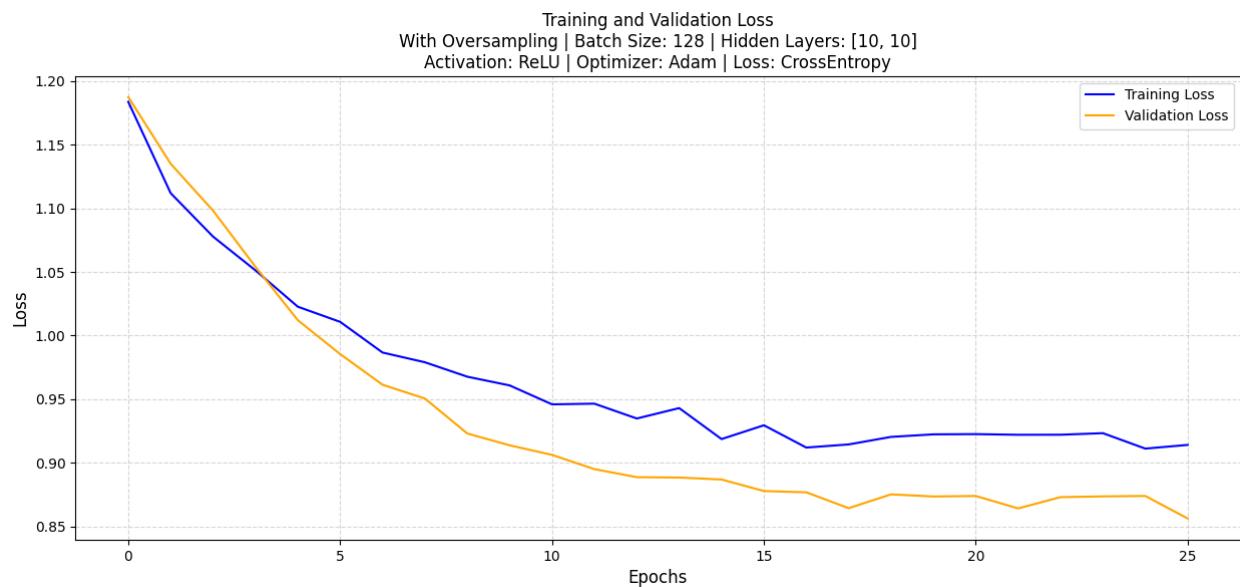
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
```

```
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.
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```
_warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```

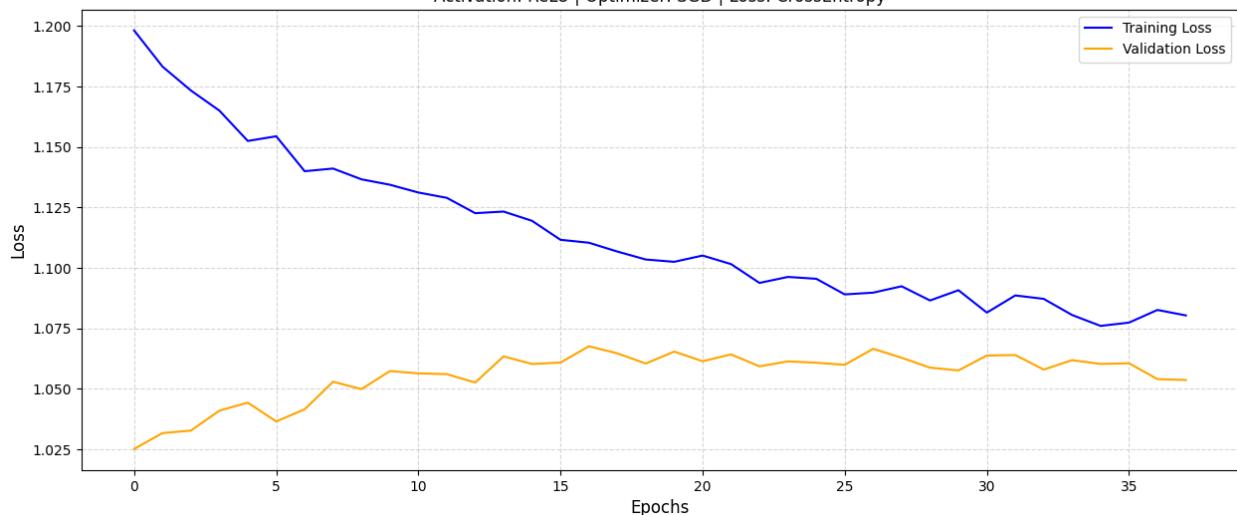


Early stopping triggered



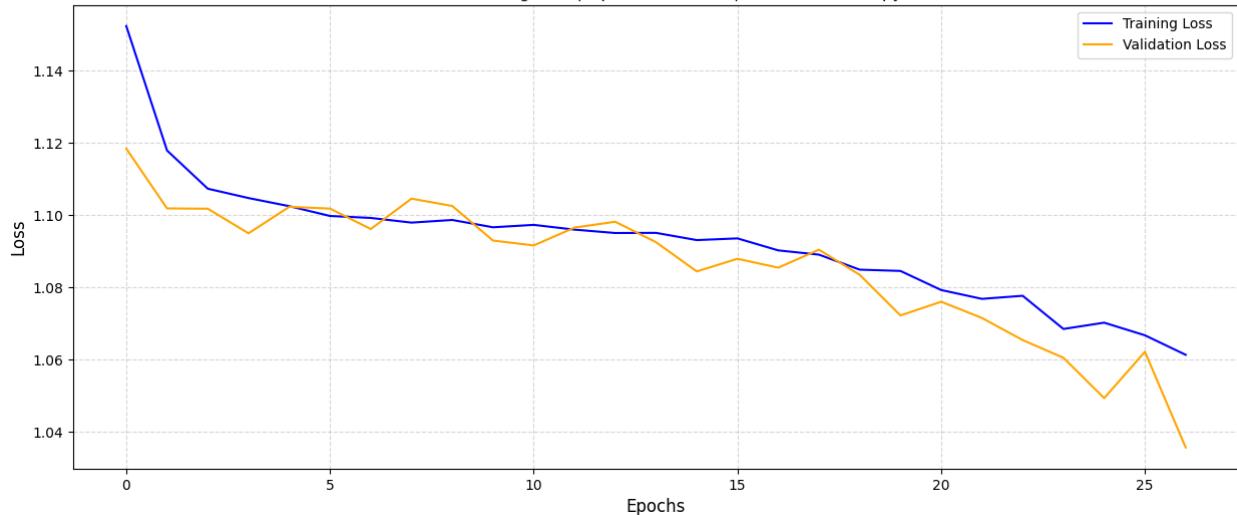
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



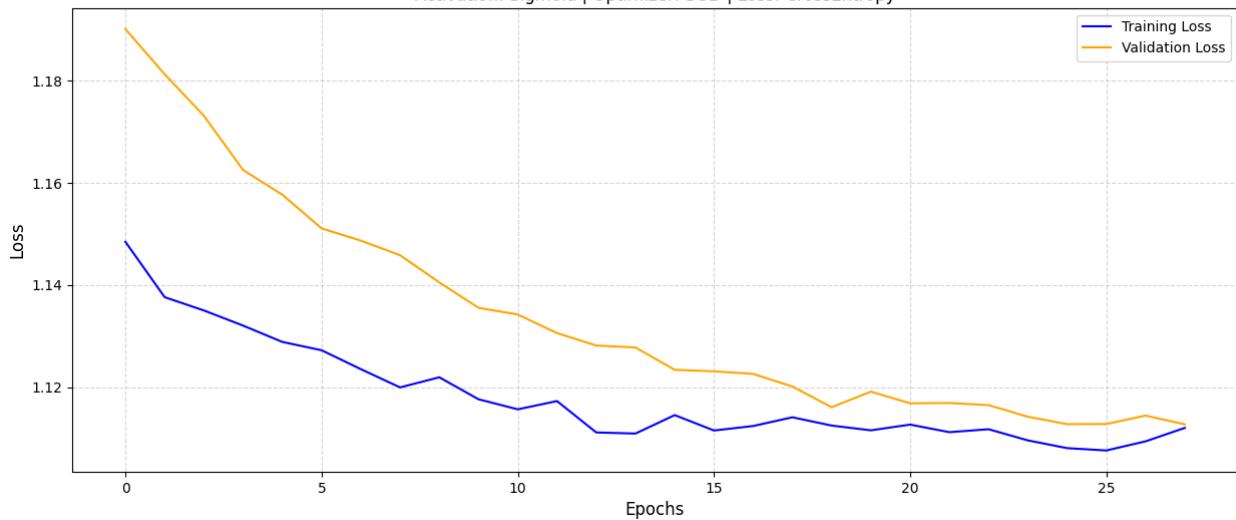
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Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



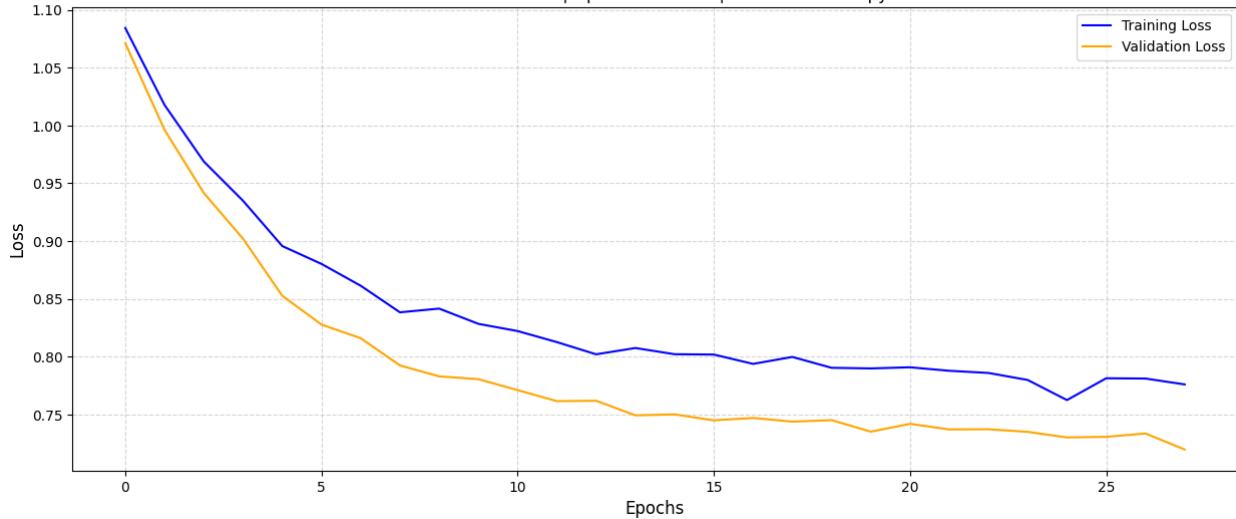
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Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



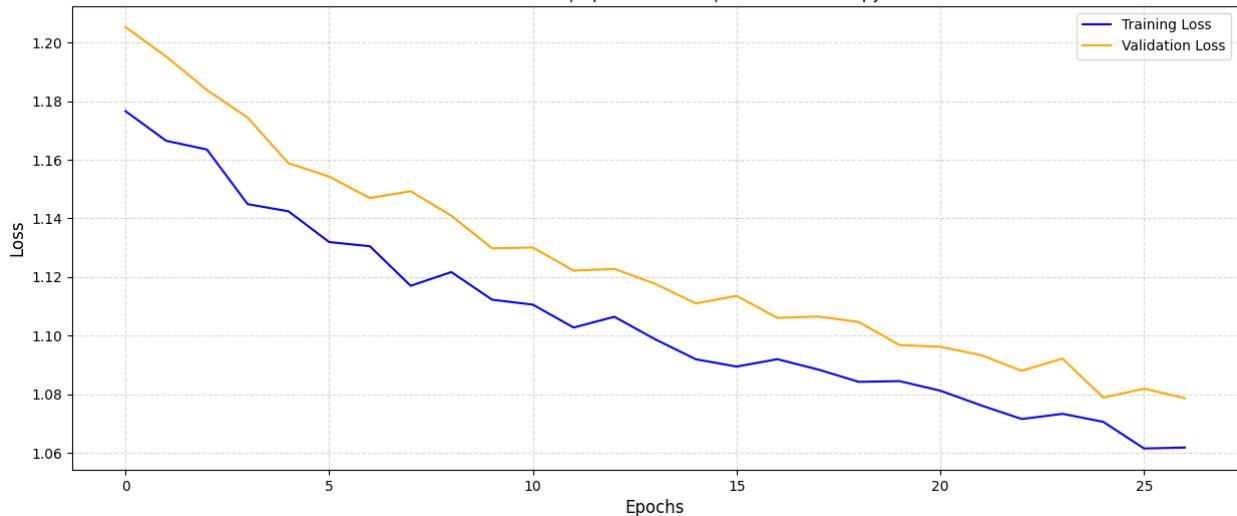
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



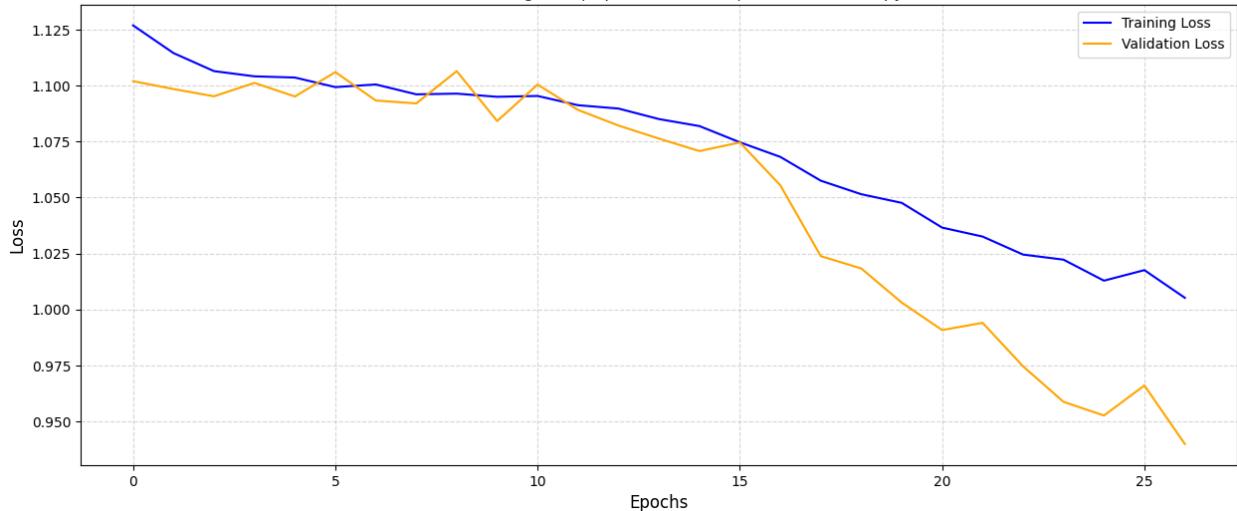
Early stopping triggered

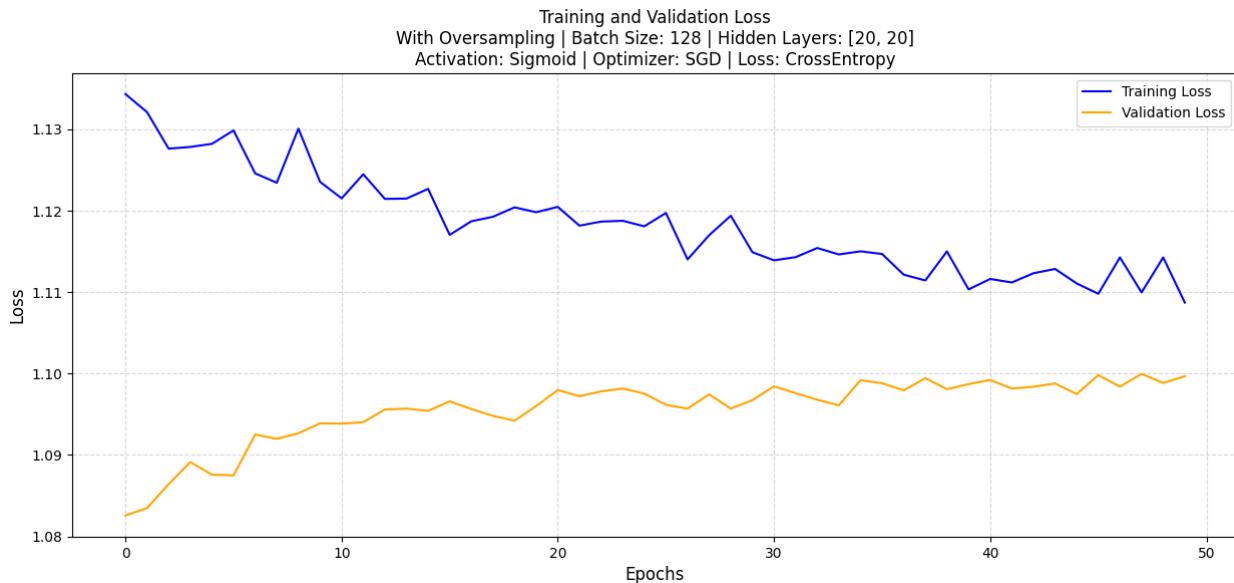
Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



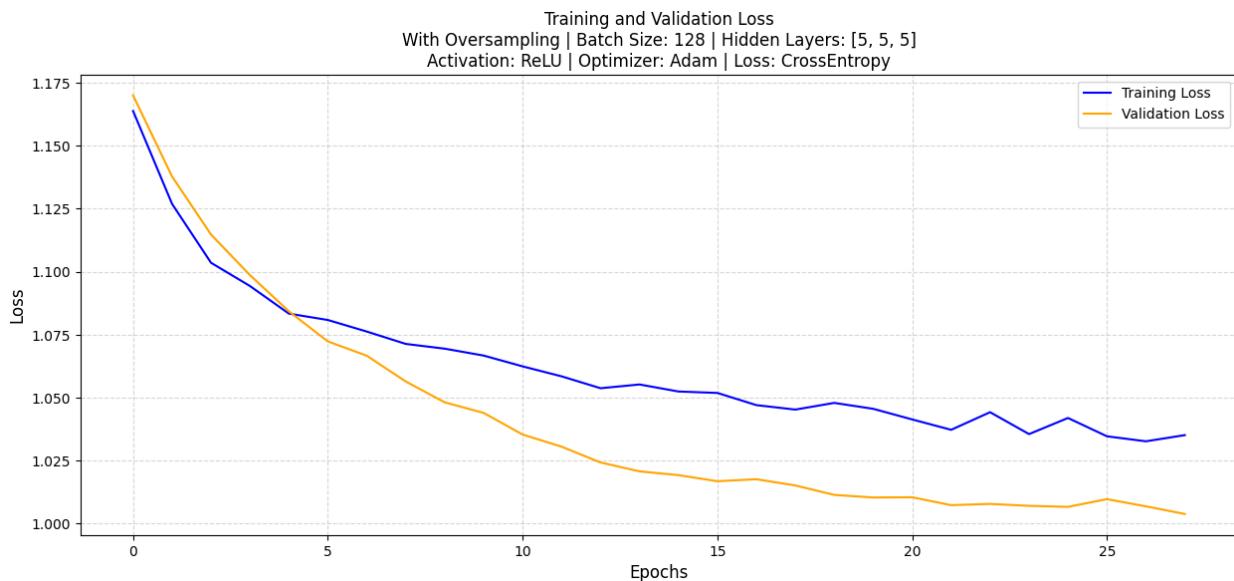
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



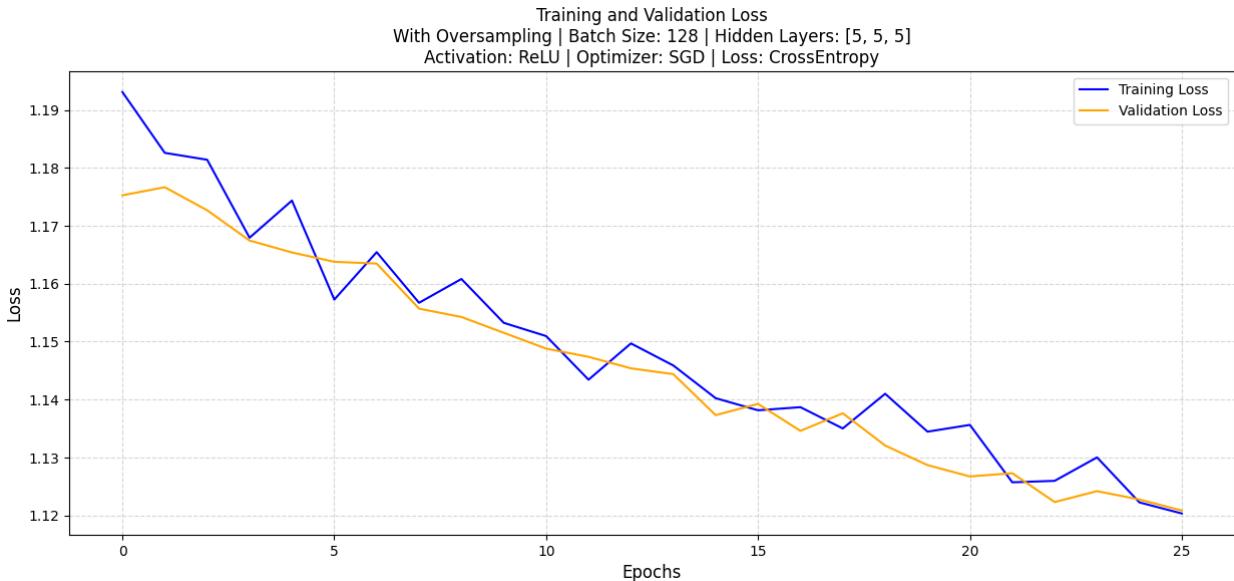


Early stopping triggered



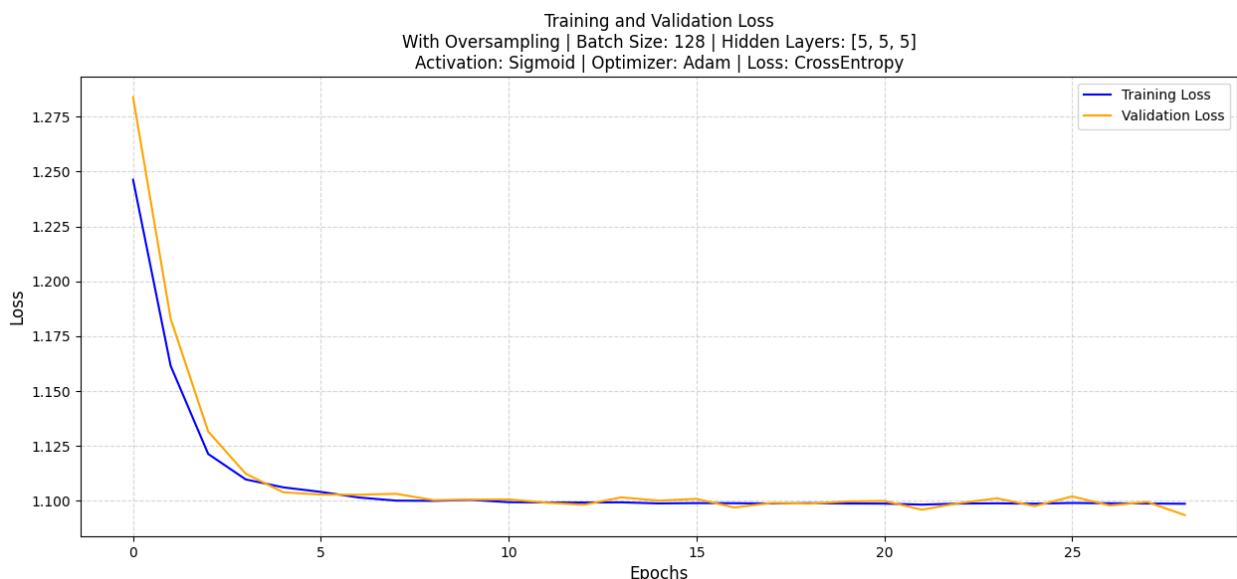
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
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Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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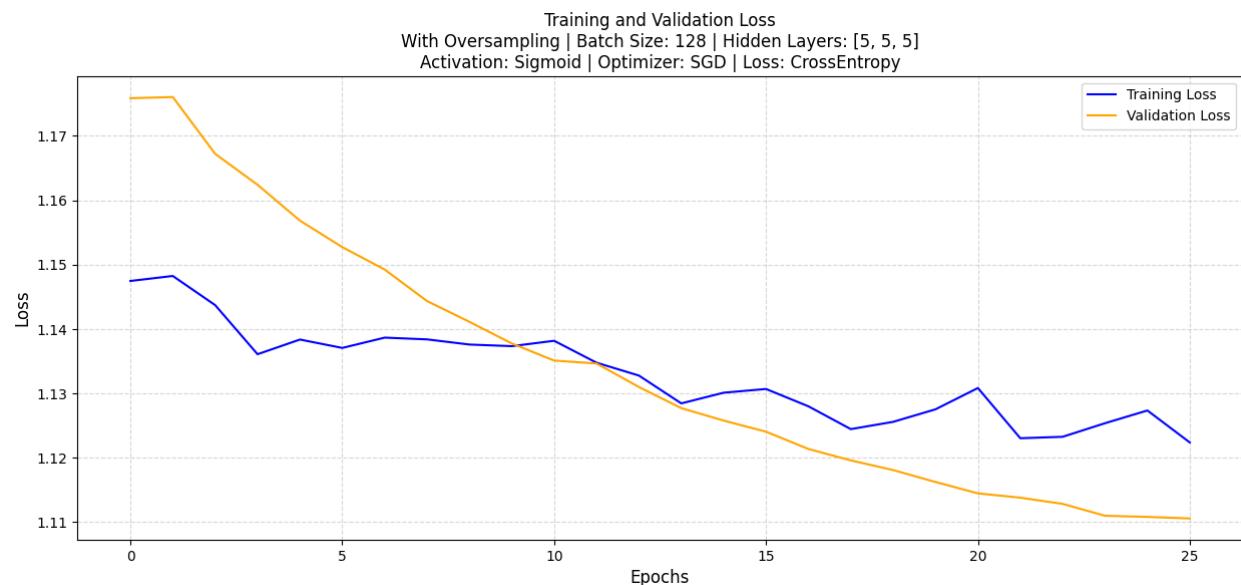


Early stopping triggered

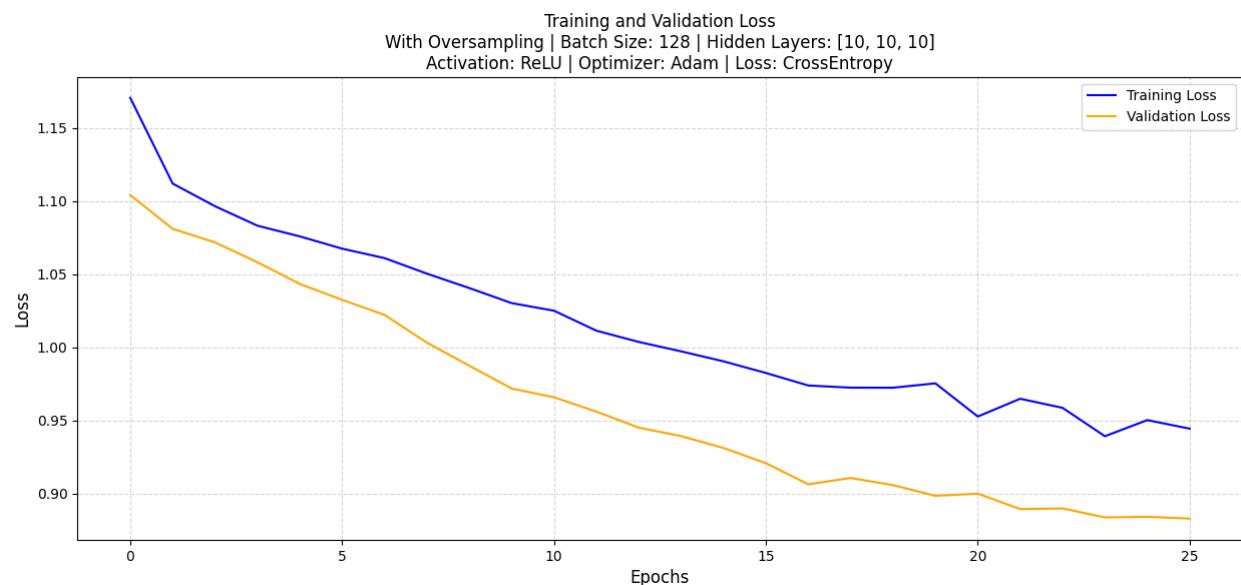
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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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len(result))

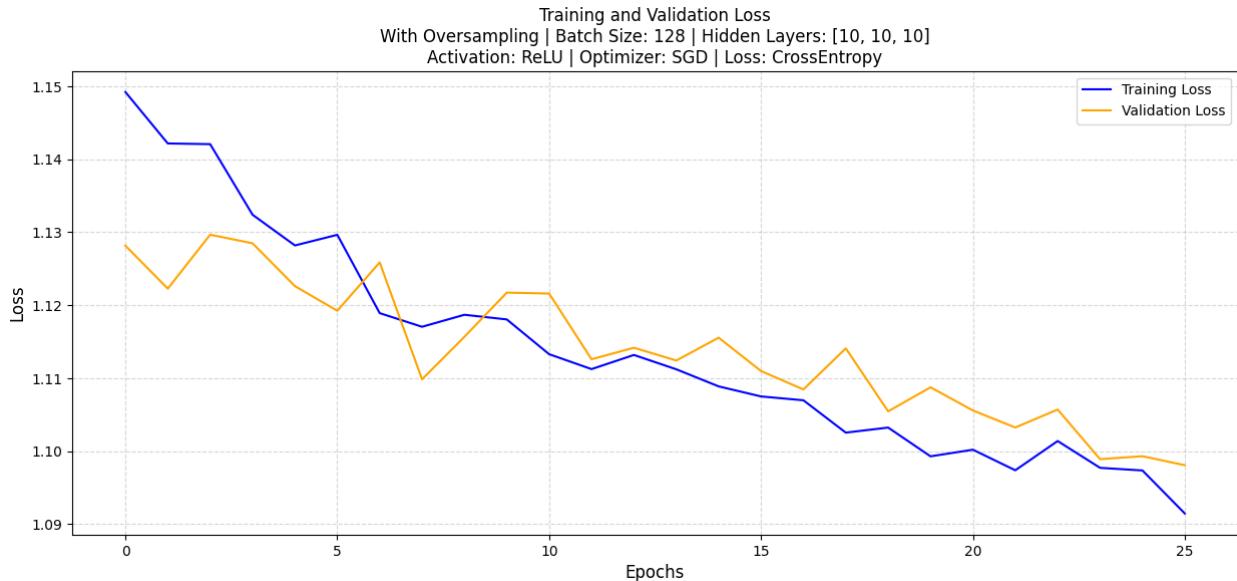
```



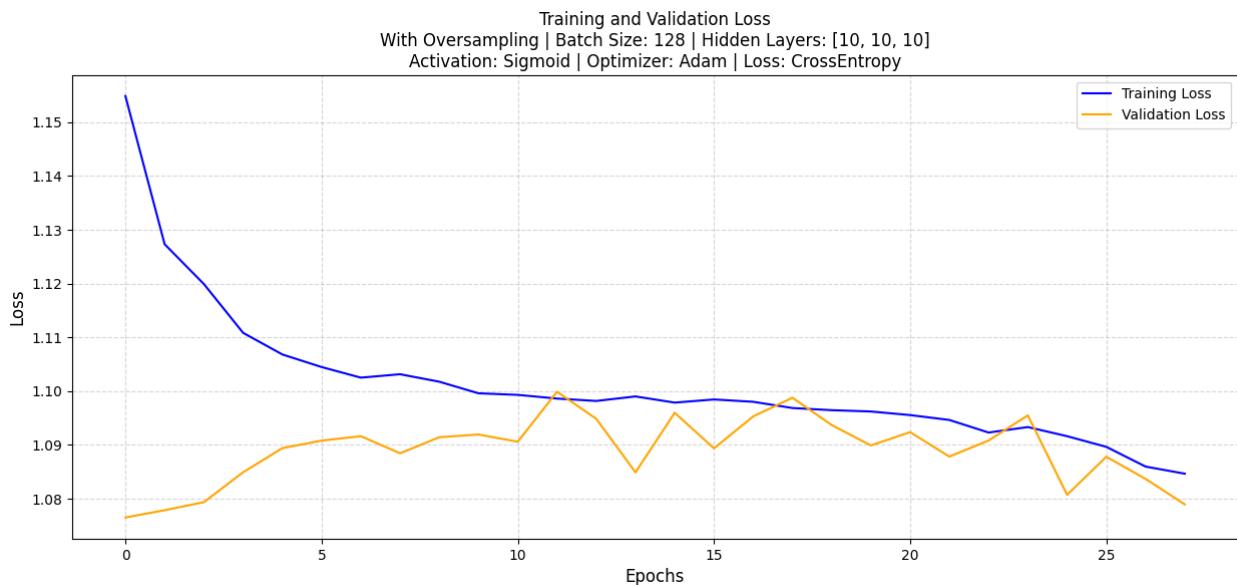
Early stopping triggered



Early stopping triggered

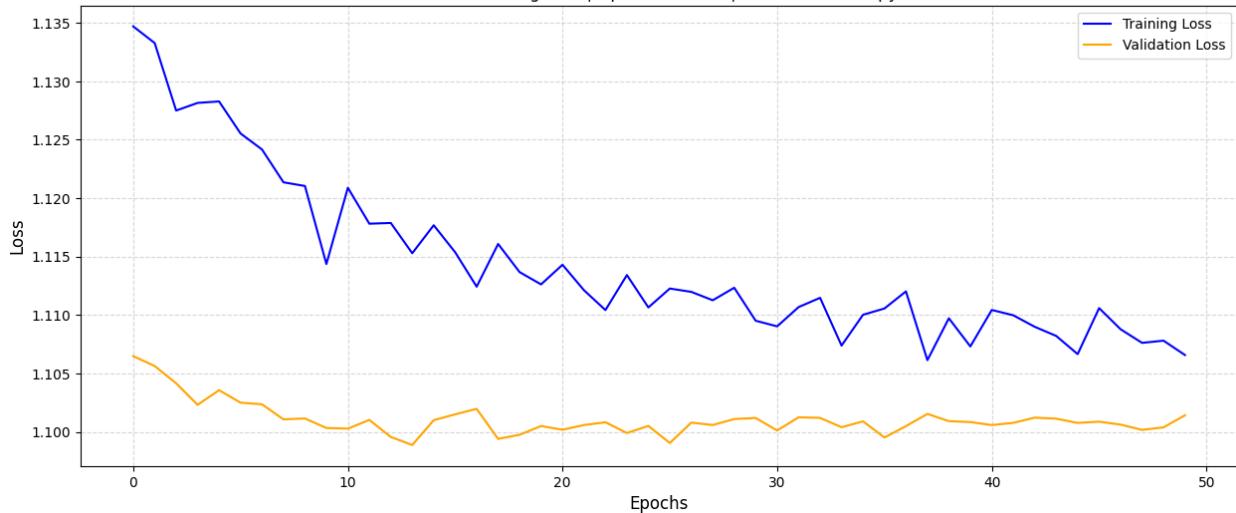


Early stopping triggered



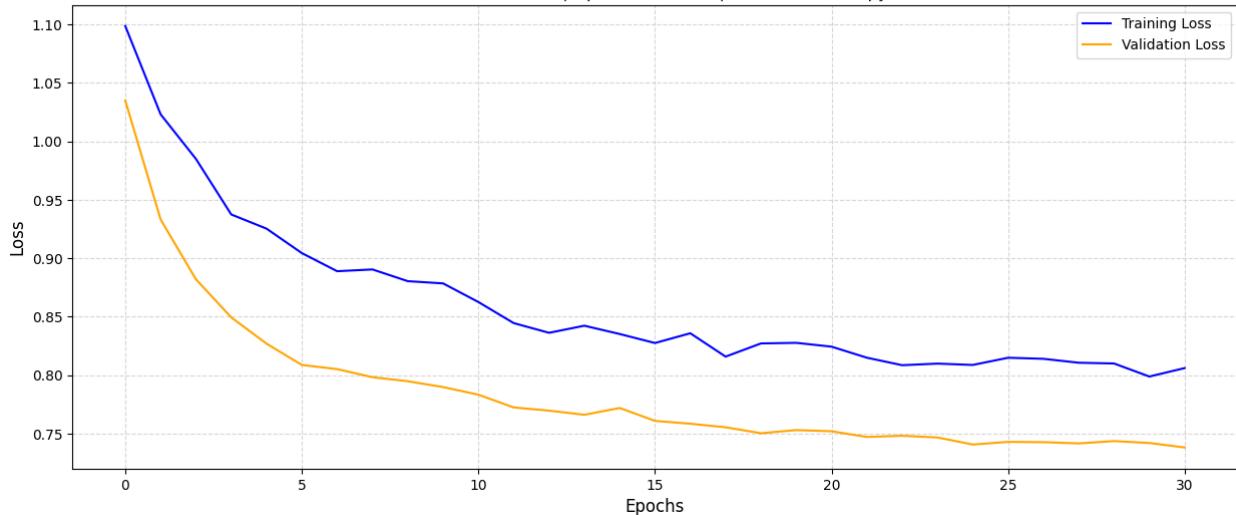
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10, 10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

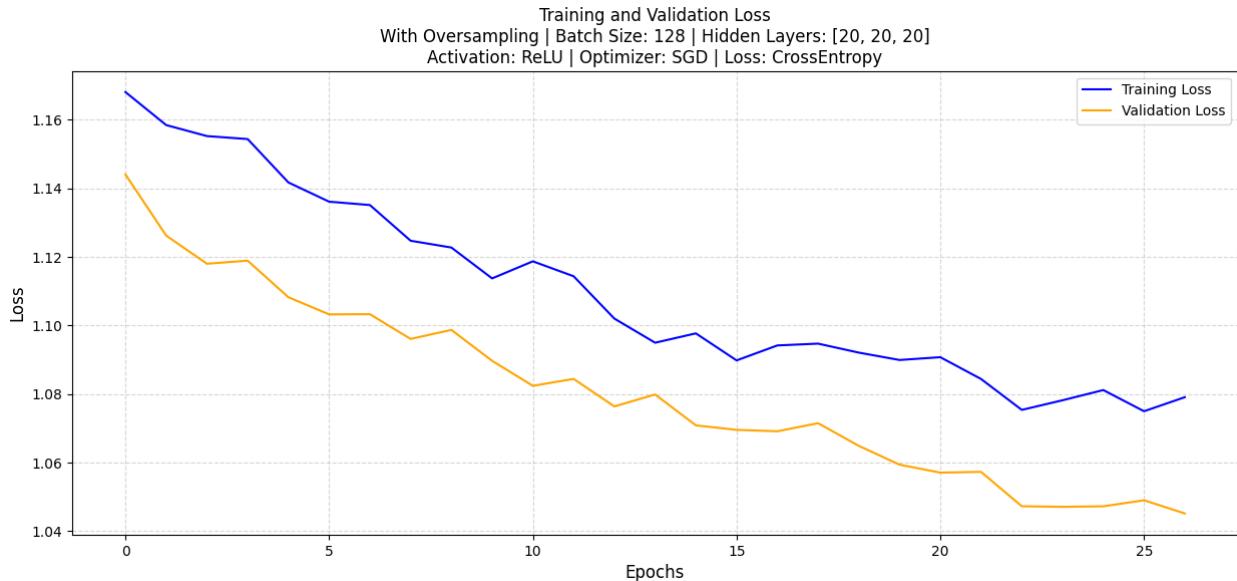


Early stopping triggered

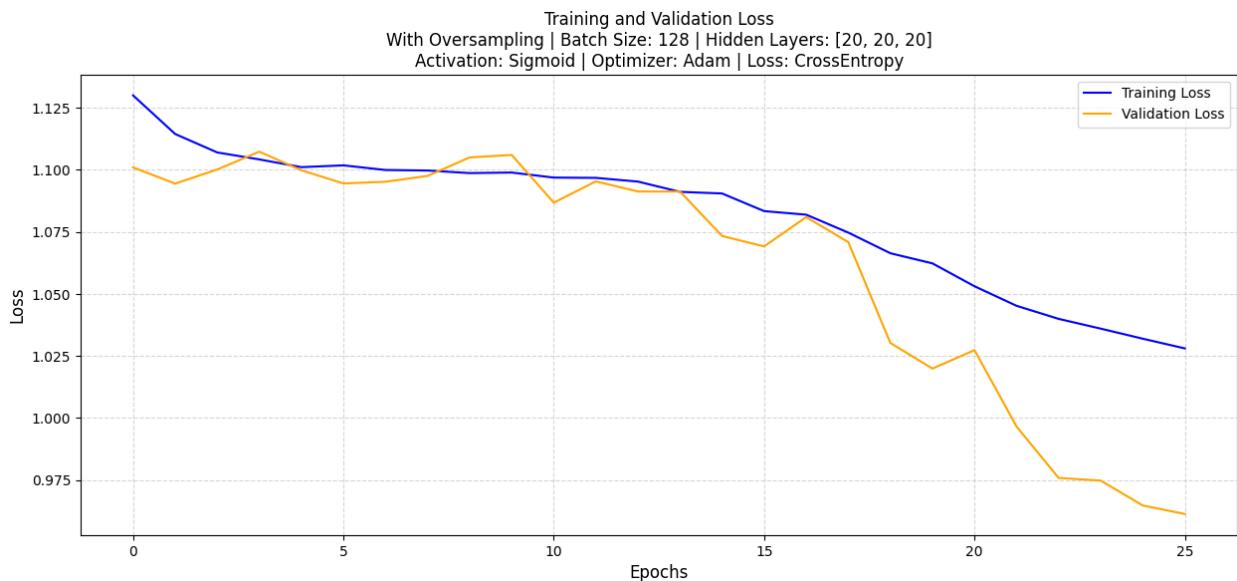
Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20, 20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



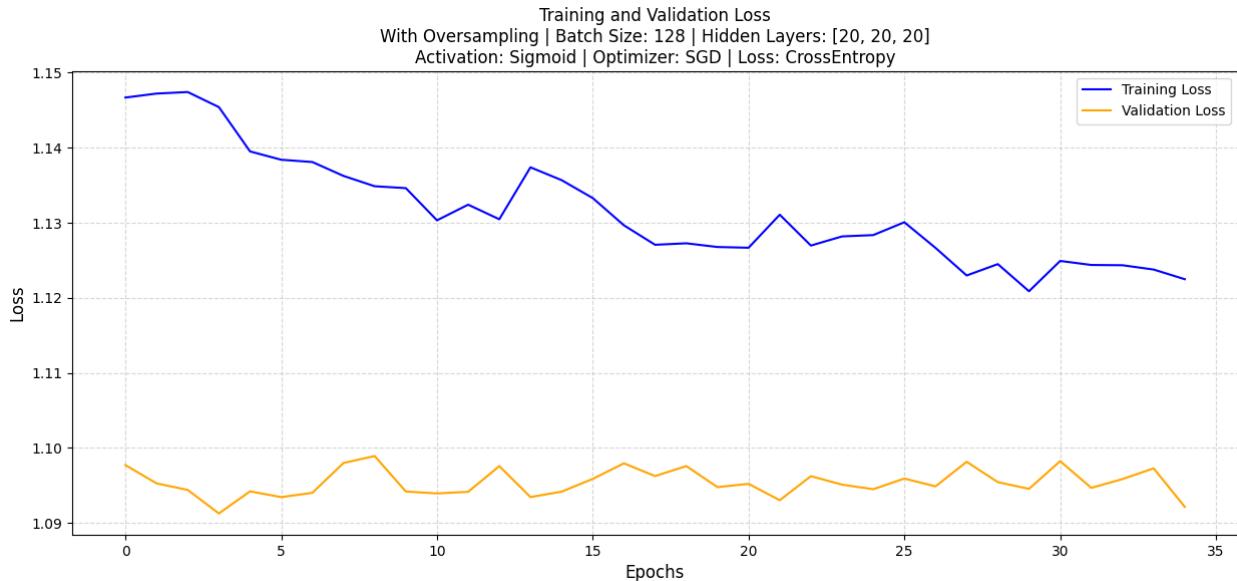
Early stopping triggered



Early stopping triggered



Early stopping triggered



```
Global best model is saved at: best_model_With
Oversampling_32_[20].pth with validation accuracy: 0.7361344537815127
```

```
df_results = pd.DataFrame(results)
top_10_results = df_results.sort_values(by='val_accuracy',
                                         ascending=False).head(10)
print("Top 10 Results based on Validation Accuracy:")
display(top_10_results)
```

Top 10 Results based on Validation Accuracy:

	oversample	batch_size	hidden_layers	activation_fn
optimizer \				
116 With Oversampling		32	[20]	ReLU
Adam				
152 With Oversampling		64	[20]	ReLU
Adam				
20 No Oversampling		32	[20, 20]	ReLU
Adam				
188 With Oversampling		128	[20]	ReLU
Adam				
44 No Oversampling		64	[20]	ReLU
Adam				
56 No Oversampling		64	[20, 20]	ReLU
Adam				
118 With Oversampling		32	[20]	Sigmoid
Adam				
8 No Oversampling		32	[20]	ReLU
Adam				
112 With Oversampling		32	[10]	ReLU
Adam				
80 No Oversampling		128	[20]	ReLU

Adam

```
    loss_function  val_accuracy  test_accuracy  precision      recall
f1_score \
116  CrossEntropy      0.736134        0.704623  0.725090  0.704623
0.704795
152  CrossEntropy      0.728852        0.709361  0.729186  0.709361
0.711195
20   CrossEntropy      0.728291        0.689593  0.673134  0.689593
0.667681
188  CrossEntropy      0.711485        0.699232  0.724180  0.699232
0.702391
44   CrossEntropy      0.700280        0.710341  0.685129  0.710341
0.697218
56   CrossEntropy      0.699720        0.677667  0.663676  0.677667
0.653386
118  CrossEntropy      0.696919        0.633230  0.666685  0.633230
0.624333
8    CrossEntropy      0.688515        0.696782  0.671936  0.696782
0.682688
112  CrossEntropy      0.677311        0.659696  0.679798  0.659696
0.658794
80   CrossEntropy      0.664426        0.661003  0.639252  0.661003
0.643404

                                              confusion_matrix      time
116  [[210, 1, 0], [319, 1649, 882], [26, 580, 2454]]  24.820155
152  [[210, 1, 0], [316, 1720, 814], [30, 618, 2412]]  17.312466
20   [[0, 211, 0], [0, 1528, 1322], [0, 367, 2693]]  24.491289
188  [[211, 0, 0], [361, 1673, 816], [42, 622, 2396]]  11.658684
44   [[0, 211, 0], [0, 1952, 898], [0, 664, 2396]]  9.046268
56   [[0, 211, 0], [0, 1437, 1413], [0, 349, 2711]]  12.343395
118  [[203, 8, 0], [417, 1190, 1243], [61, 516, 2483]]  25.239007
8    [[0, 210, 1], [0, 1833, 1017], [0, 628, 2432]]  13.682465
112  [[201, 10, 0], [348, 1485, 1017], [35, 673, 23...  21.616693
80   [[0, 200, 11], [0, 1565, 1285], [0, 579, 2481]]  7.325312

activation_functions = {
    "ReLU": nn.ReLU,
    "Sigmoid": nn.Sigmoid,
    "Tanh": nn.Tanh
}

if global_best_path:
    print(f"Loading global best model from: {global_best_path}")

    global_best_model_info = max(results, key=lambda x:
x['val_accuracy'])

    print("Global Best Model Information:")
```

```

    print(f"Validation Accuracy: {global_best_model_info['val_accuracy']:.4f}")
    print(f"Test Accuracy: {global_best_model_info['test_accuracy']:.4f}")
    print(f"Precision: {global_best_model_info['precision']:.4f}")
    print(f"Recall: {global_best_model_info['recall']:.4f}")
    print(f"F1 Score: {global_best_model_info['f1_score']:.4f}")
    print(f"Hidden Layers: {global_best_model_info['hidden_layers']}")
    print(f"Activation Function: {global_best_model_info['activation_fn']}")
    print(f"Optimizer: {global_best_model_info['optimizer']}")
    print(f"Loss Function: {global_best_model_info['loss_function']}")
    print(f"Oversampling: {global_best_model_info['oversample']}")
    print(f"Batch Size: {global_best_model_info['batch_size']}")

    best_conf_matrix = global_best_model_info['confusion_matrix']
    print("Confusion Matrix for Best Model:")
    print(best_conf_matrix)

    disp = ConfusionMatrixDisplay(confusion_matrix=best_conf_matrix,
display_labels=['Class 1', 'Class 2', 'Class 3'])
    disp.plot(cmap=plt.cm.Blues)
    plt.title("Confusion Matrix for Global Best Model")
    plt.show()

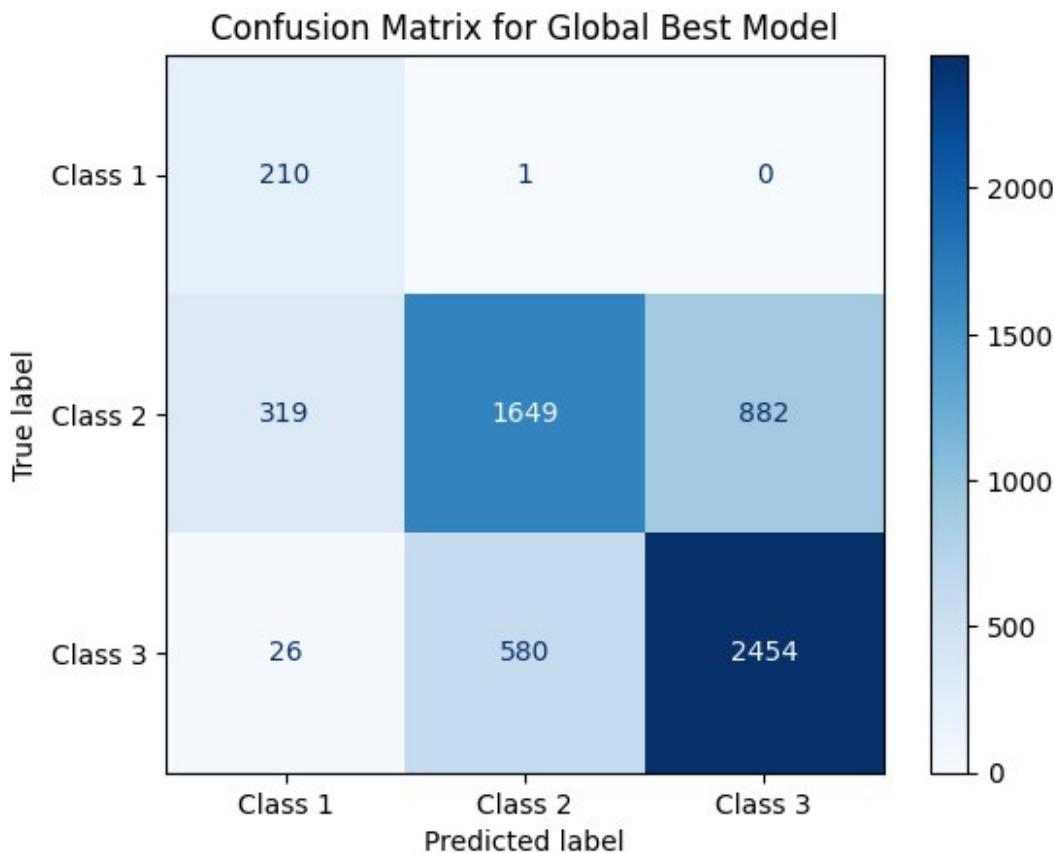
    hidden_layers = global_best_model_info['hidden_layers']
    activation_fn =
activation_functions[global_best_model_info['activation_fn']]
    global_best_model = MLP(input_size=10,
hidden_layers=hidden_layers, activation_fn=activation_fn)
    global_best_model.load_state_dict(torch.load(global_best_path))
    global_best_model.eval()
    print("Global best model loaded successfully!")
else:
    print("No global best model found.")

Loading global best model from: best_model_With
Oversampling_32_[20].pth
Global Best Model Information:
Validation Accuracy: 0.7361
Test Accuracy: 0.7046
Precision: 0.7251
Recall: 0.7046
F1 Score: 0.7048
Hidden Layers: [20]
Activation Function: ReLU
Optimizer: Adam
Loss Function: CrossEntropy
Oversampling: With Oversampling
Batch Size: 32

```

```
Confusion Matrix for Best Model:
```

```
[[ 210   1   0]
 [ 319 1649  882]
 [ 26   580 2454]]
```



```
Global best model loaded successfully!
```

Scaled data

```
column_names = [f"col_{i}" for i in range(16)]
train_data = pd.read_csv('train_1_to_3iz.dat', sep='\t', header=None,
names=column_names)
test_data = pd.read_csv('test_1_to_3iz.dat', sep='\t', header=None,
names=column_names)

X = train_data.iloc[:, [1, 2, 3, 4, 5, 7, 8, 9, 10, 11]].values
y = train_data.iloc[:, 15].values
X_test = test_data.iloc[:, [1, 2, 3, 4, 5, 7, 8, 9, 10, 11]].values
y_test = test_data.iloc[:, 15].values

X_train, X_val, y_train, y_val = train_test_split(X, y, test_size=0.2,
random_state=42)
```

```

X_train_os, y_train_os = oversample_data(X_train, y_train)
scaler = StandardScaler()

X_train_scaled = scaler.fit_transform(X_train)
X_train_os_scaled = scaler.transform(X_train_os)
X_val_scaled = scaler.transform(X_val)
X_test_scaled = scaler.transform(X_test)

X_train = torch.tensor(X_train_scaled, dtype=torch.float32)
y_train = torch.tensor(y_train, dtype=torch.long)
X_train_os = torch.tensor(X_train_os_scaled, dtype=torch.float32)
y_train_os = torch.tensor(y_train_os, dtype=torch.long)
X_val = torch.tensor(X_val_scaled, dtype=torch.float32)
y_val = torch.tensor(y_val, dtype=torch.long)
X_test = torch.tensor(X_test_scaled, dtype=torch.float32)
y_test = torch.tensor(y_test, dtype=torch.long)

batch_sizes = [32, 64, 128]
train_dataset_no_oversample = TensorDataset(X_train, y_train)
train_dataset_with_oversample = TensorDataset(X_train_os, y_train_os)
val_dataset = TensorDataset(X_val, y_val)
test_dataset = TensorDataset(X_test, y_test)

hidden_layer_configs = [[5], [10], [20], [5, 5], [10, 10], [20, 20],
[5, 5, 5], [10, 10, 10], [20, 20, 20]]
activation_fns = [nn.ReLU, nn.Sigmoid]
optimizers = [optim.Adam, optim.SGD]
loss_functions = {
    'CrossEntropy': nn.CrossEntropyLoss()
}
learning_rate = 0.001
num_epochs = 50

results_scaled = []
global_best_model = None
global_best_path = None
global_best_val_accuracy = 0

for train_dataset, oversample_flag in [(train_dataset_no_oversample,
'No Oversampling'), (train_dataset_with_oversample, 'With
Oversampling')]:
    for batch_size in batch_sizes:
        train_loader = DataLoader(train_dataset,
batch_size=batch_size, shuffle=True)
        val_loader = DataLoader(val_dataset, batch_size=batch_size,
shuffle=False)
        test_loader = DataLoader(test_dataset, batch_size=batch_size,
shuffle=False)

```

```

    for hidden_layers in hidden_layer_configs:
        for activation_fn in activation_fns:
            for optimizer_fn in optimizers:
                for loss_name, criterion in
loss_functions.items():

                    model = MLP(input_size=10,
hidden_layers=hidden_layers, activation_fn=activation_fn)
                    optimizer = optimizer_fn(model.parameters(),
lr=learning_rate)

                    start_time = time.time()
                    best_val_accuracy = 0
                    best_val_loss = float('inf')
                    history = {'loss': [], 'val_loss': []}

                    for epoch in range(num_epochs):
                        model.train()
                        epoch_loss = 0
                        for X_batch, y_batch in train_loader:
                            optimizer.zero_grad()
                            outputs = model(X_batch)
                            y_batch = y_batch - 1
                            loss = criterion(outputs, y_batch)
                            loss.backward()
                            optimizer.step()
                            epoch_loss += loss.item()
                        history['loss'].append(epoch_loss /
len(train_loader))

                        model.eval()
                        val_loss = 0
                        val_preds = []
                        val_targets = []
                        with torch.no_grad():
                            for X_batch, y_batch in val_loader:
                                outputs = model(X_batch)
                                y_batch = y_batch - 1
                                loss = criterion(outputs, y_batch)
                                val_loss += loss.item()
                                preds = torch.argmax(outputs,
dim=1)
                                val_preds.extend(preds.tolist())

                        val_targets.extend(y_batch.tolist())
                        history['val_loss'].append(val_loss /
len(val_loader))

                        val_accuracy = accuracy_score(val_targets,
val_preds)

```

```

        if val_accuracy > best_val_accuracy:
            best_val_accuracy = val_accuracy

        if val_loss < best_val_loss:
            best_val_loss = val_loss
            model_path =
f'best_model_{oversample_flag}_{batch_size}_{hidden_layers}_scaled.pth'
        torch.save(model.state_dict(),
model_path)

        if val_accuracy >
global_best_val_accuracy:
            global_best_val_accuracy =
val_accuracy
            global_best_path = model_path

        if len(history['val_loss']) > 25 and all(l
>= history['val_loss'][-1] for l in history['val_loss'][-25:]):
            print("Early stopping triggered")
            break

    end_time = time.time()
    model.eval()
    test_preds = []
    test_targets = []
    with torch.no_grad():
        for X_batch, y_batch in test_loader:
            outputs = model(X_batch)
            y_batch = y_batch - 1
            preds = torch.argmax(outputs, dim=1)
            test_preds.extend(preds.tolist())
            test_targets.extend(y_batch.tolist())

    test_accuracy = accuracy_score(test_targets,
test_preds)
    precision, recall, f1, _ =
precision_recall_fscore_support(test_targets, test_preds,
average='weighted')
    conf_matrix = confusion_matrix(test_targets,
test_preds)

    results_scaled.append({
        'oversample': oversample_flag,
        'batch_size': batch_size,
        'hidden_layers': hidden_layers,
        'activation_fn': activation_fn.__name__,
        'optimizer': optimizer_fn.__name__,
        'loss_function': loss_name,
        'val_accuracy': best_val_accuracy,
    })

```

```

        'test_accuracy': test_accuracy,
        'precision': precision,
        'recall': recall,
        'f1_score': f1,
        'confusion_matrix': conf_matrix,
        'time': end_time - start_time
    })

    plot_train_history(history, oversample_flag,
batch_size, hidden_layers, activation_fn.__name__,
optimizer_fn.__name__, loss_name)

print(f"Global best model is saved at: {global_best_path} with
validation accuracy: {global_best_val_accuracy}")

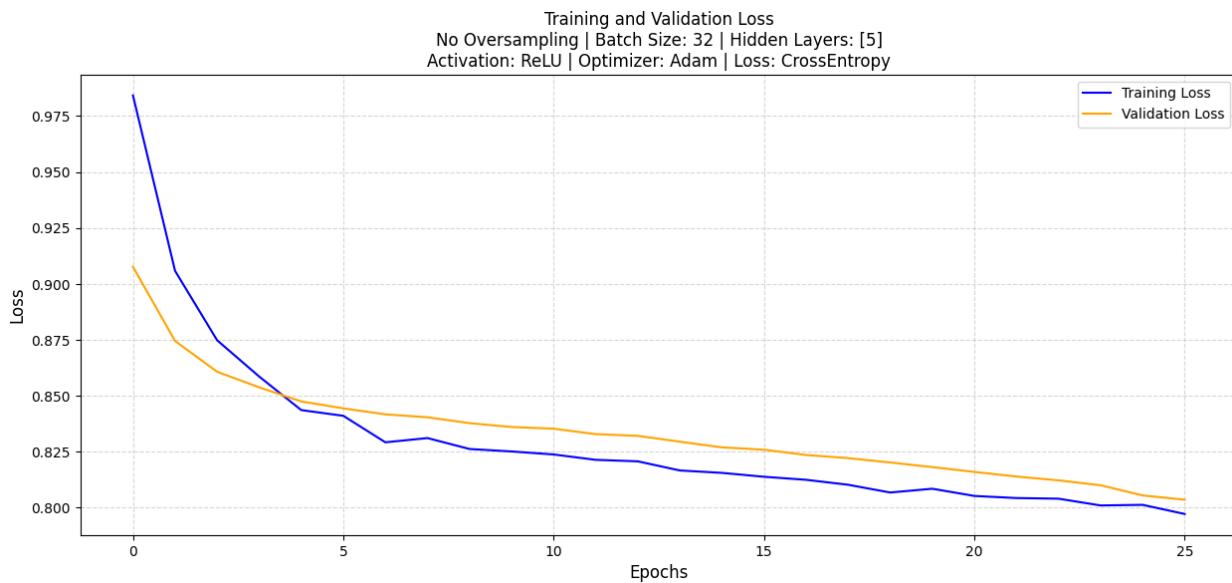
```

Early stopping triggered

```

c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))

```



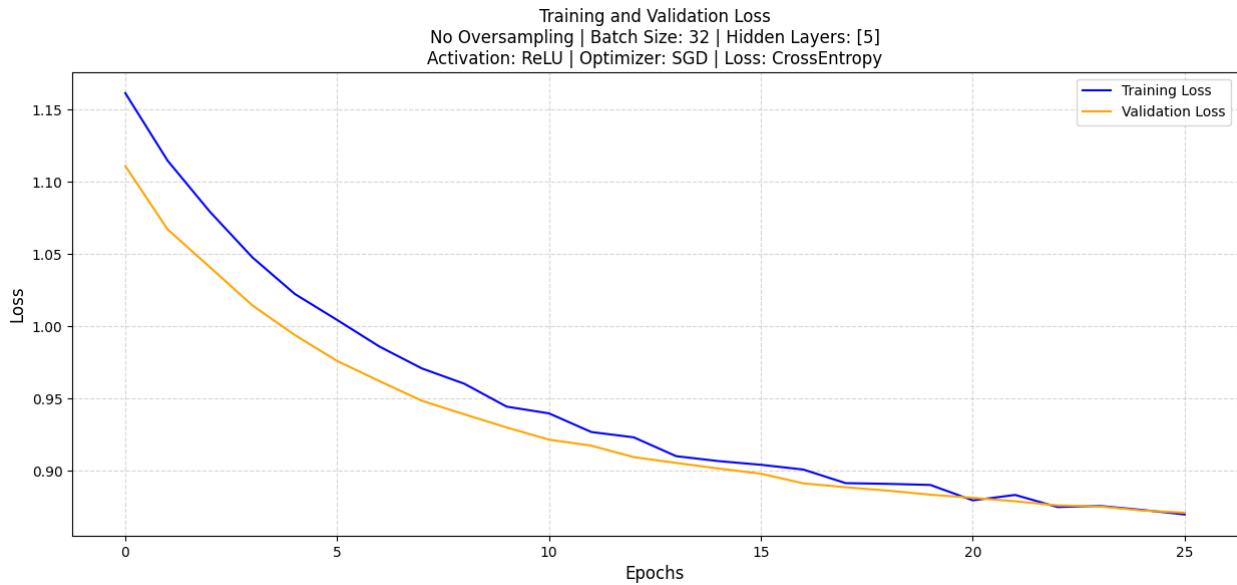
Early stopping triggered

```

c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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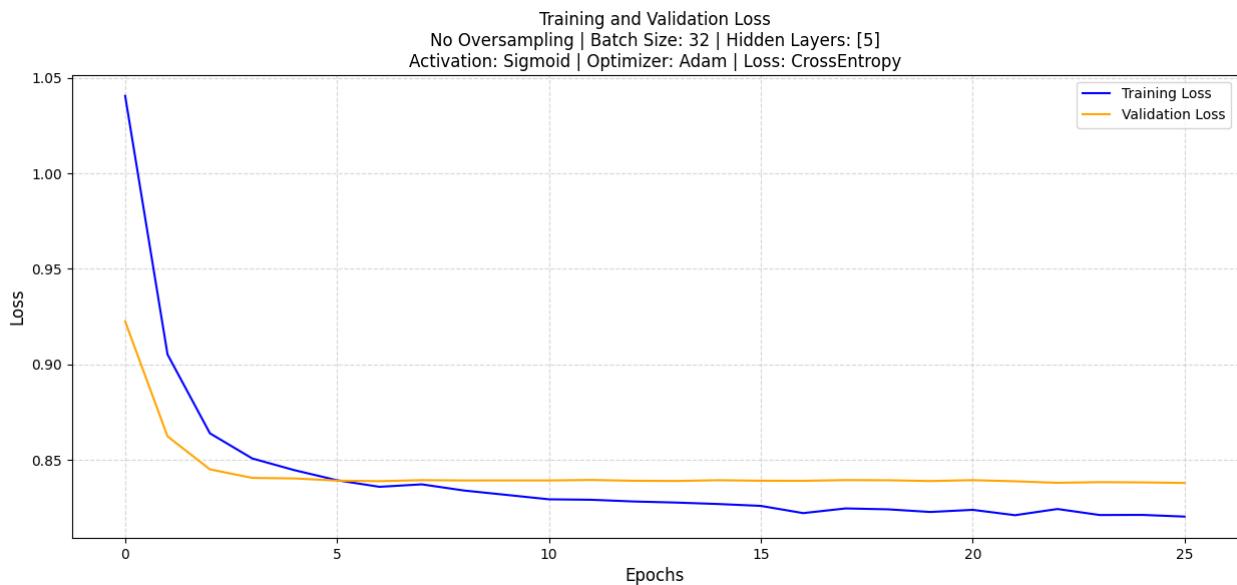
```

```
_warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



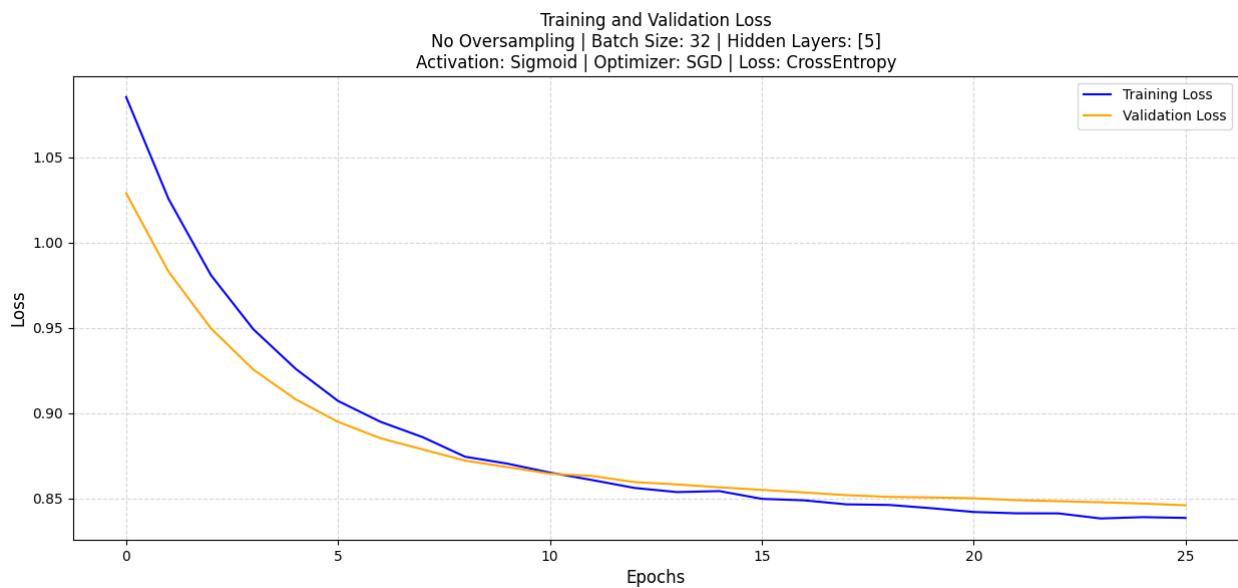
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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_warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



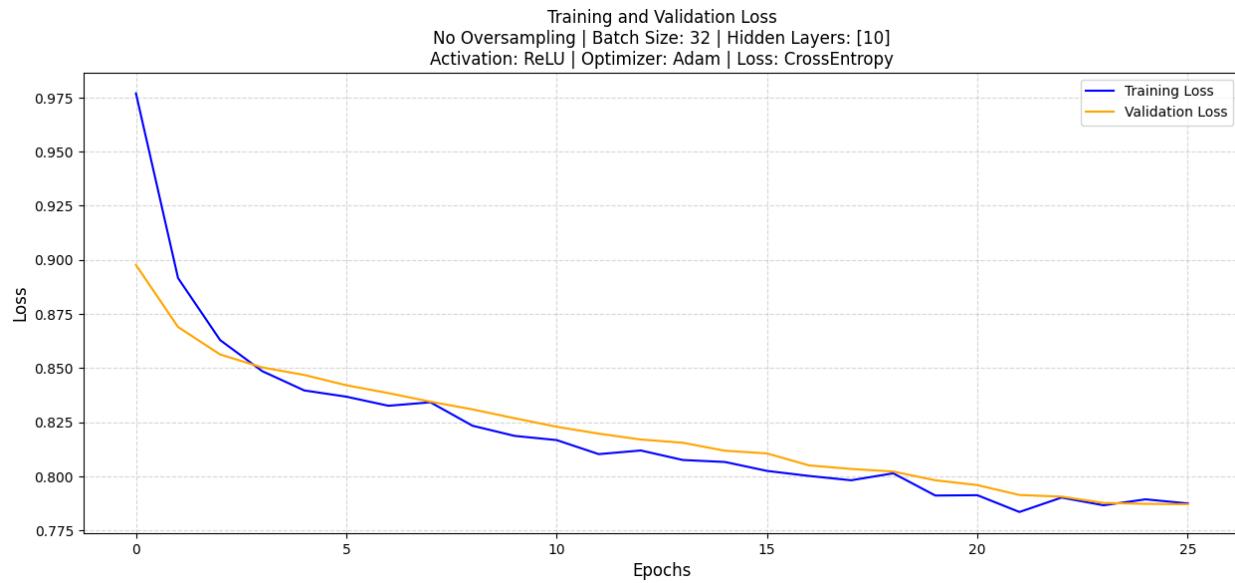
```
Early stopping triggered
```

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



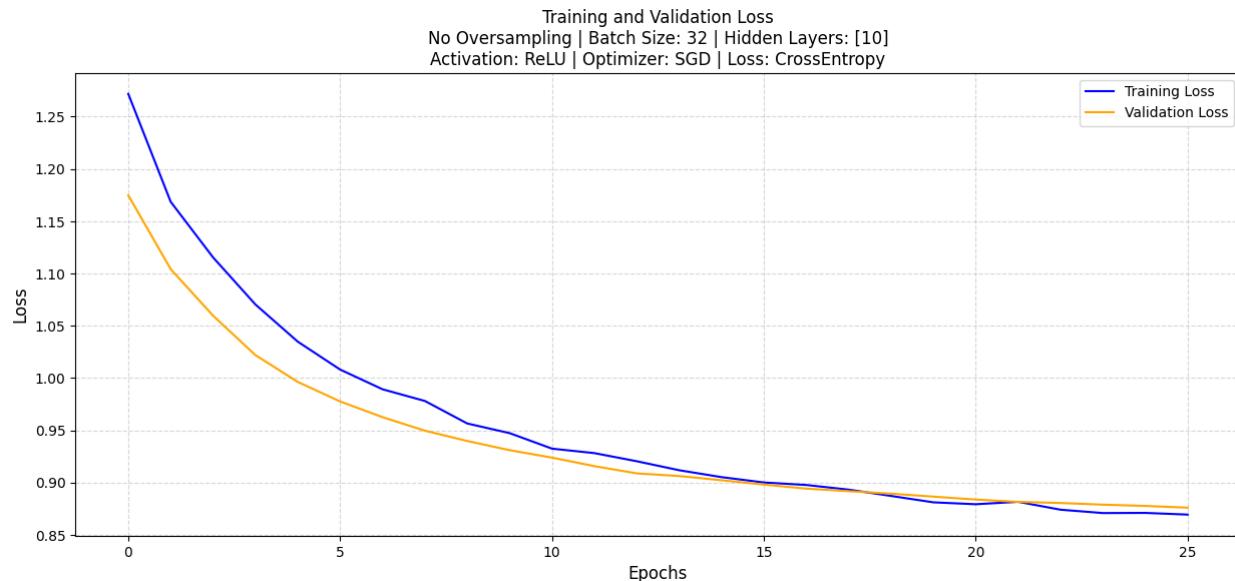
```
Early stopping triggered
```

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



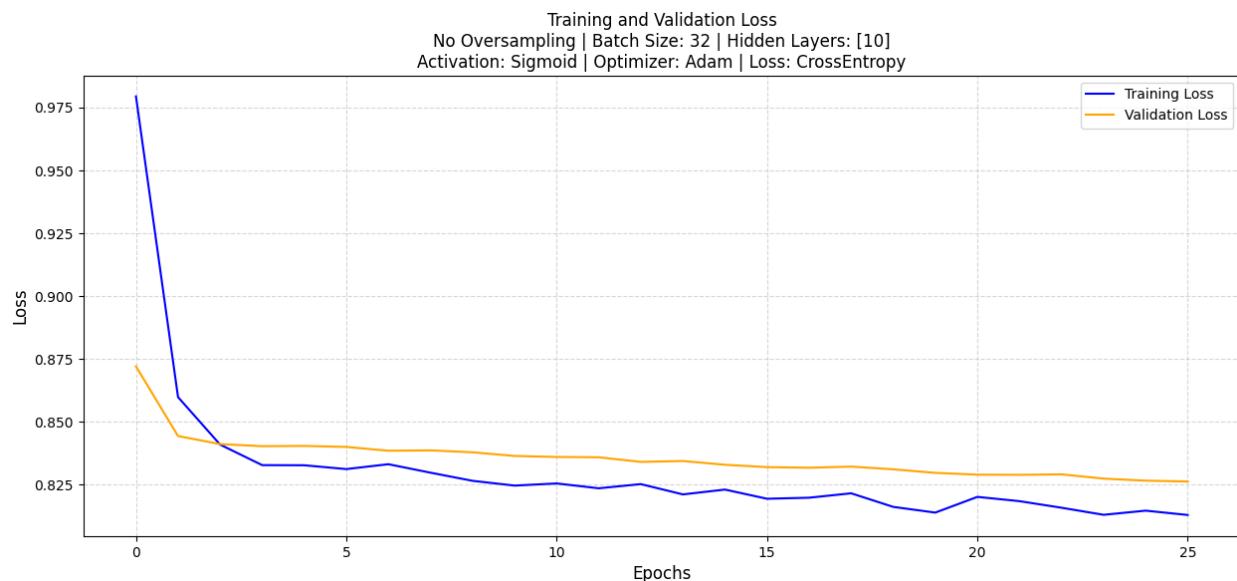
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



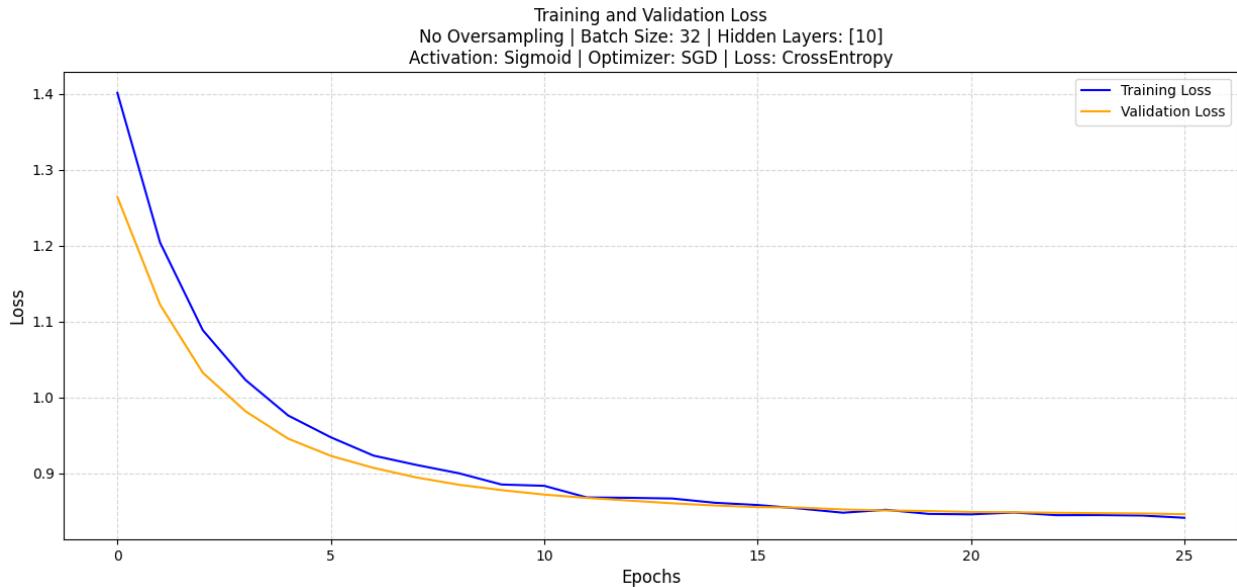
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



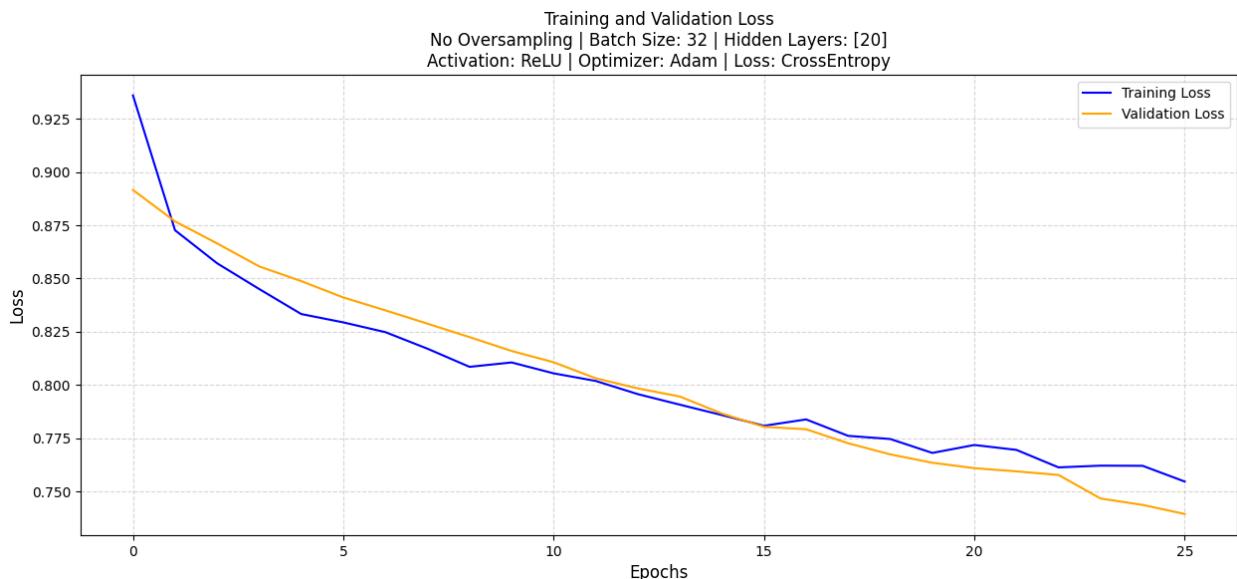
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



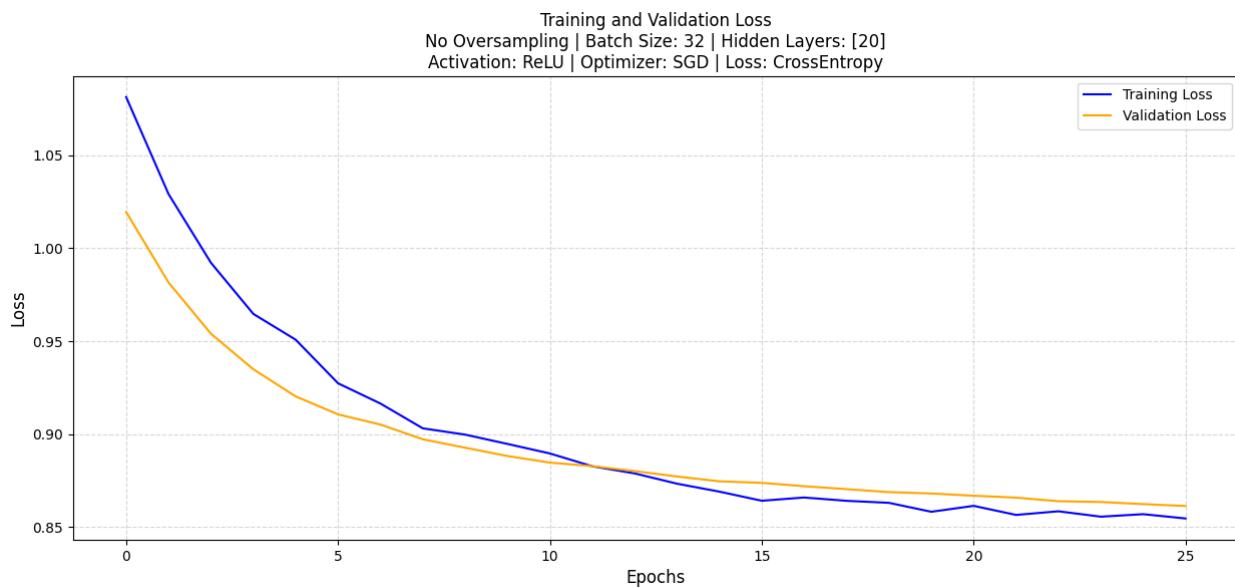
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



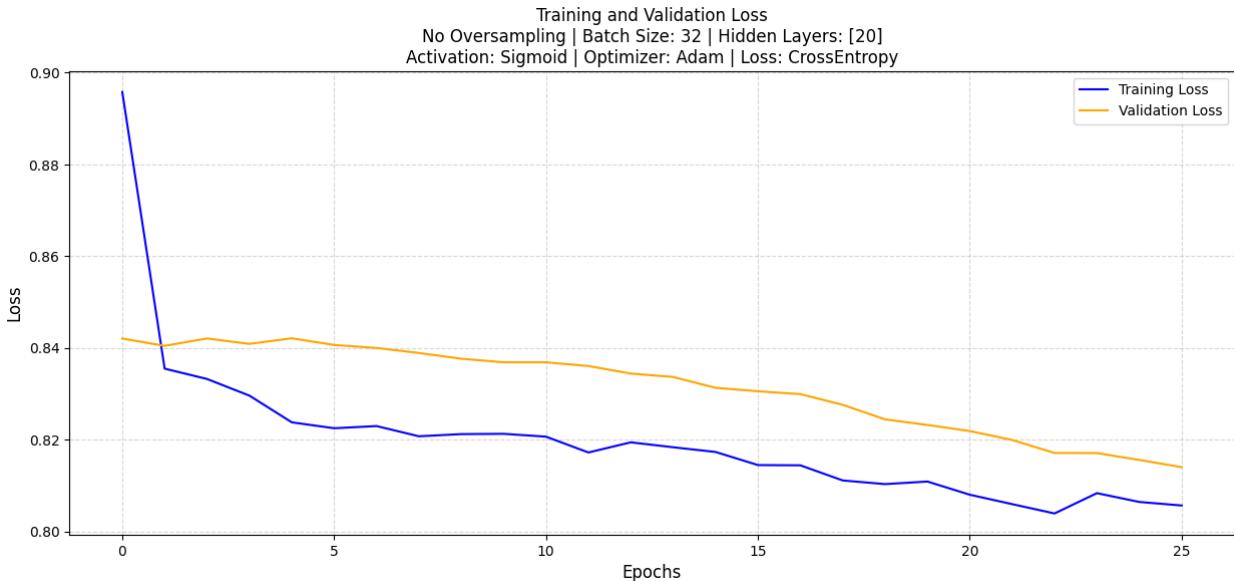
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



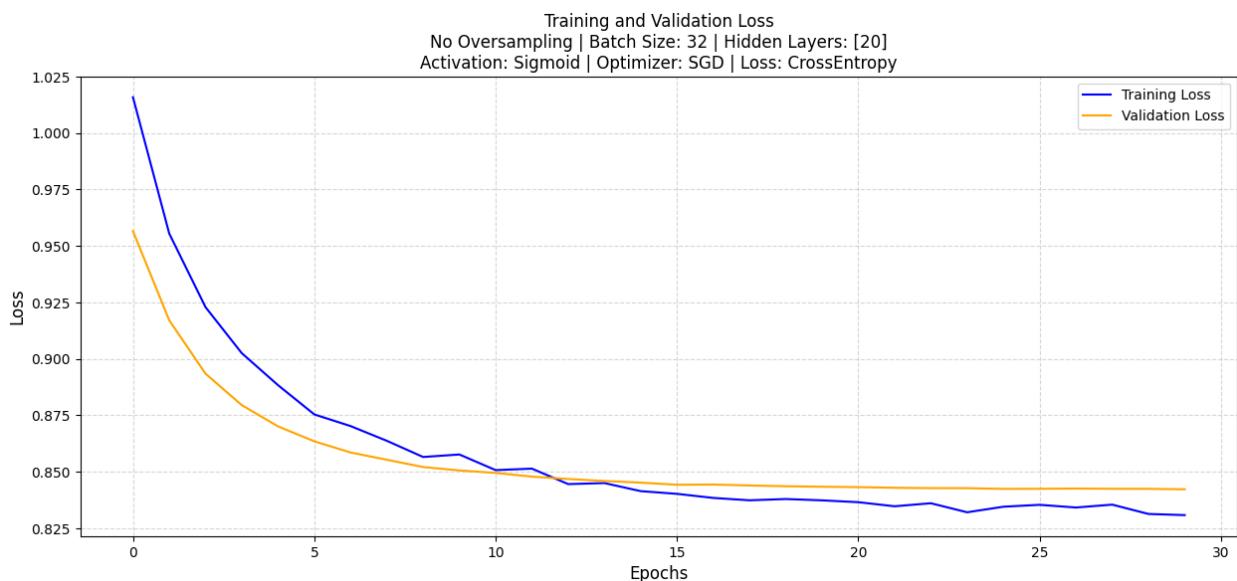
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



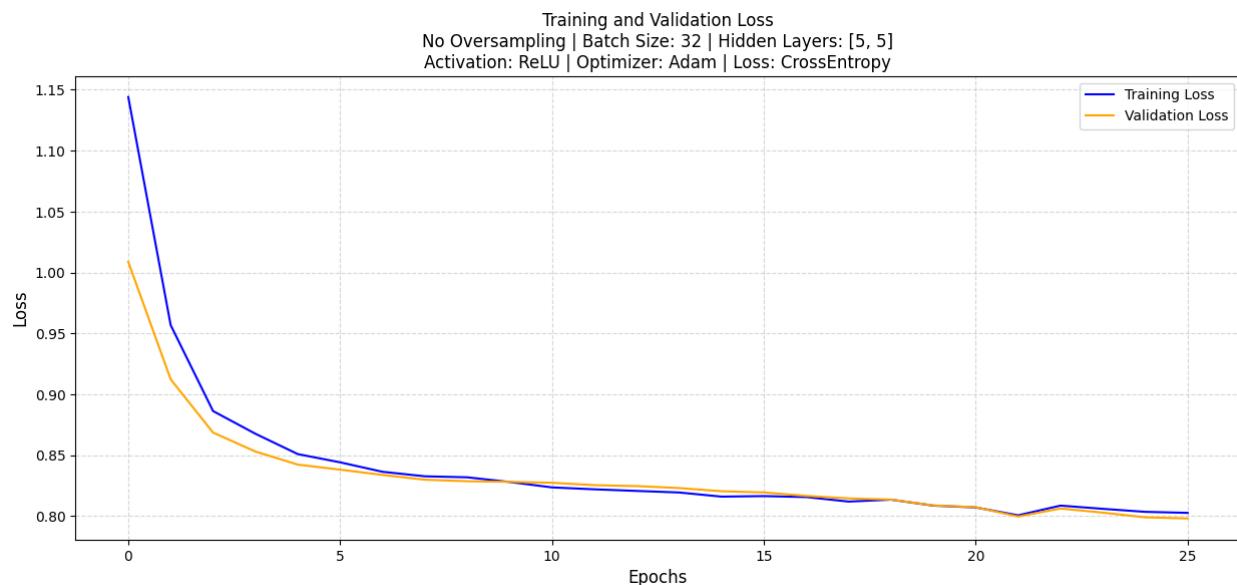
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



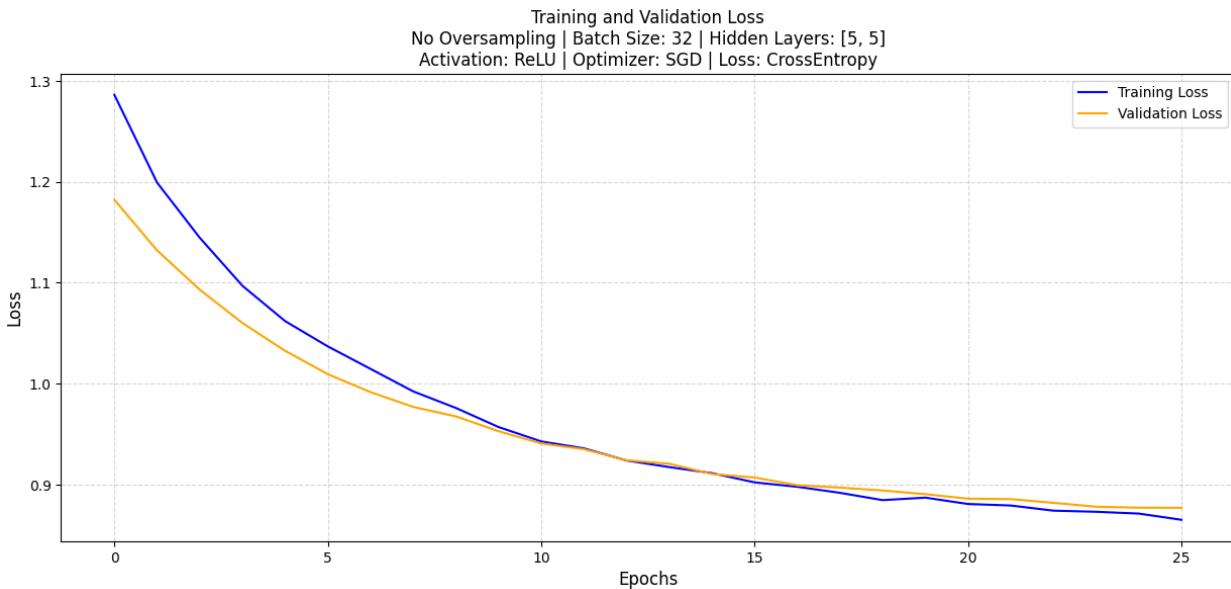
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



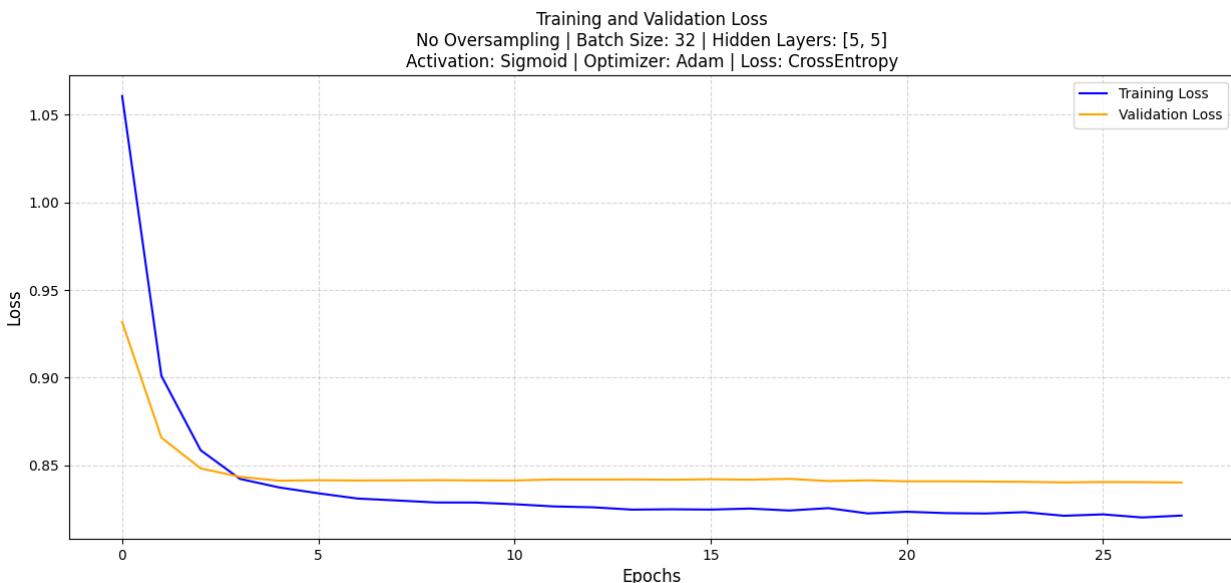
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



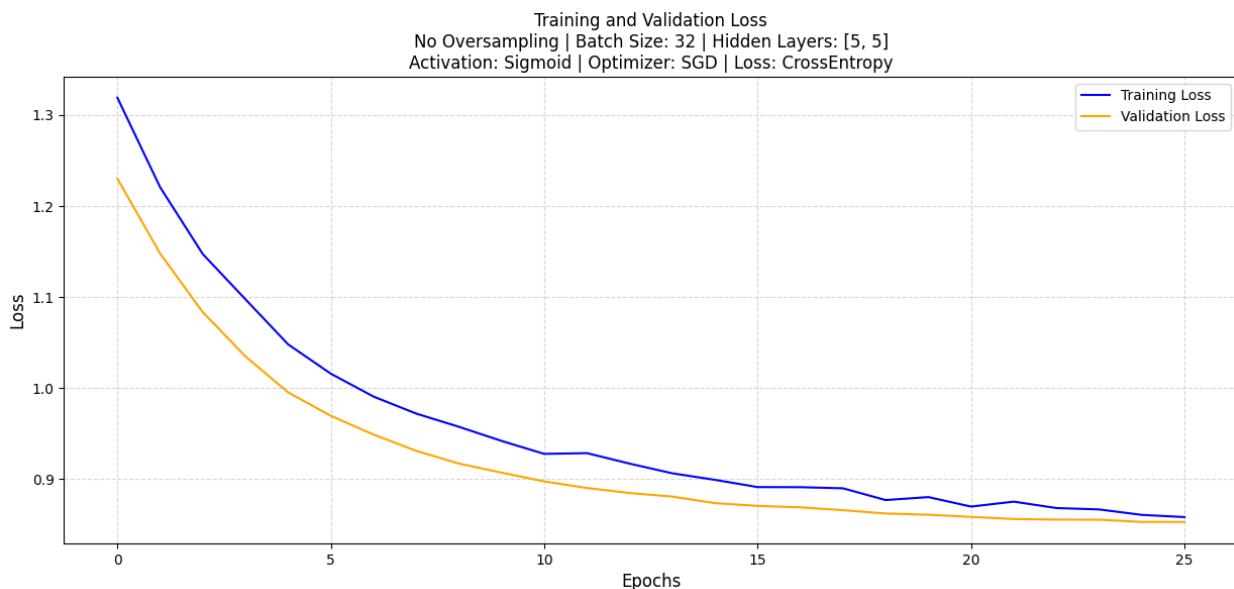
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



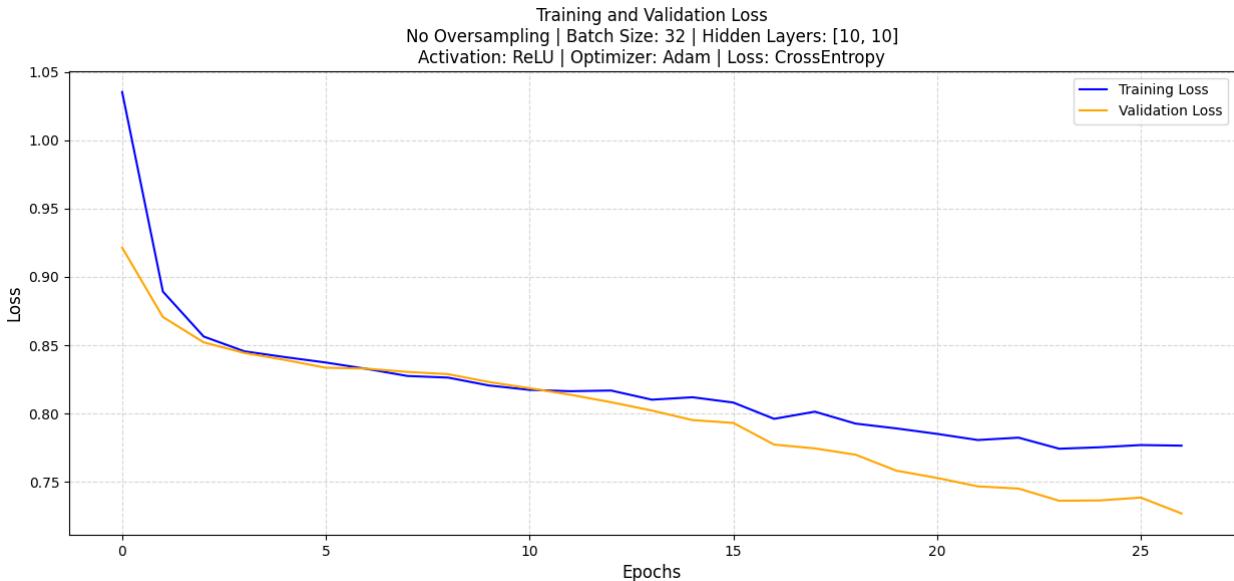
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



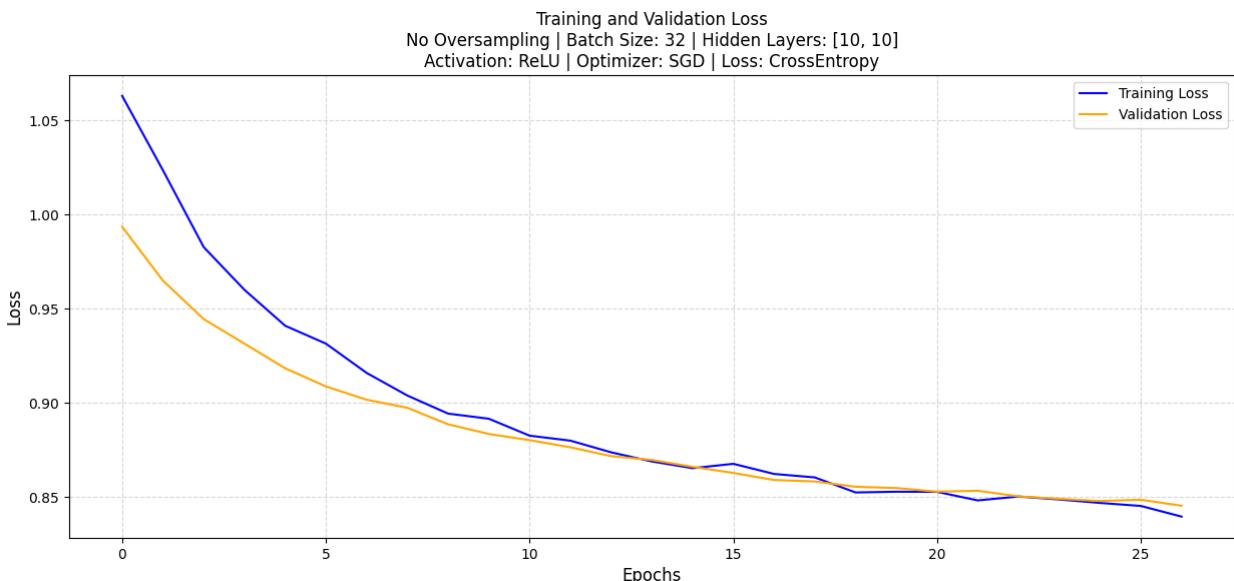
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



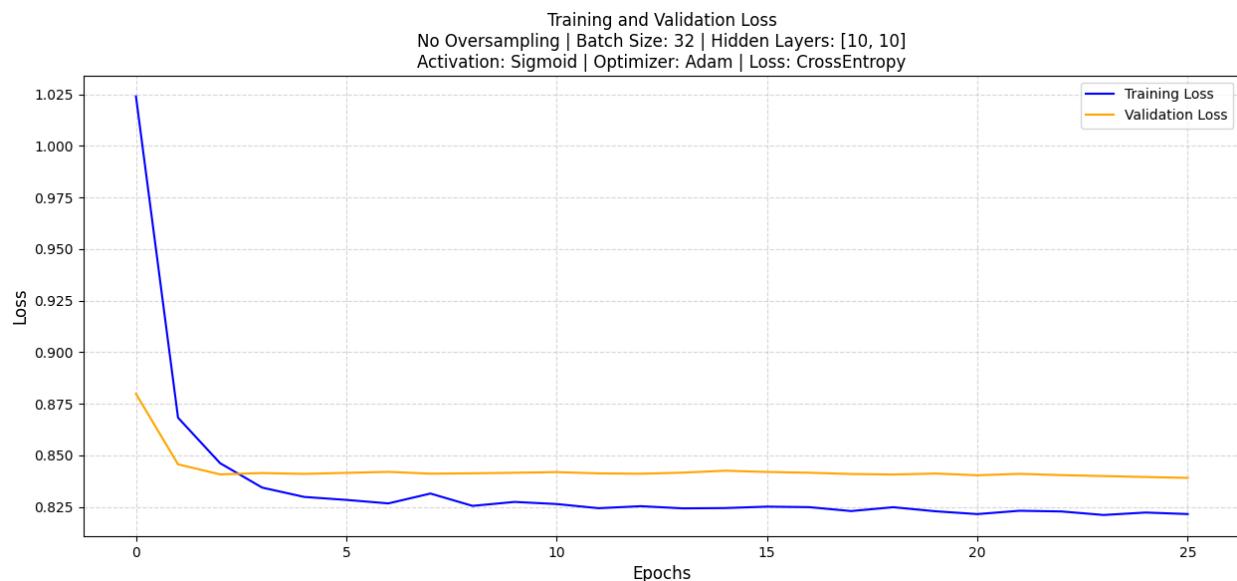
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



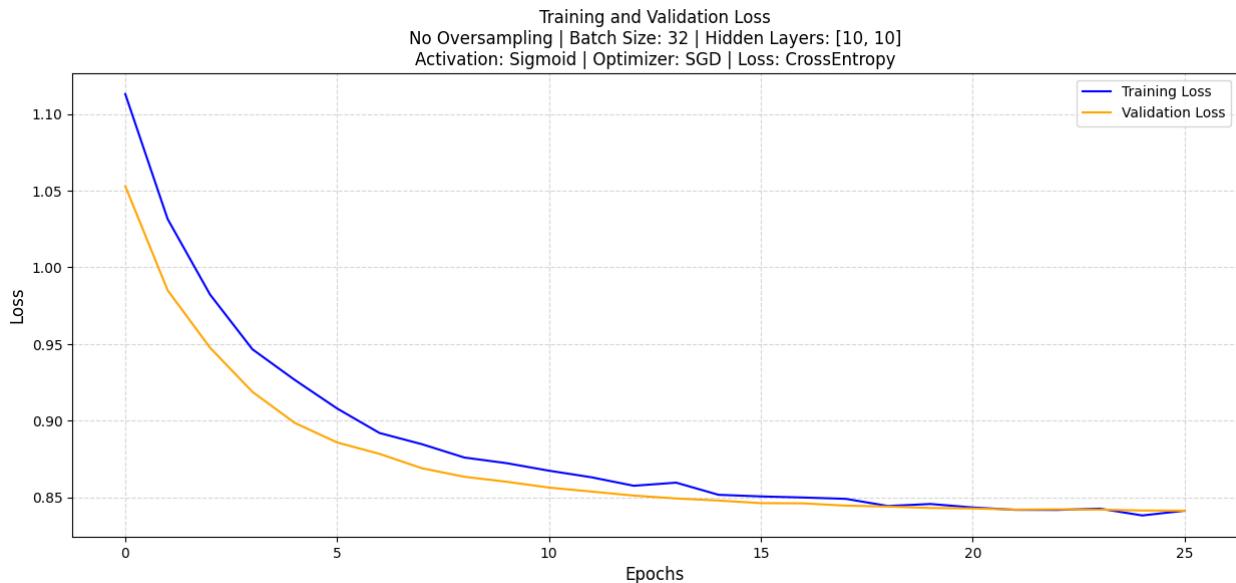
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



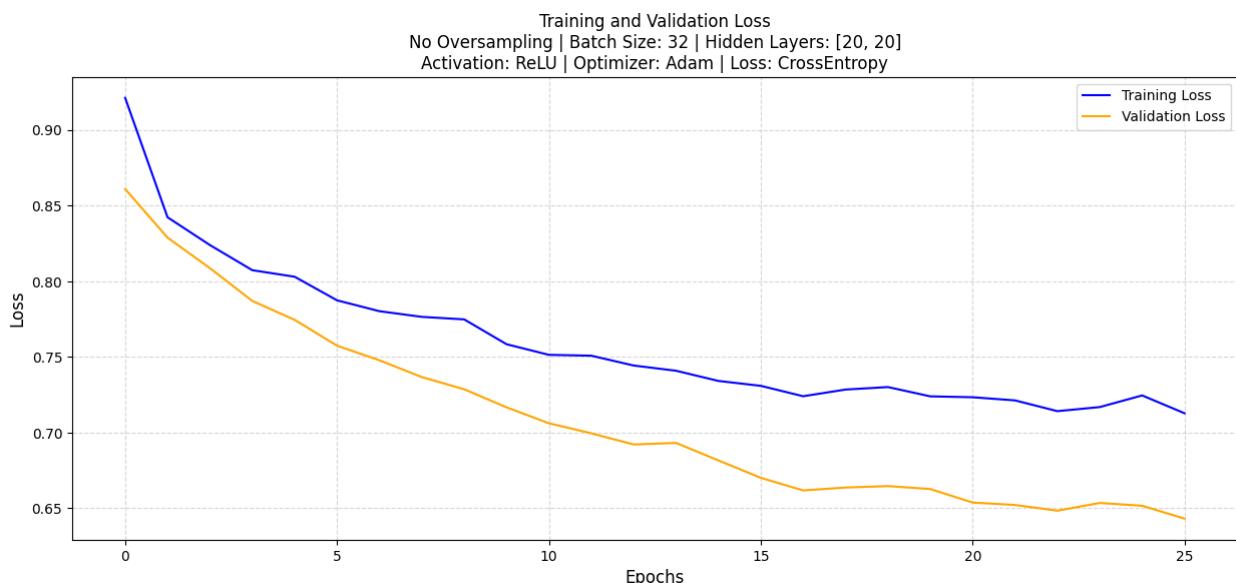
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



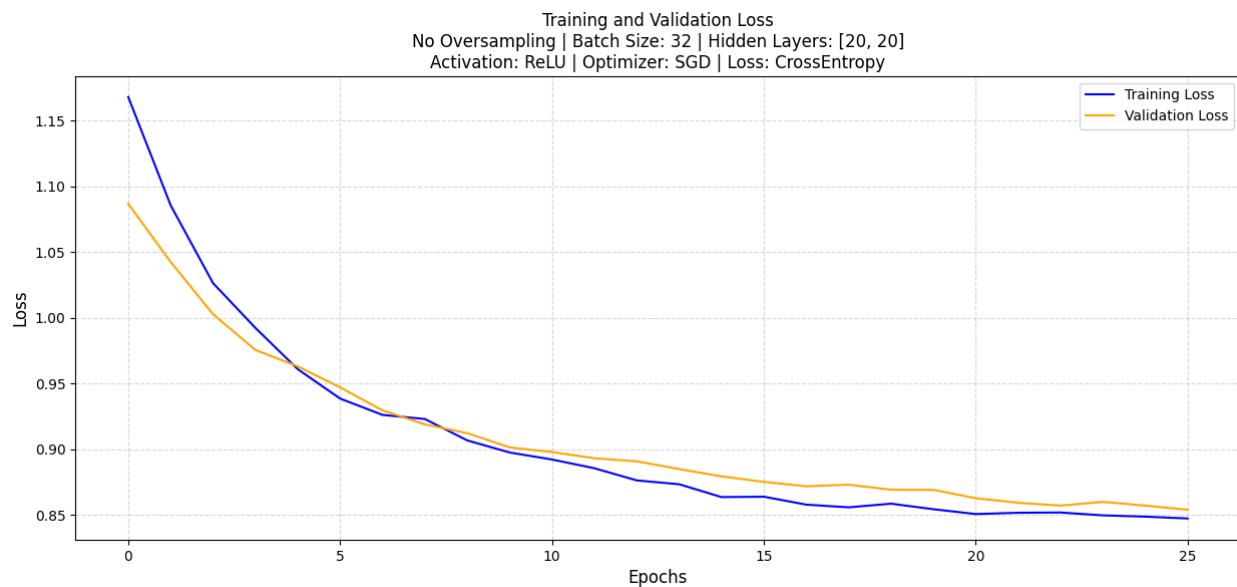
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



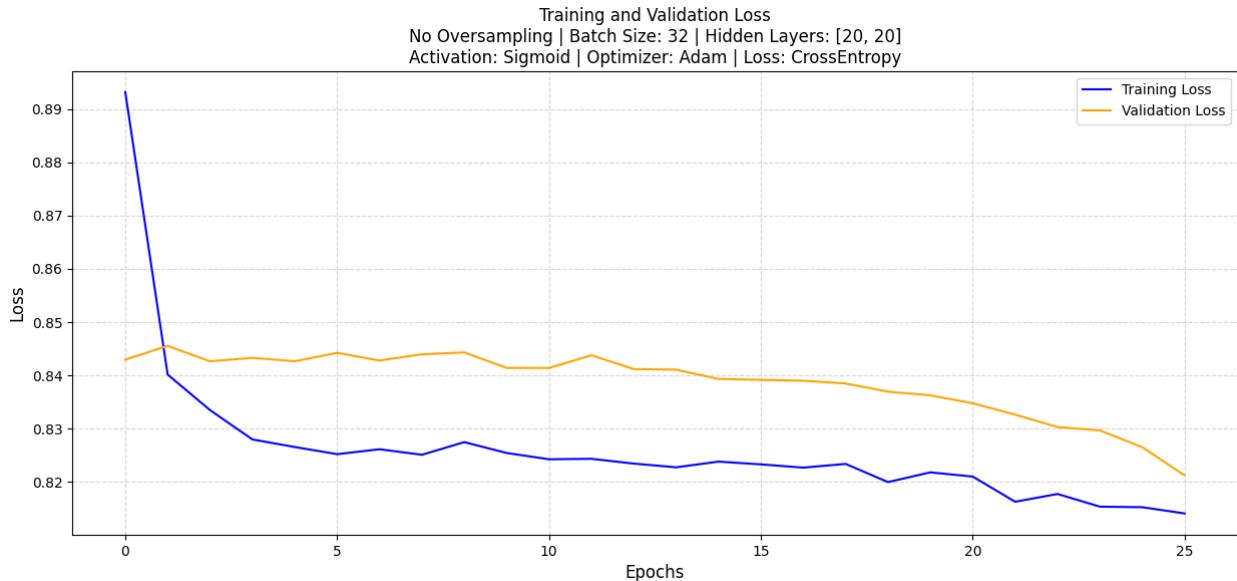
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```

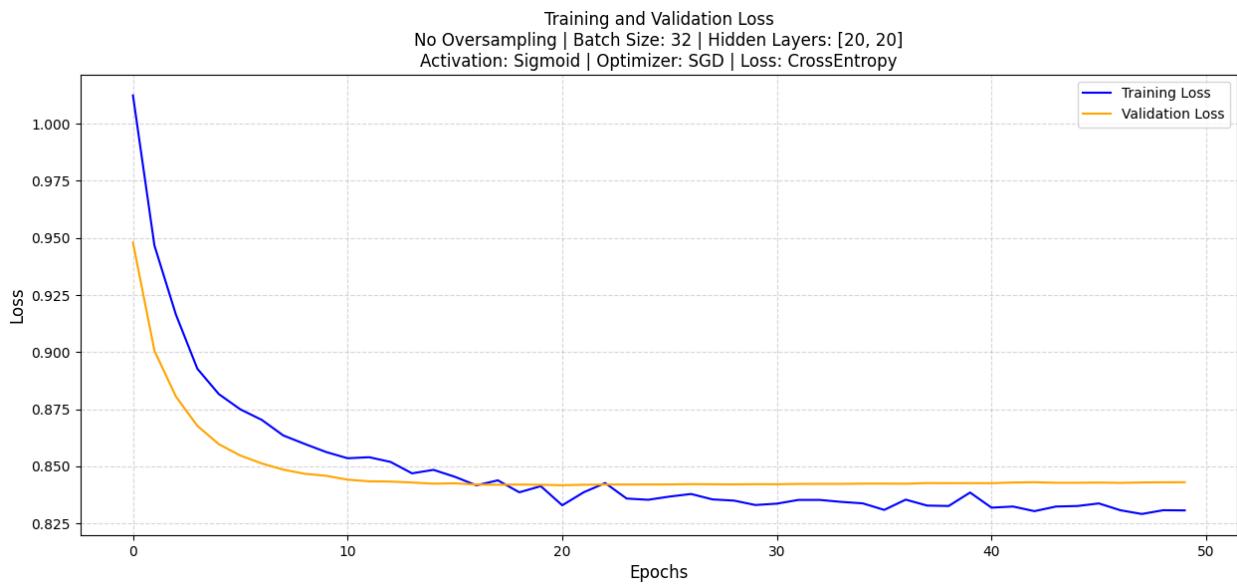


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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len(result))
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```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```

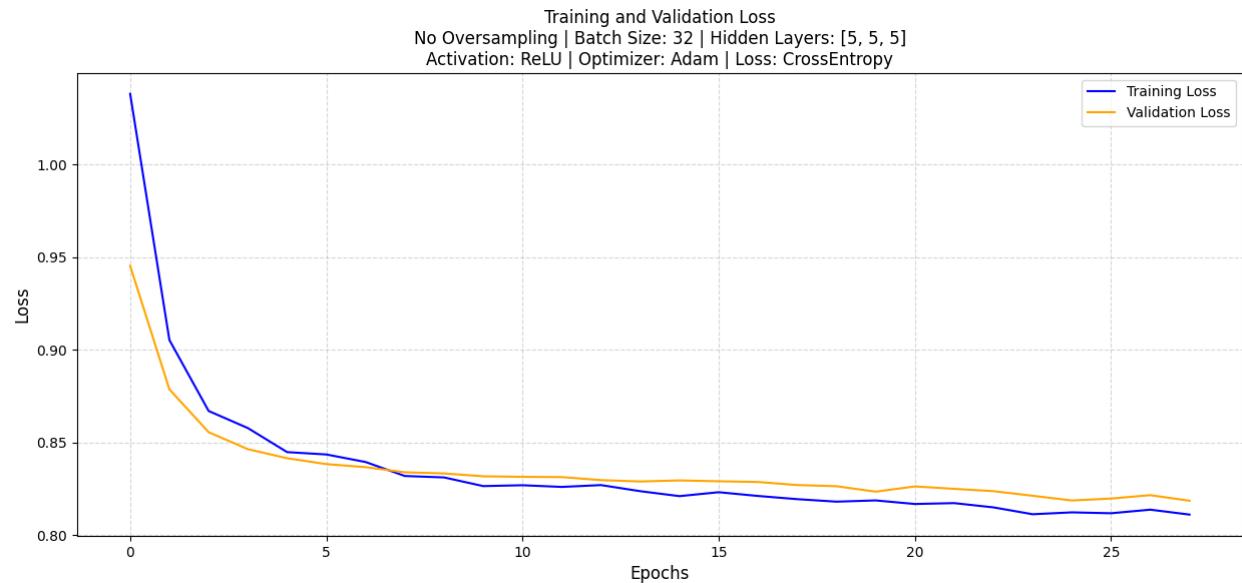


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
```

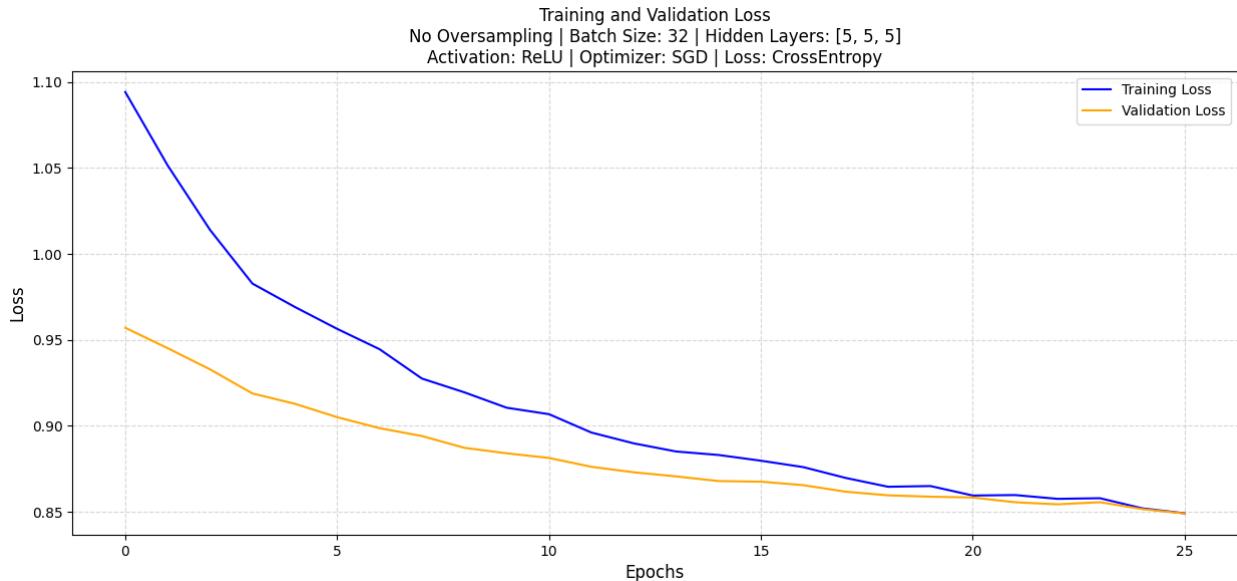
```
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.
```

```
_warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



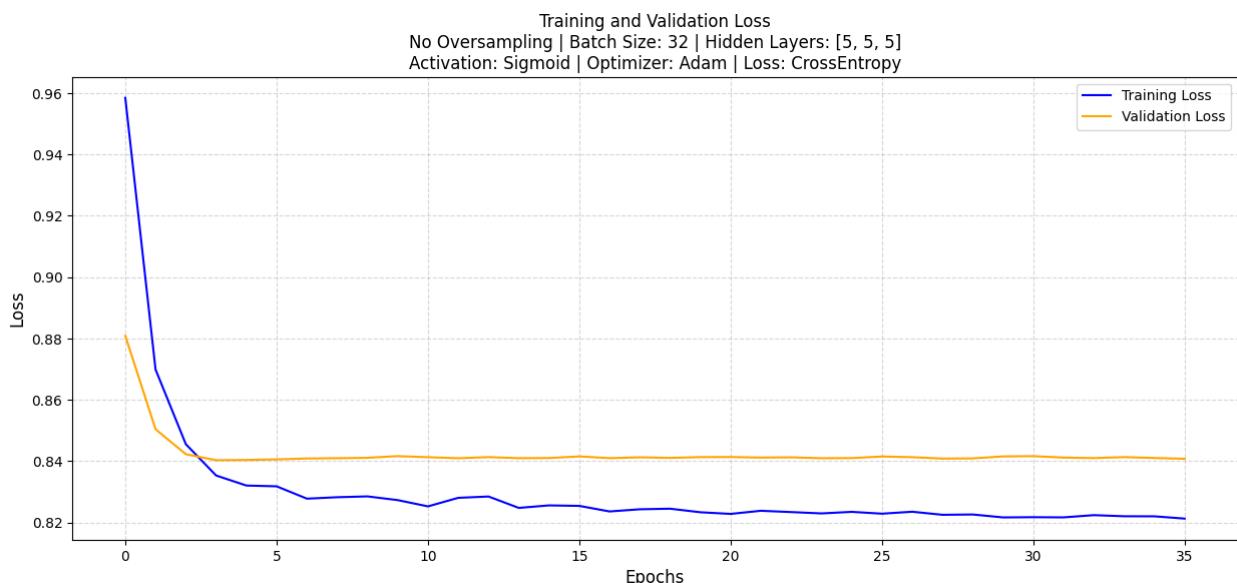
```
Early stopping triggered
```

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-  
packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
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_warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



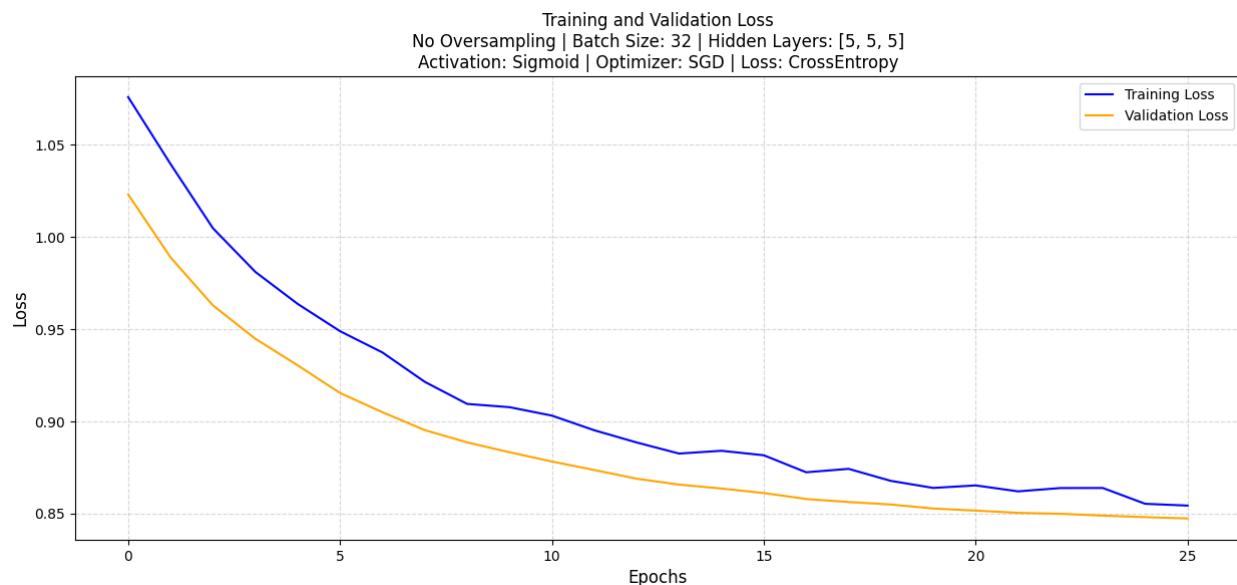
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



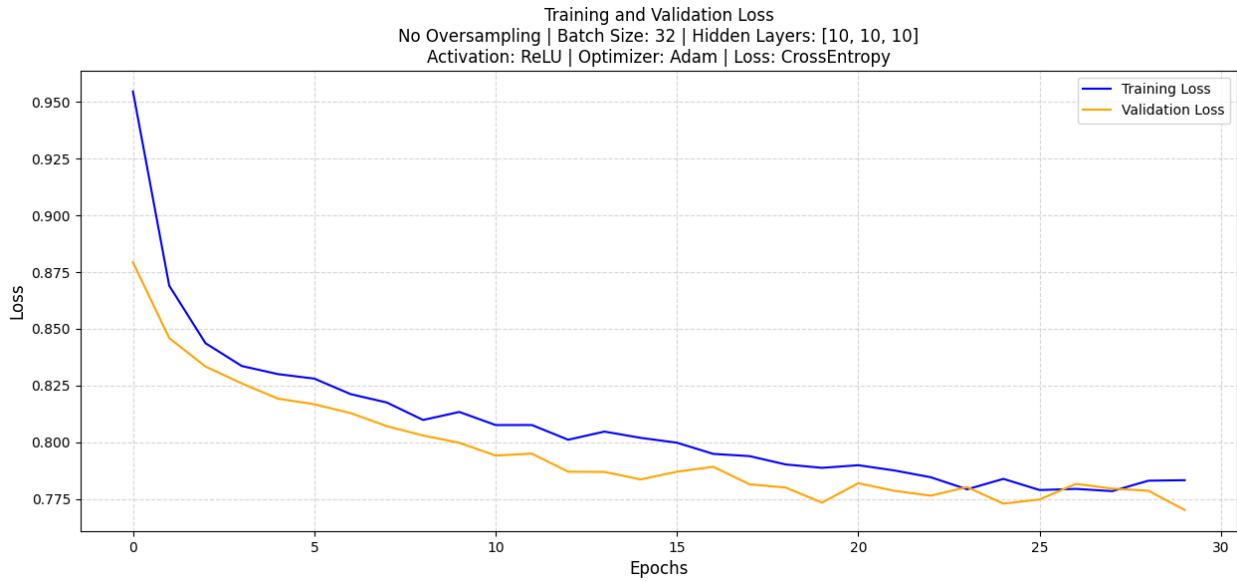
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



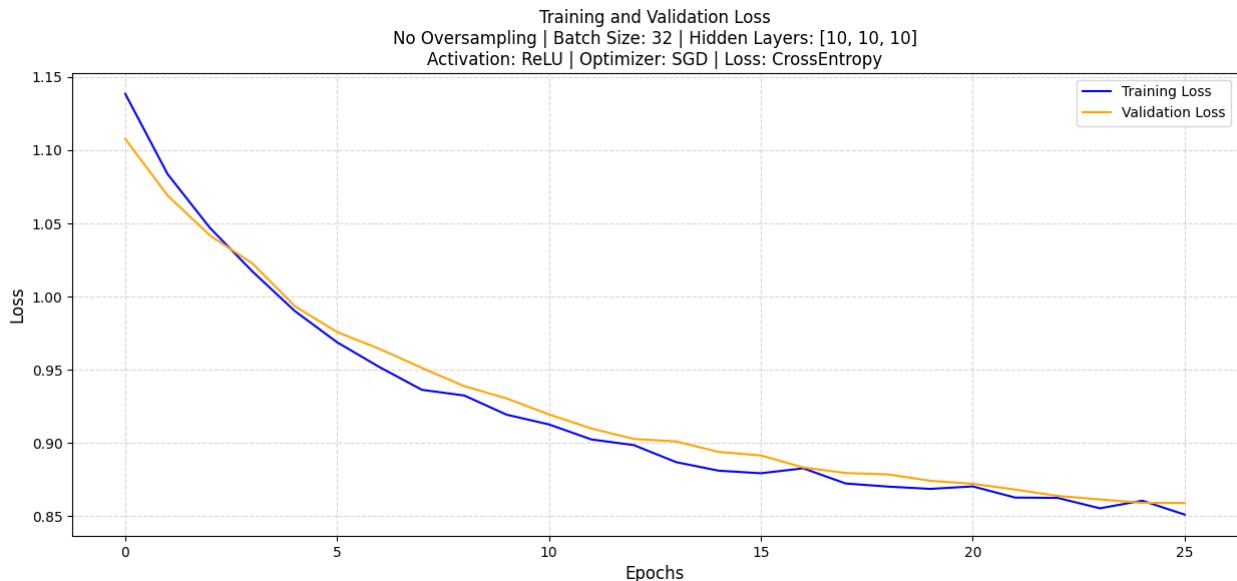
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



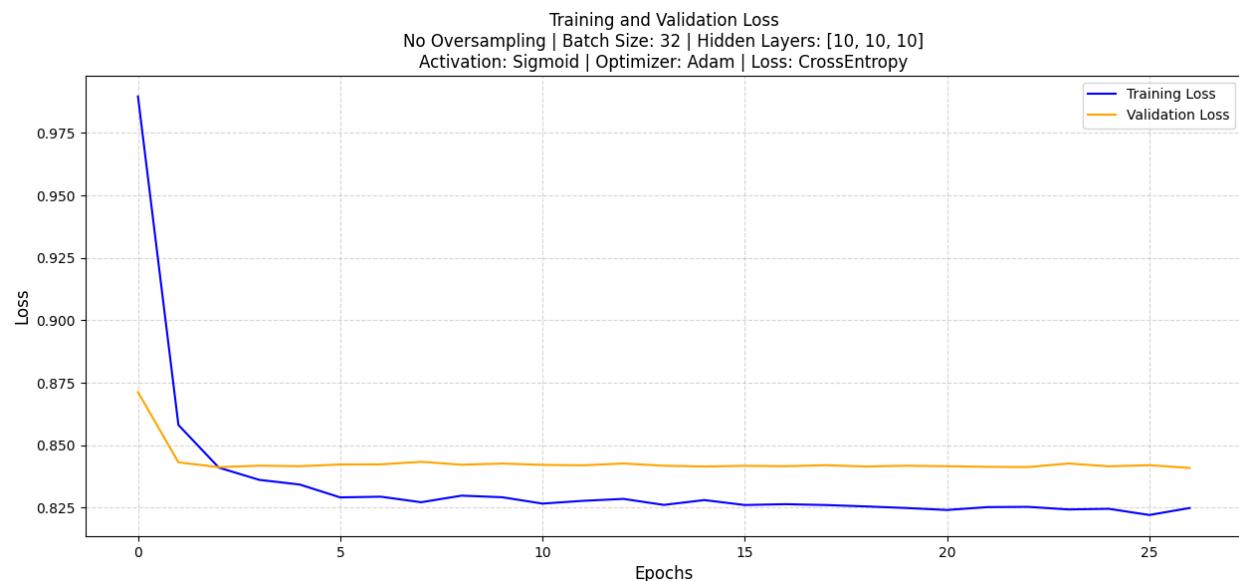
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



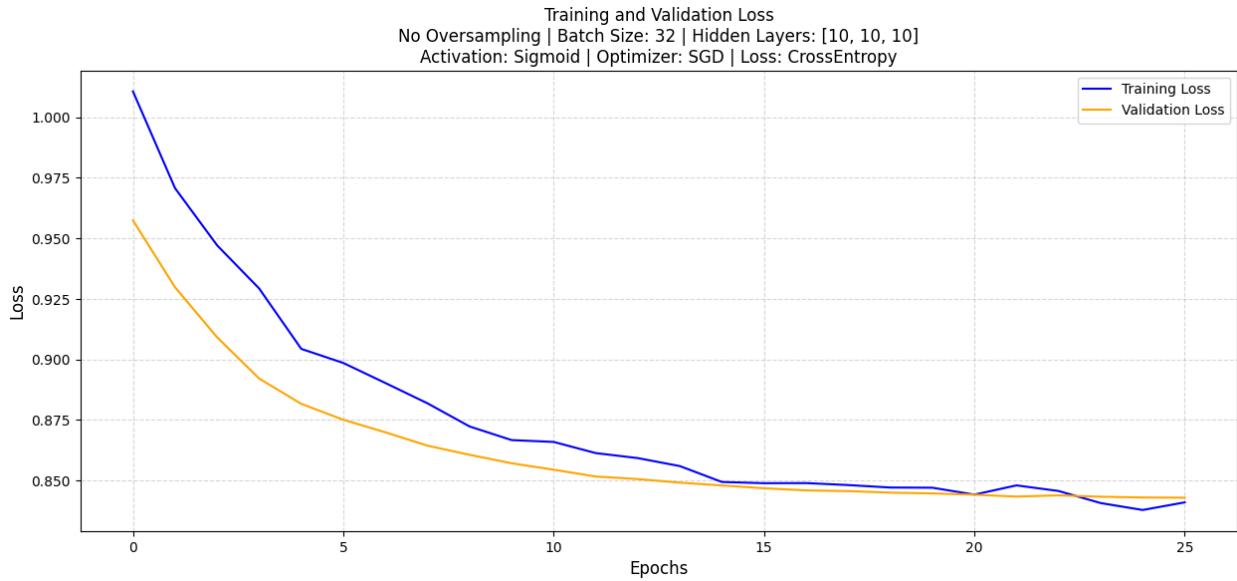
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



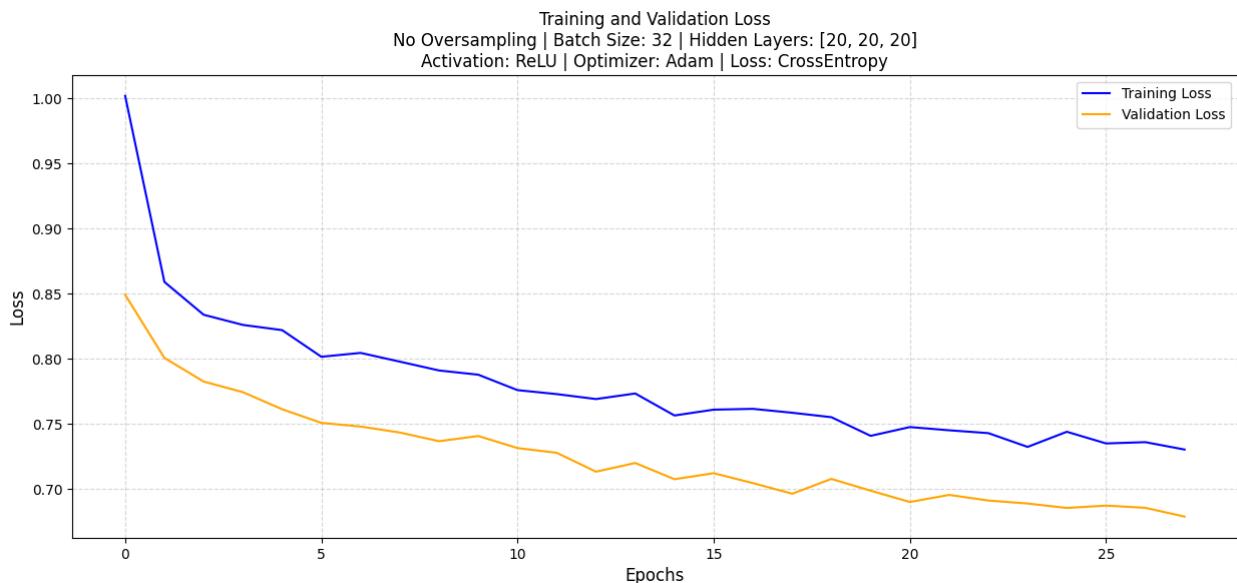
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



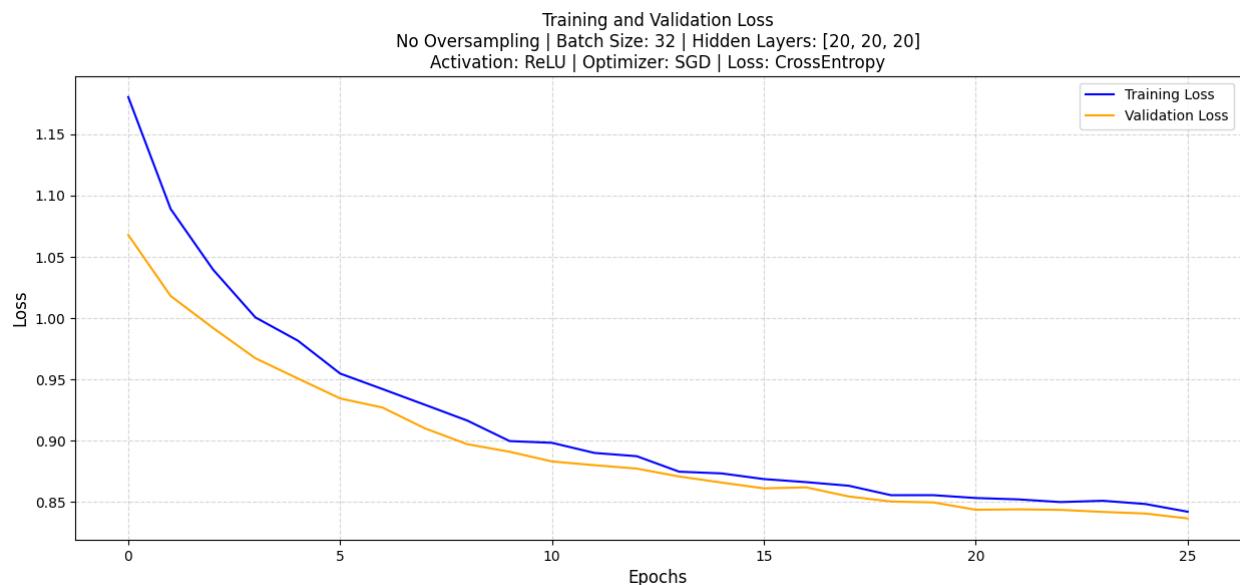
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



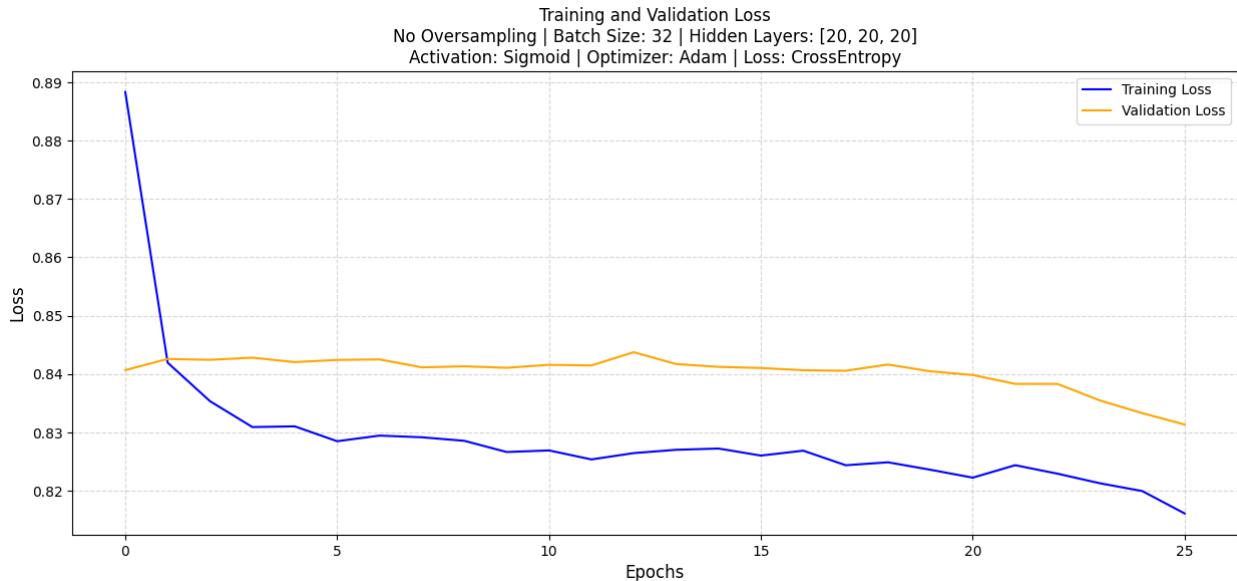
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```

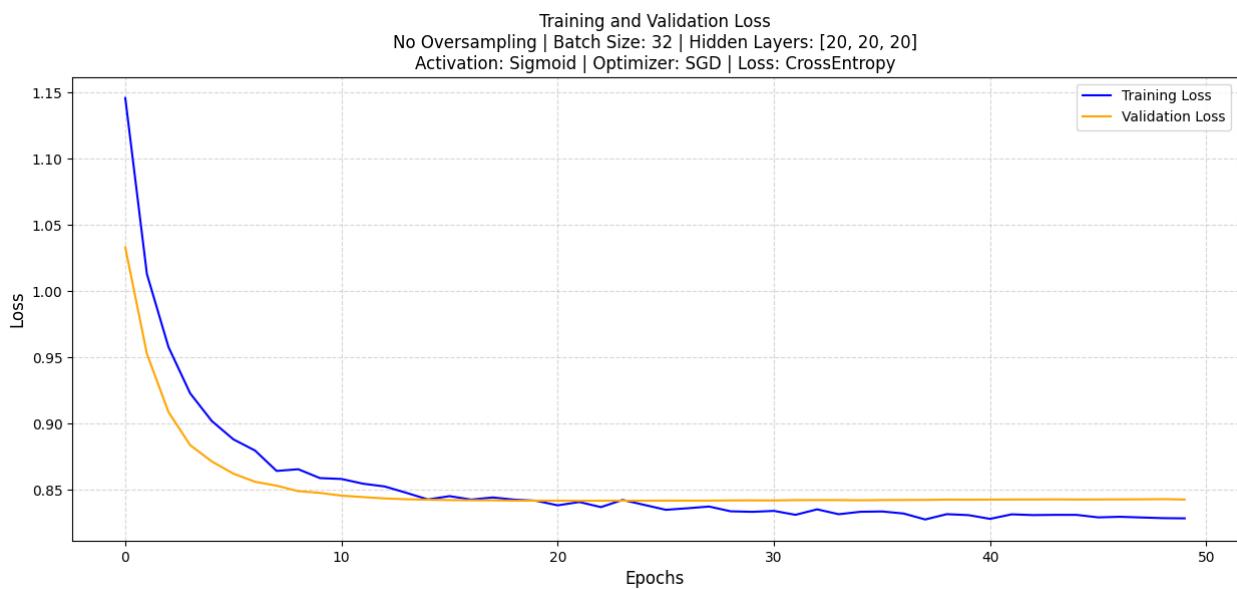


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



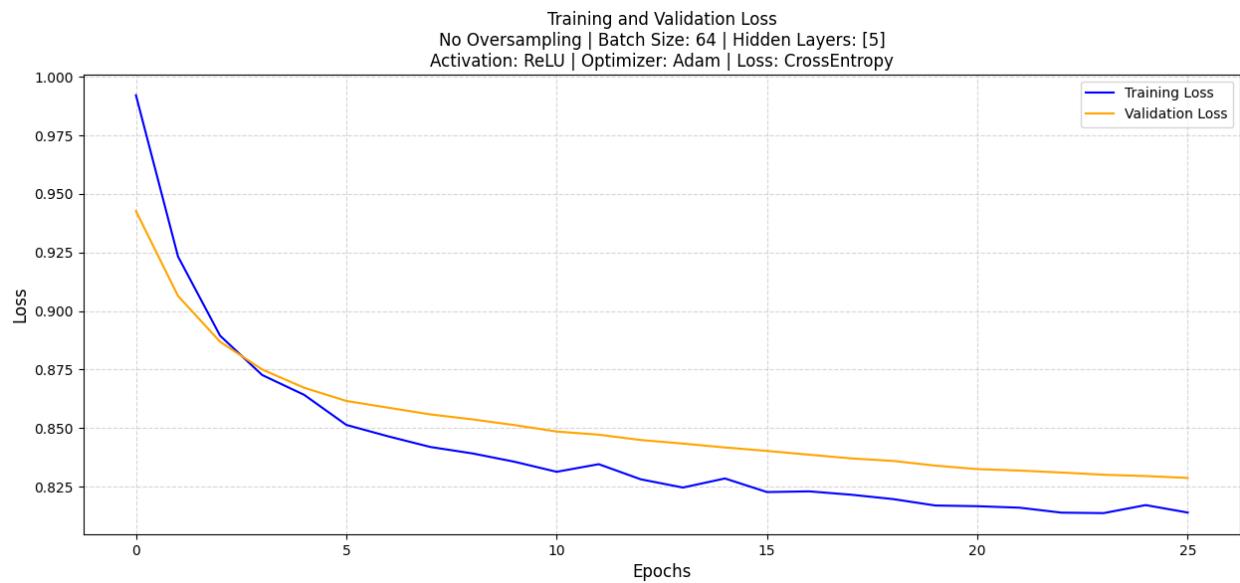
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



Early stopping triggered

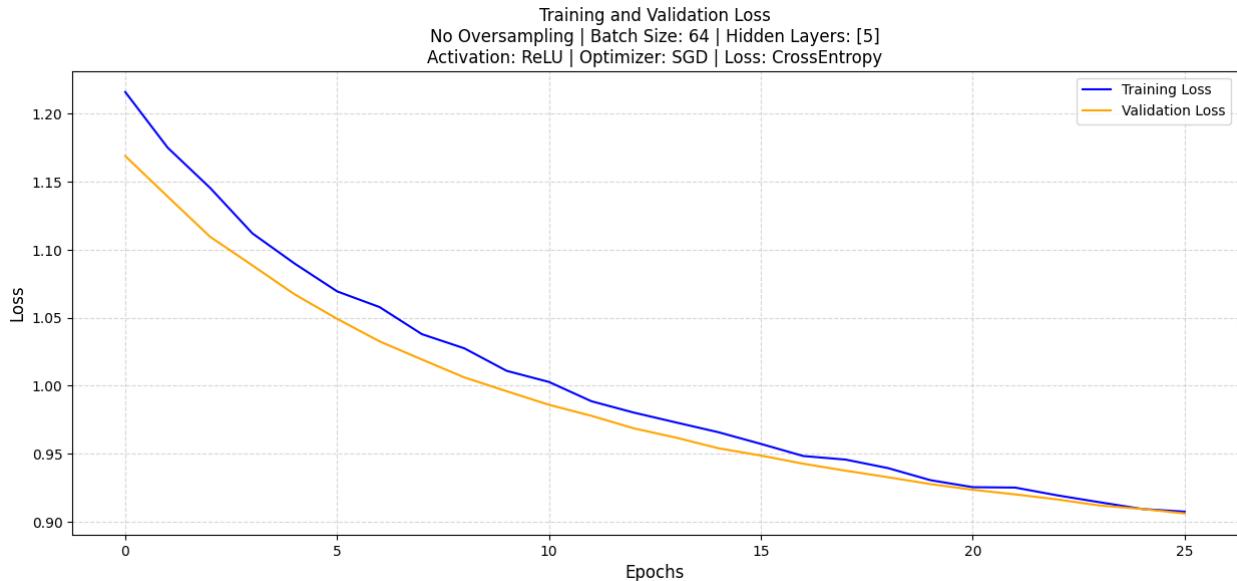
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
```

```
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



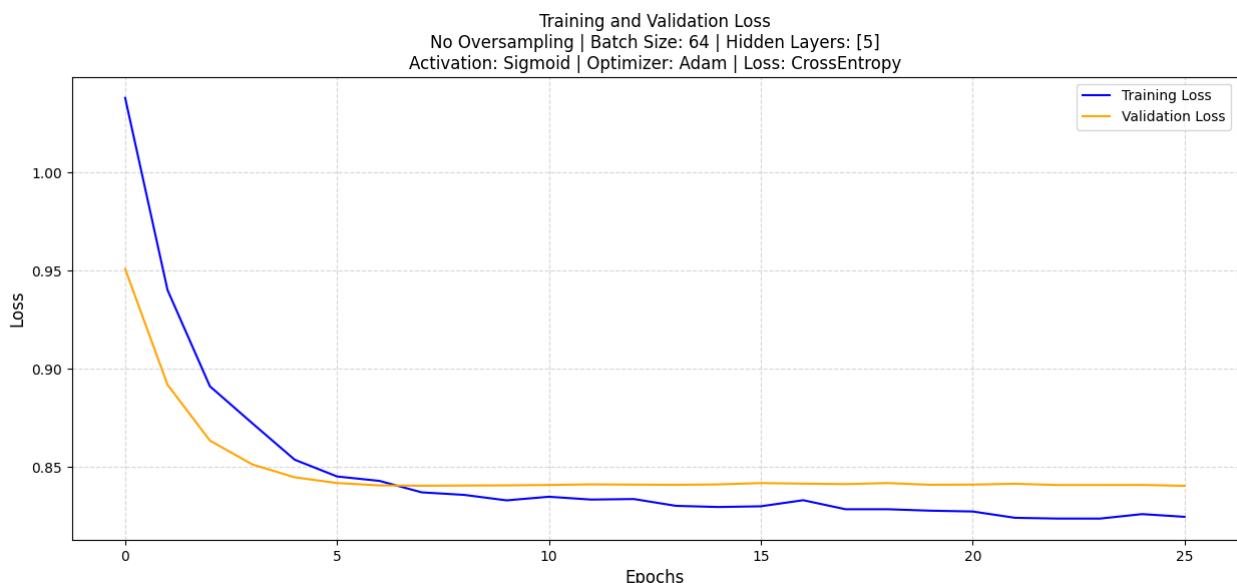
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



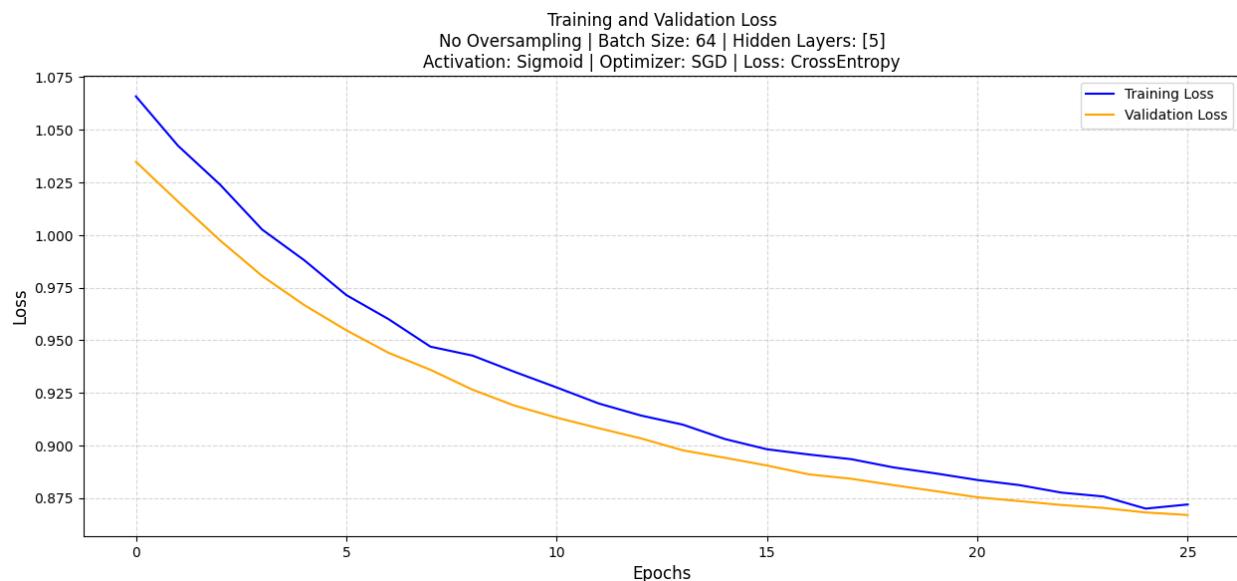
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



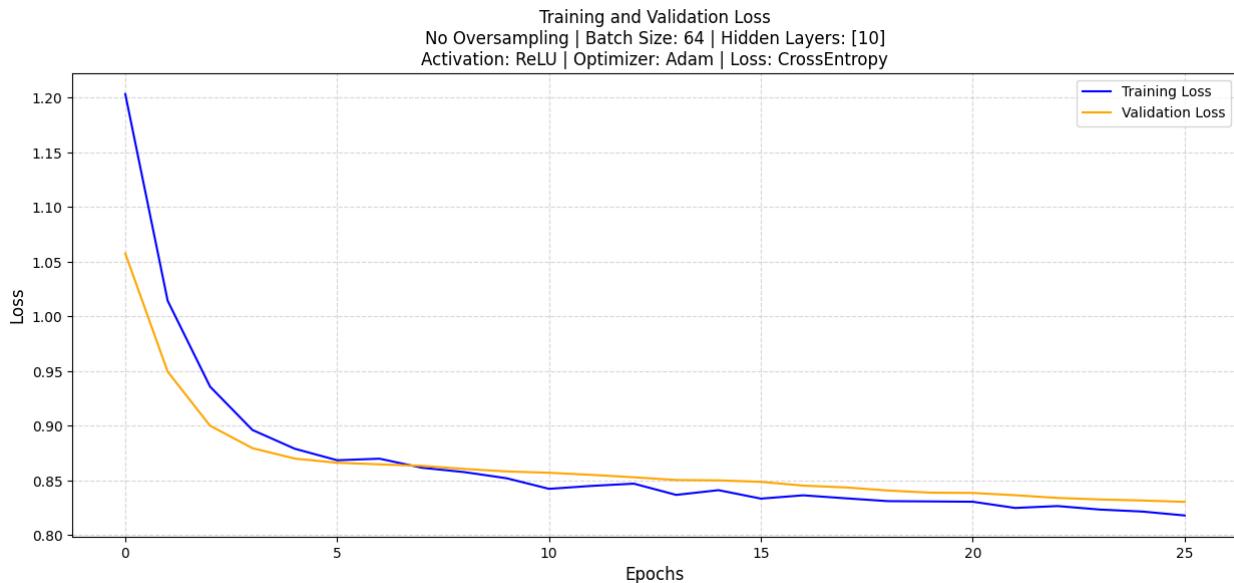
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



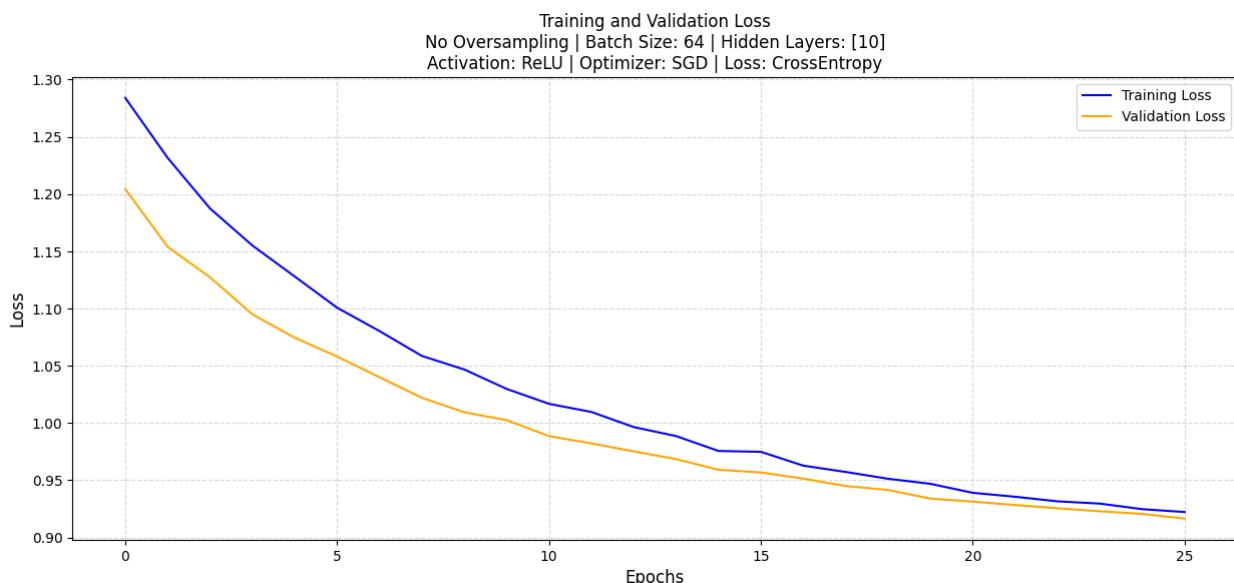
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
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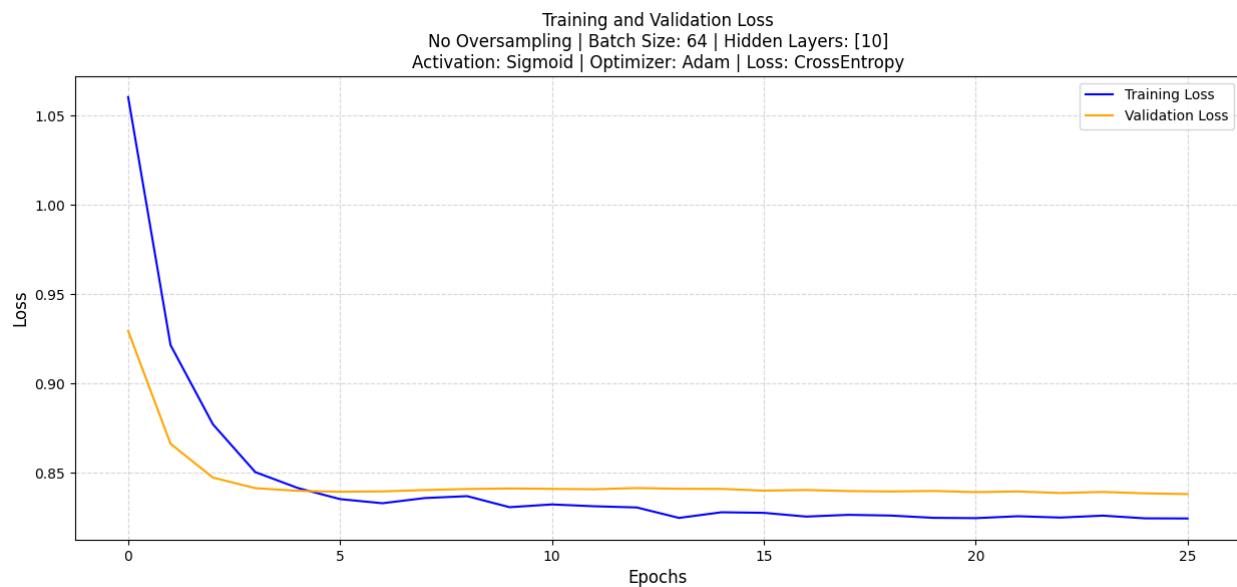
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



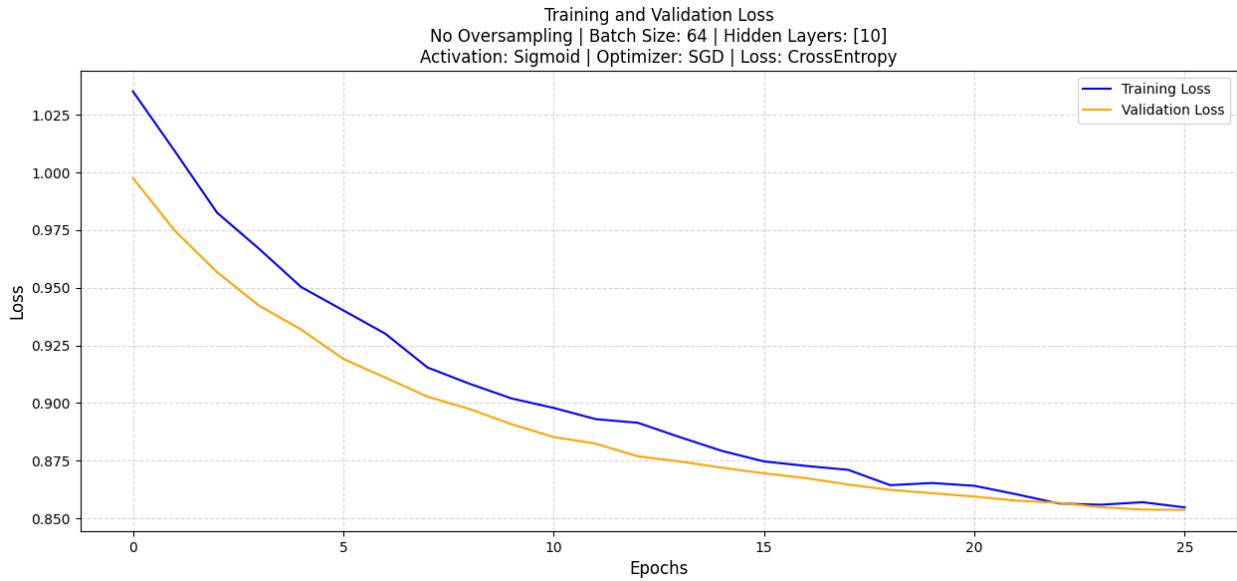
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
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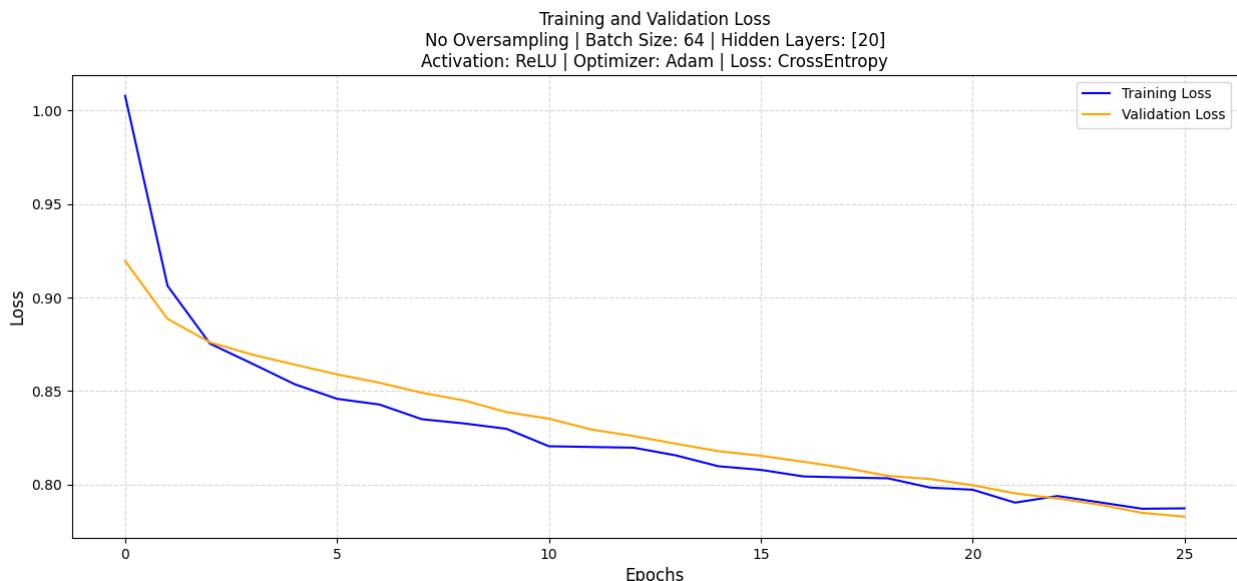
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



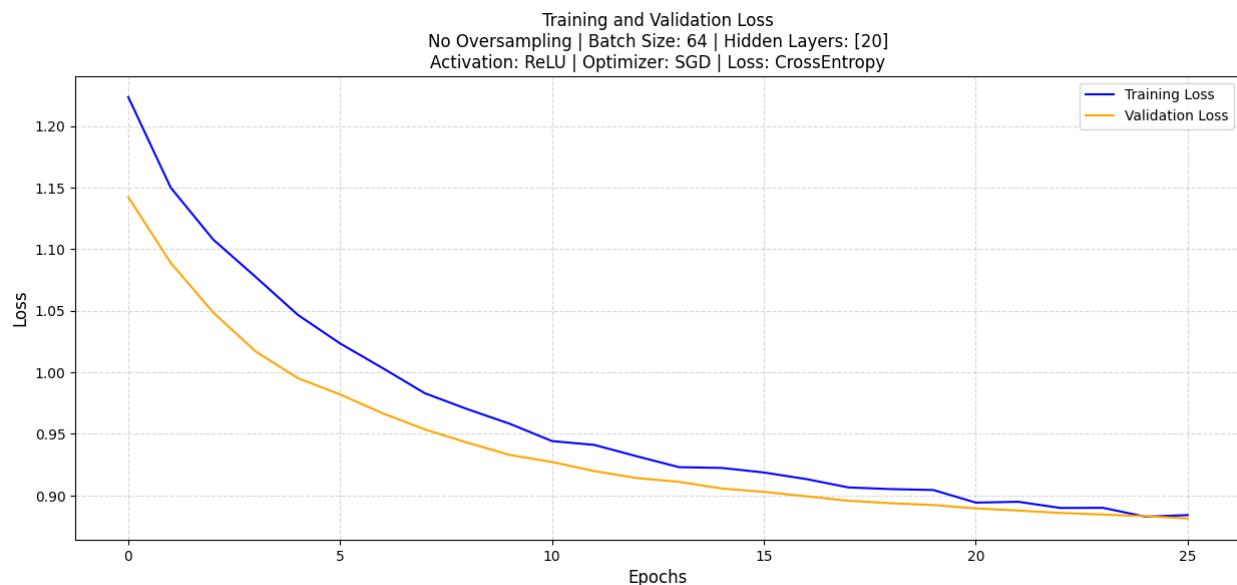
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



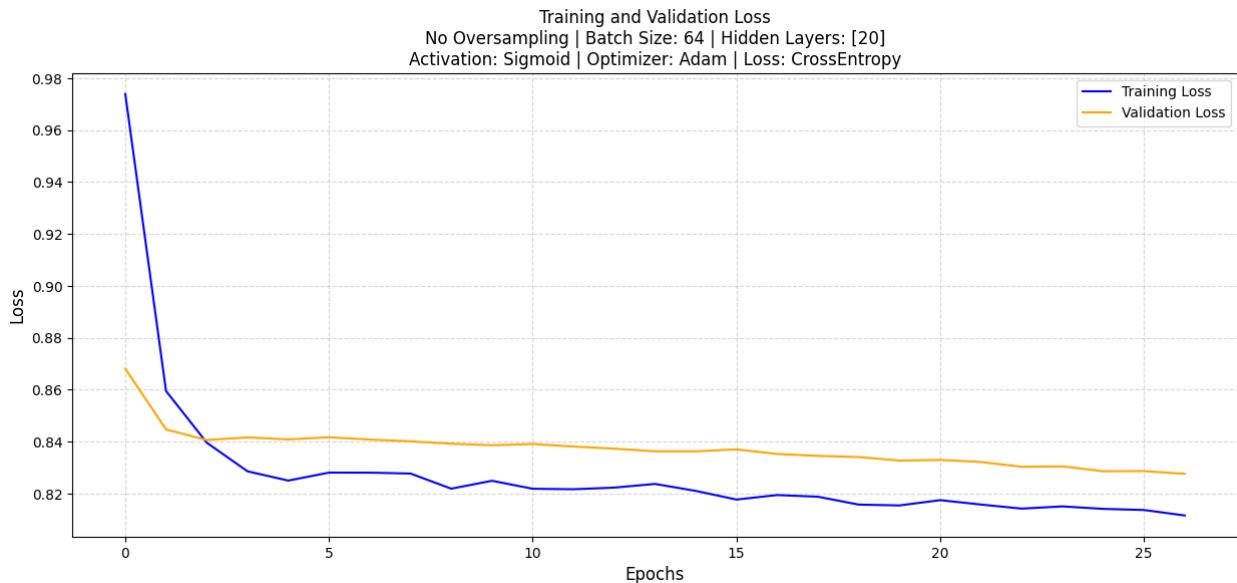
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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len(result))
```



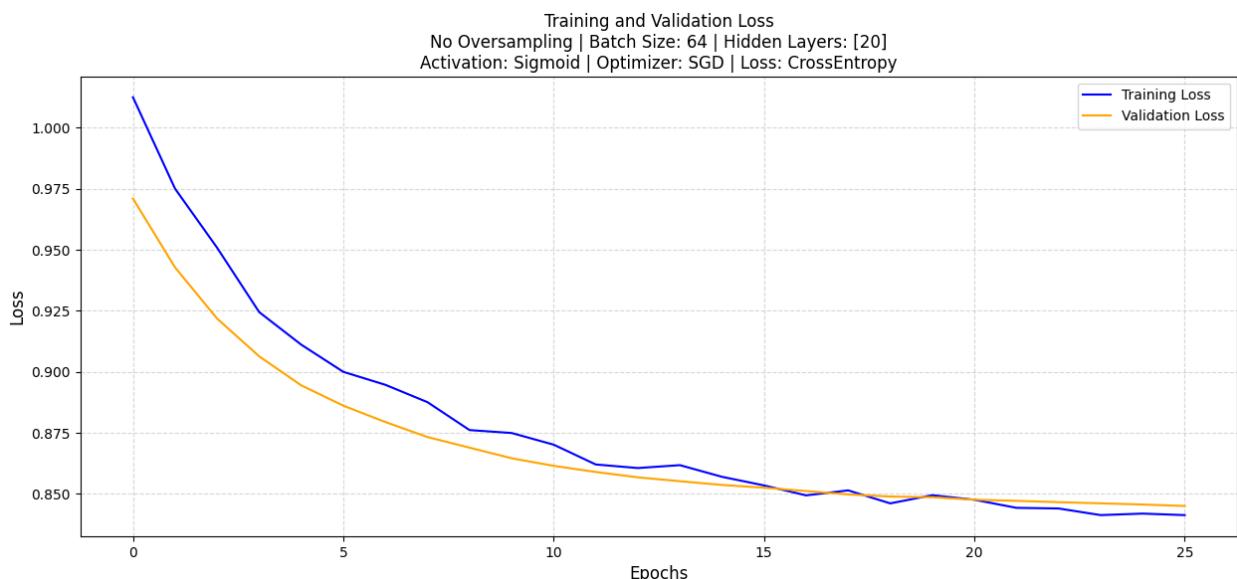
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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len(result))
```



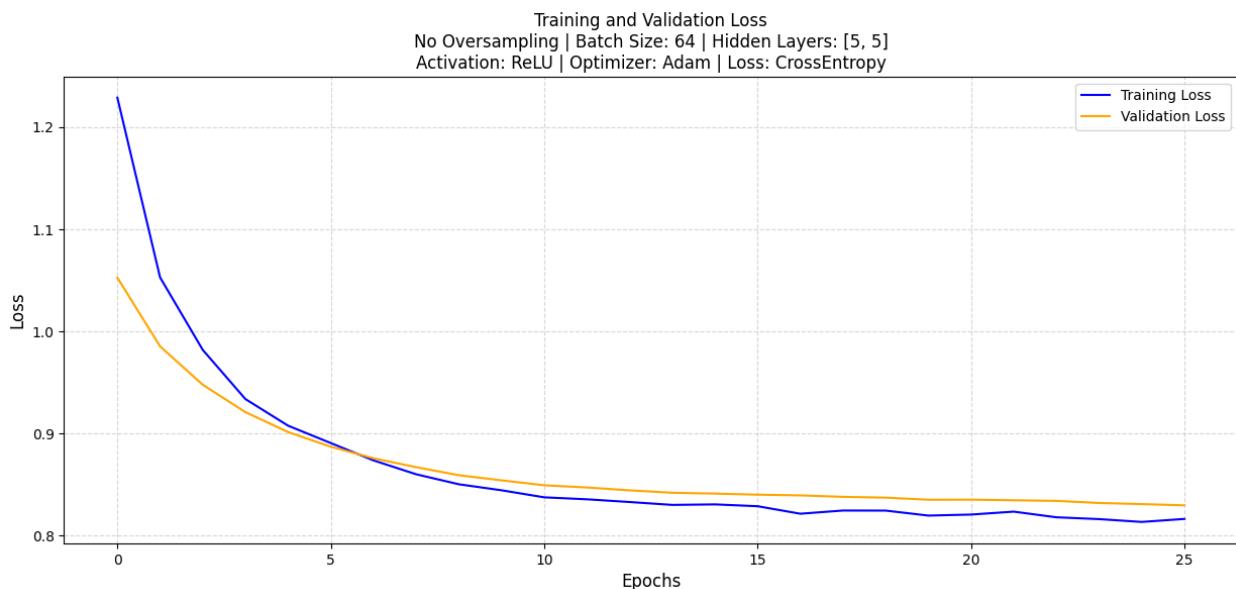
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



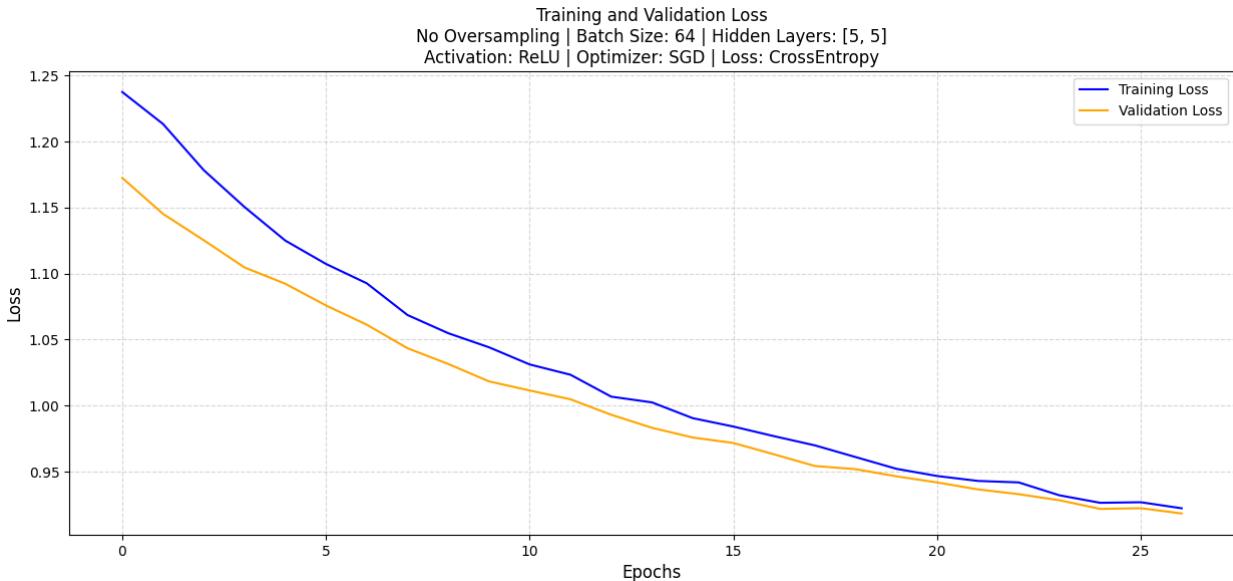
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



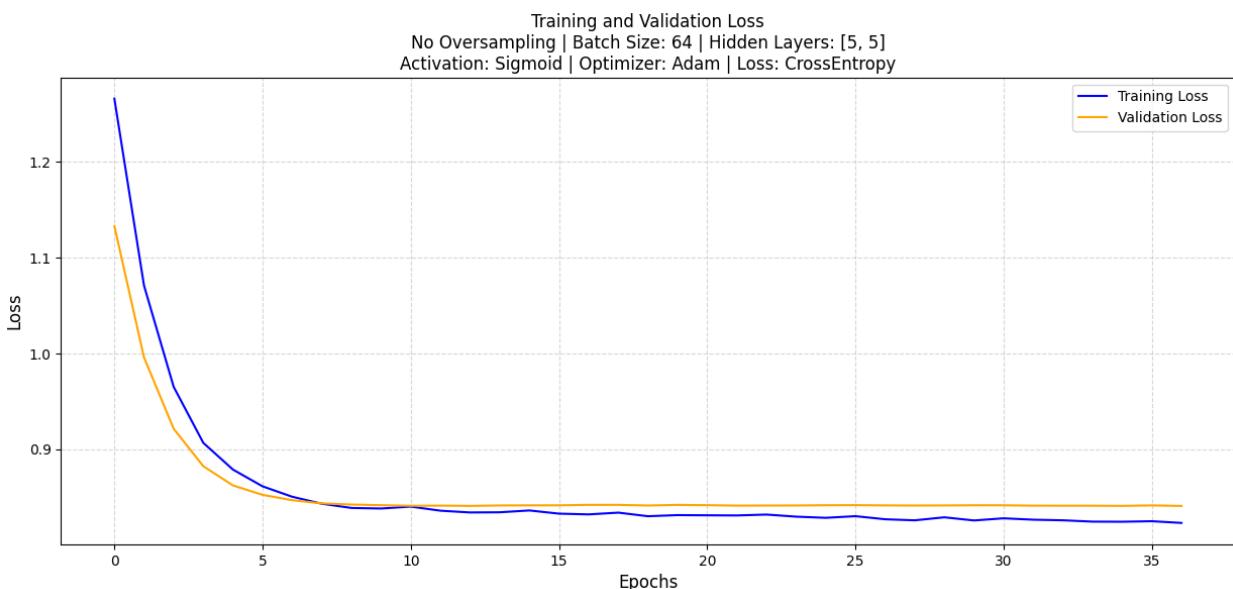
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



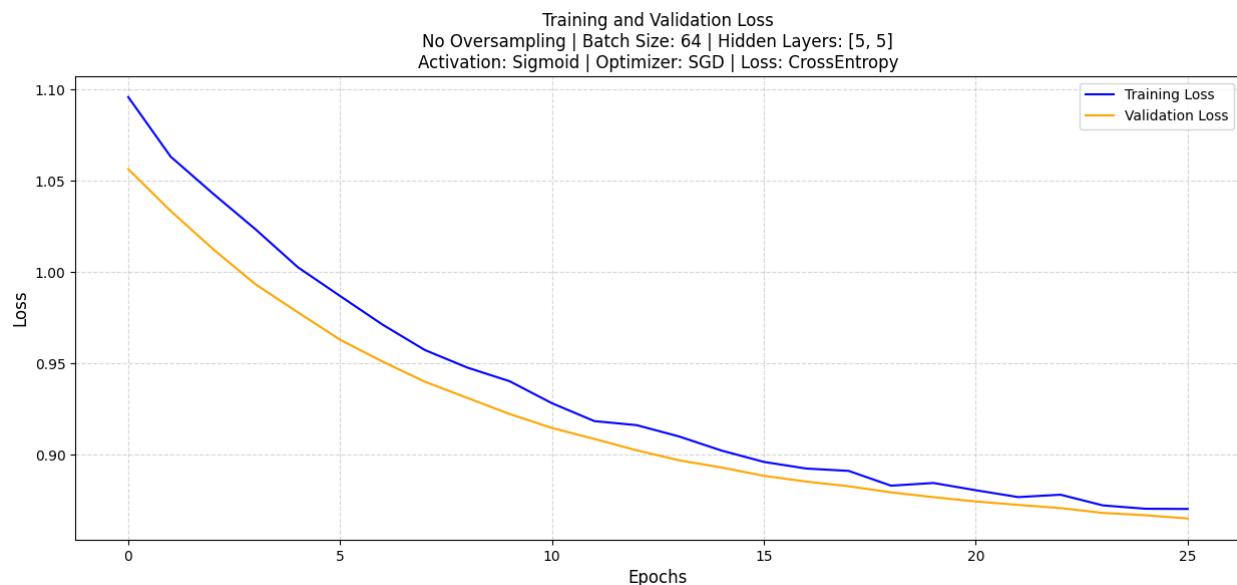
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



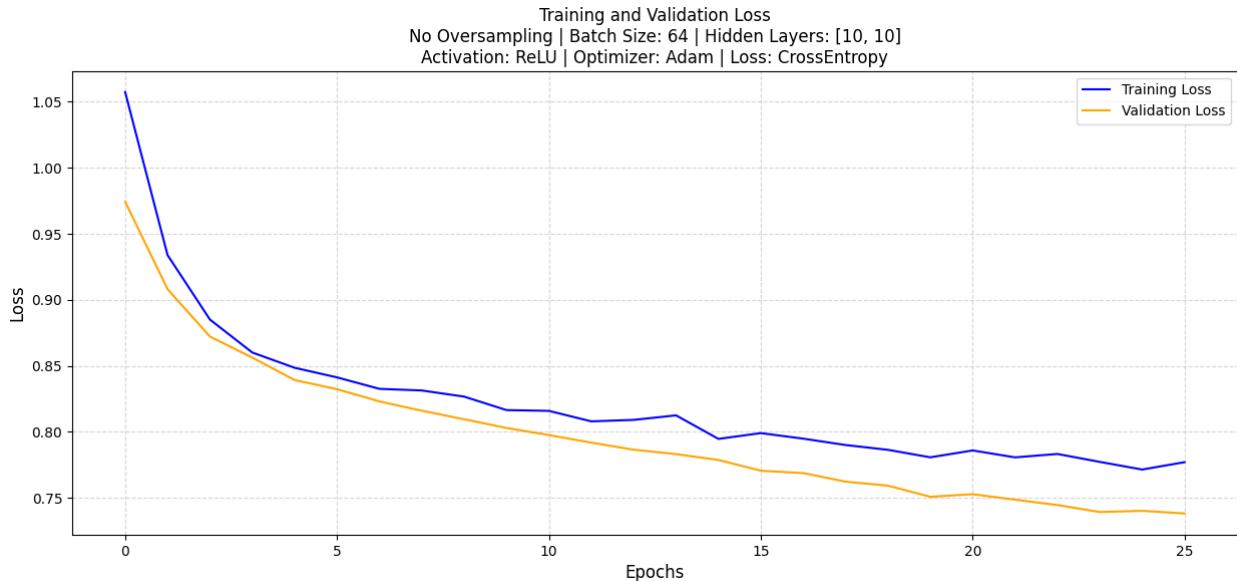
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



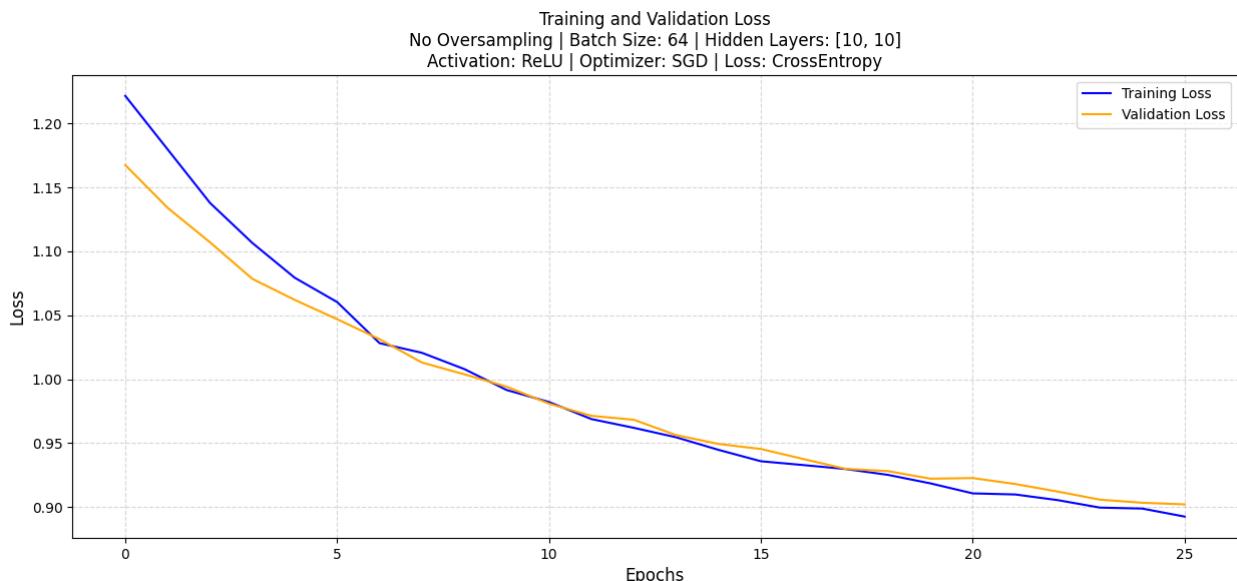
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



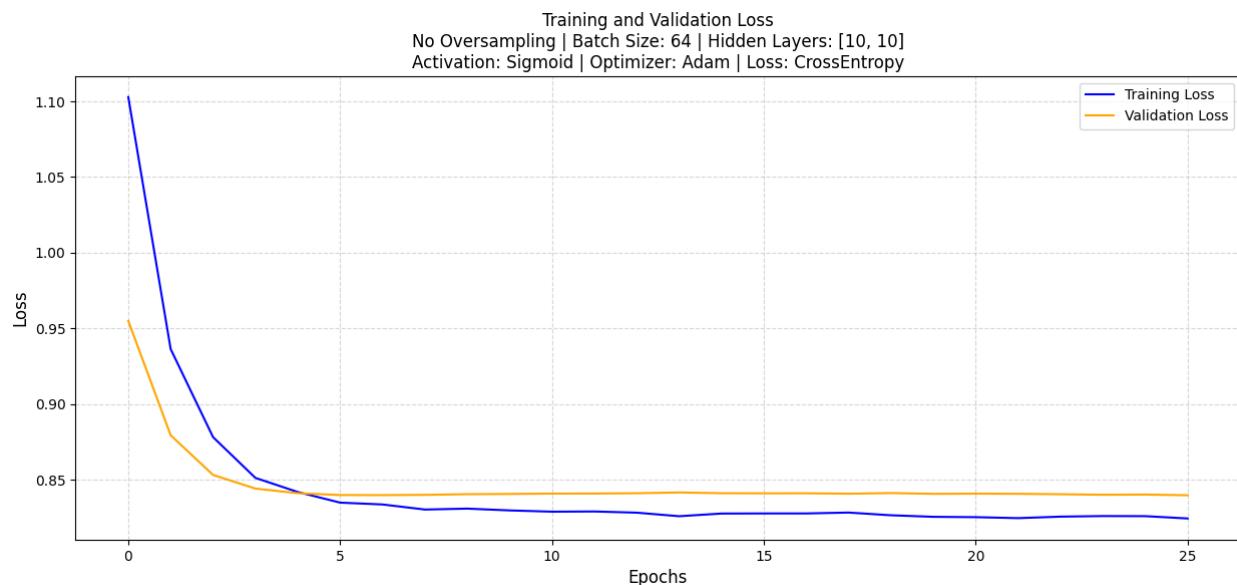
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



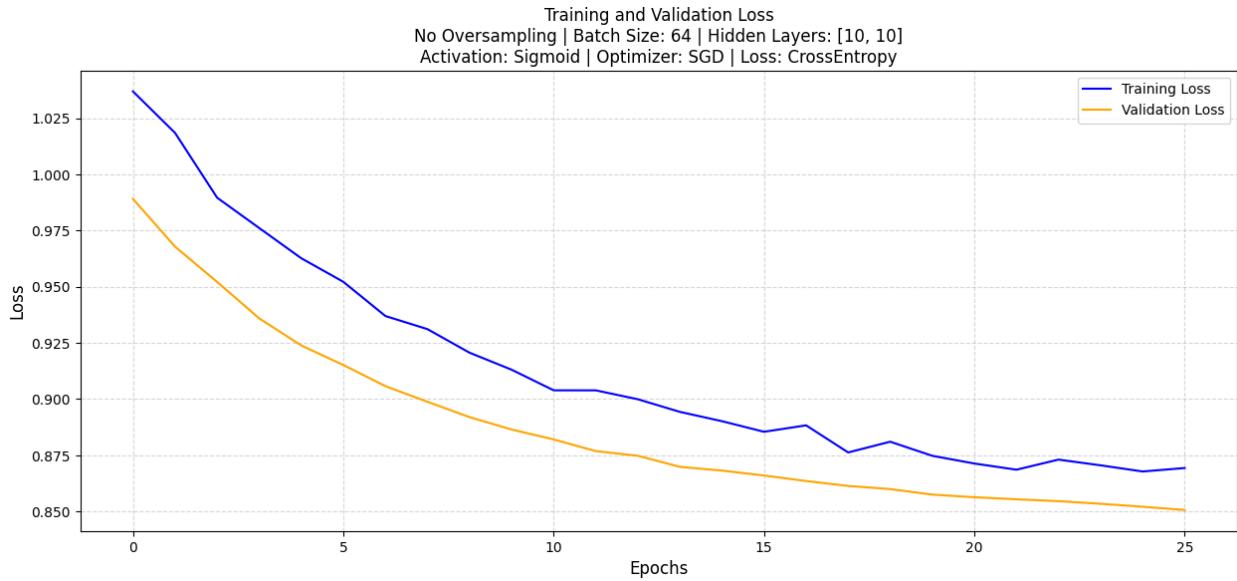
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



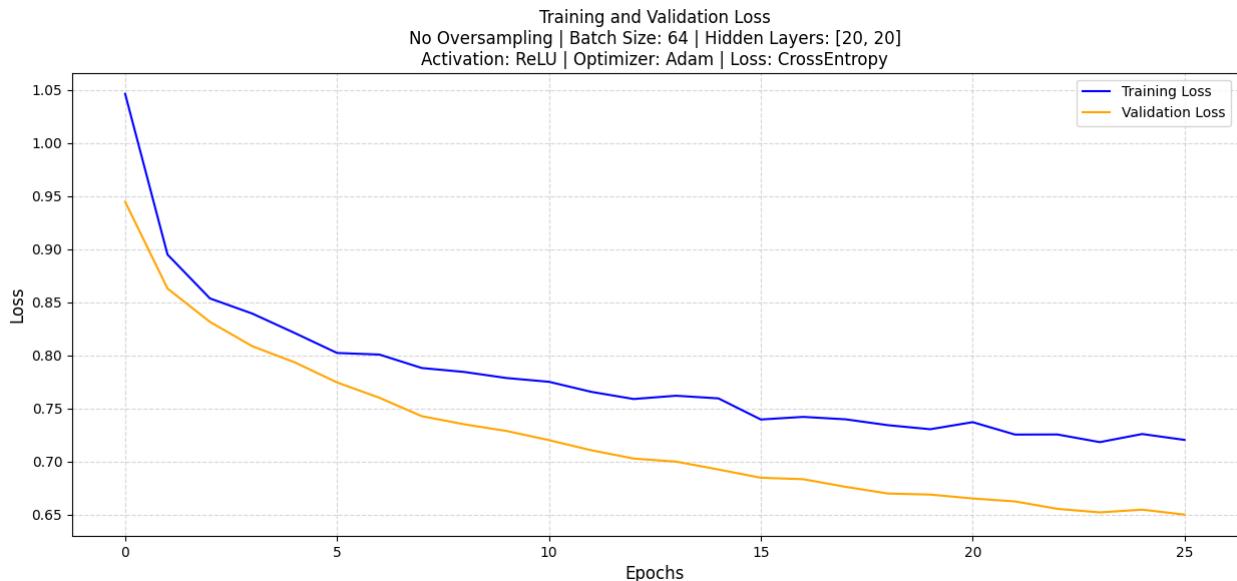
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



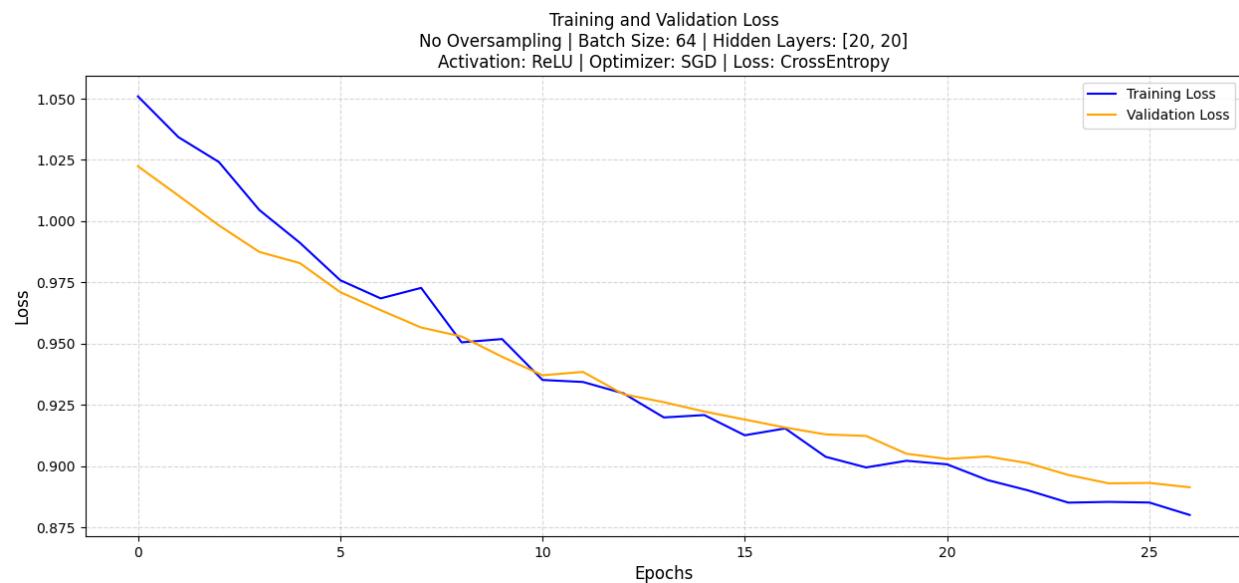
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



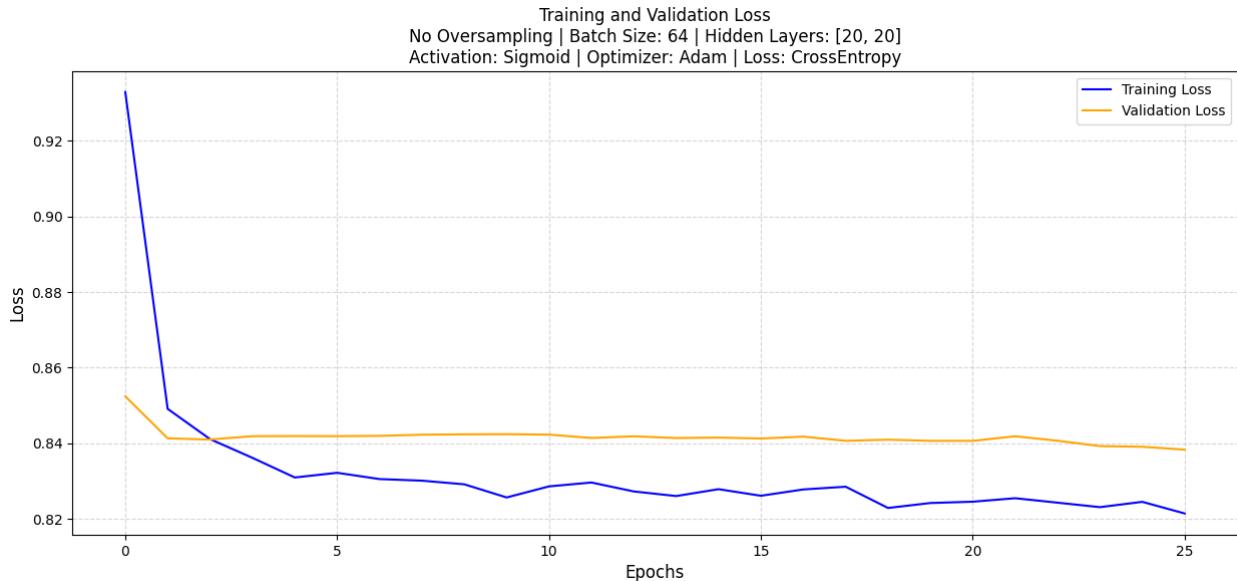
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



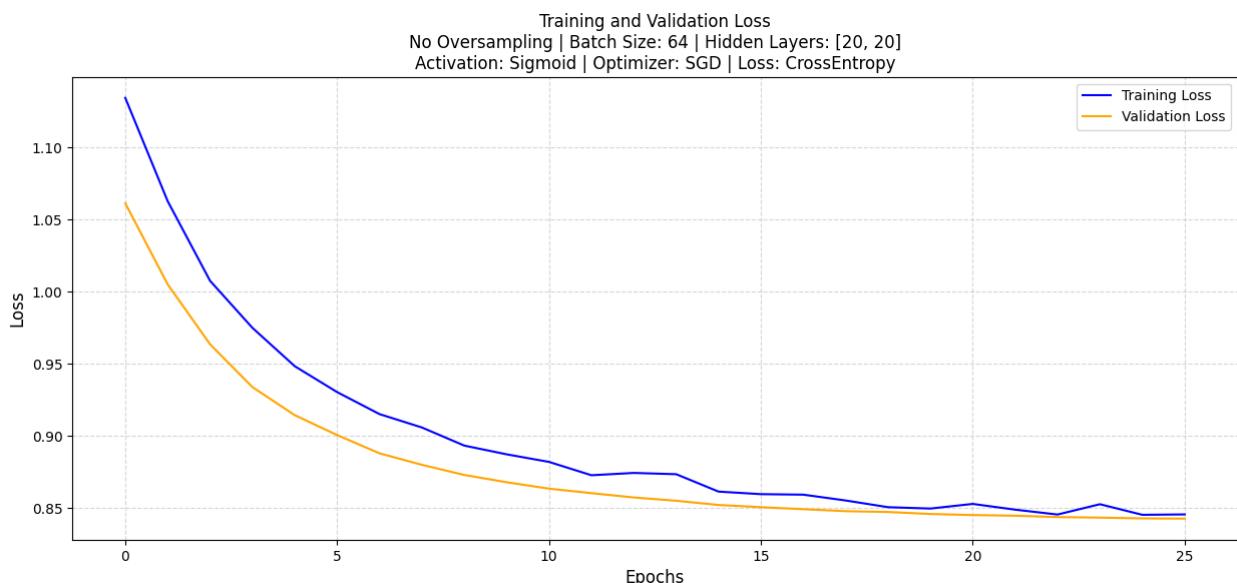
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



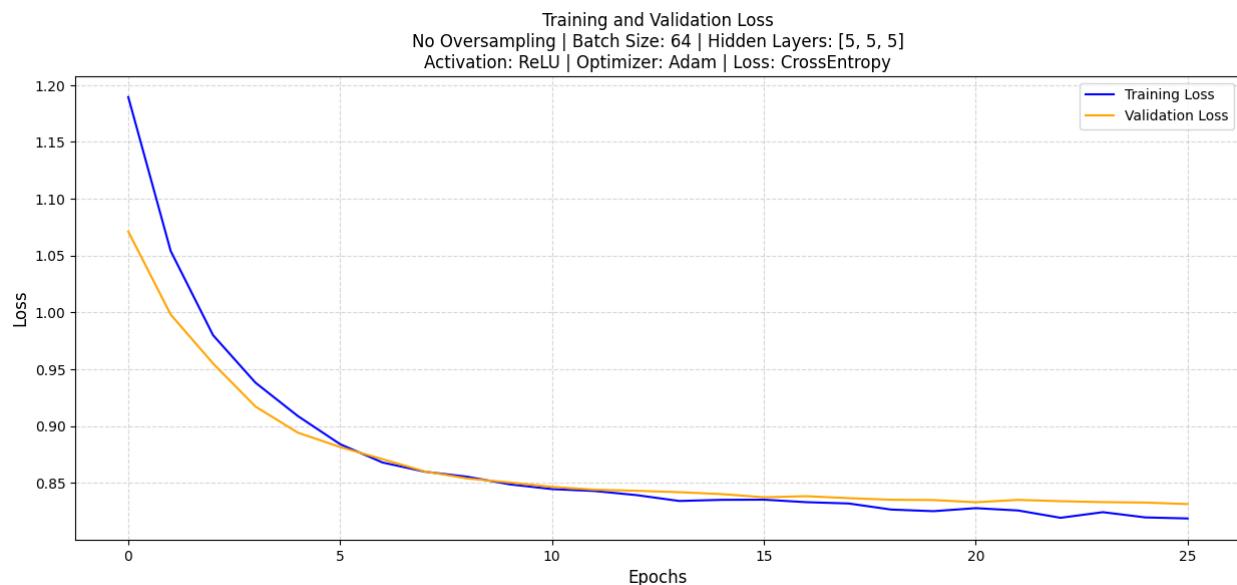
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



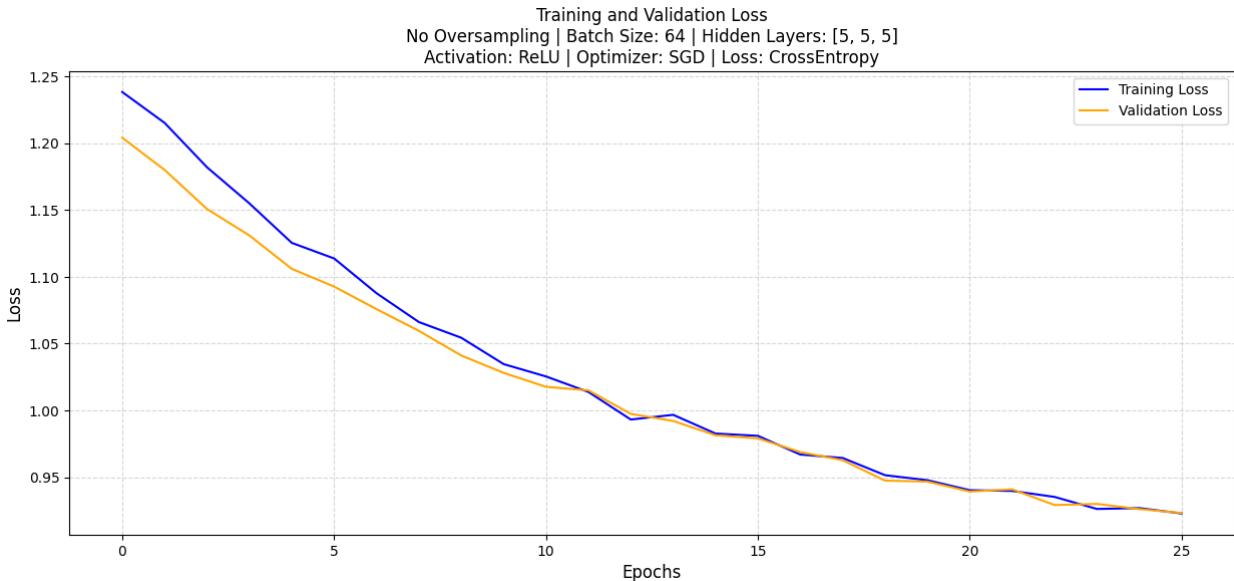
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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len(result))
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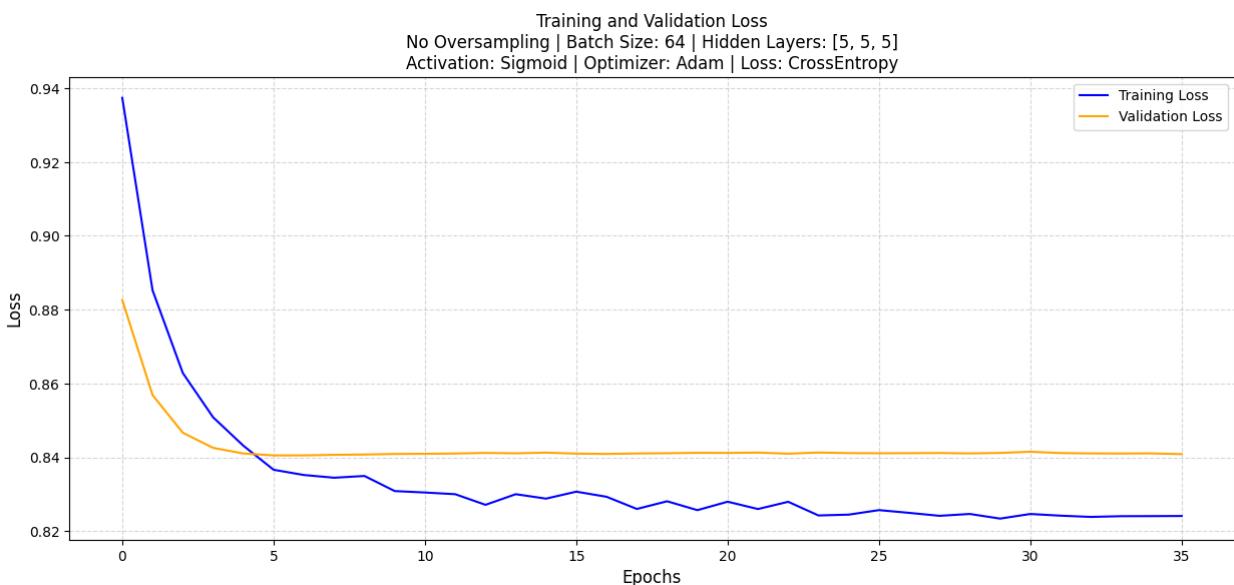
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



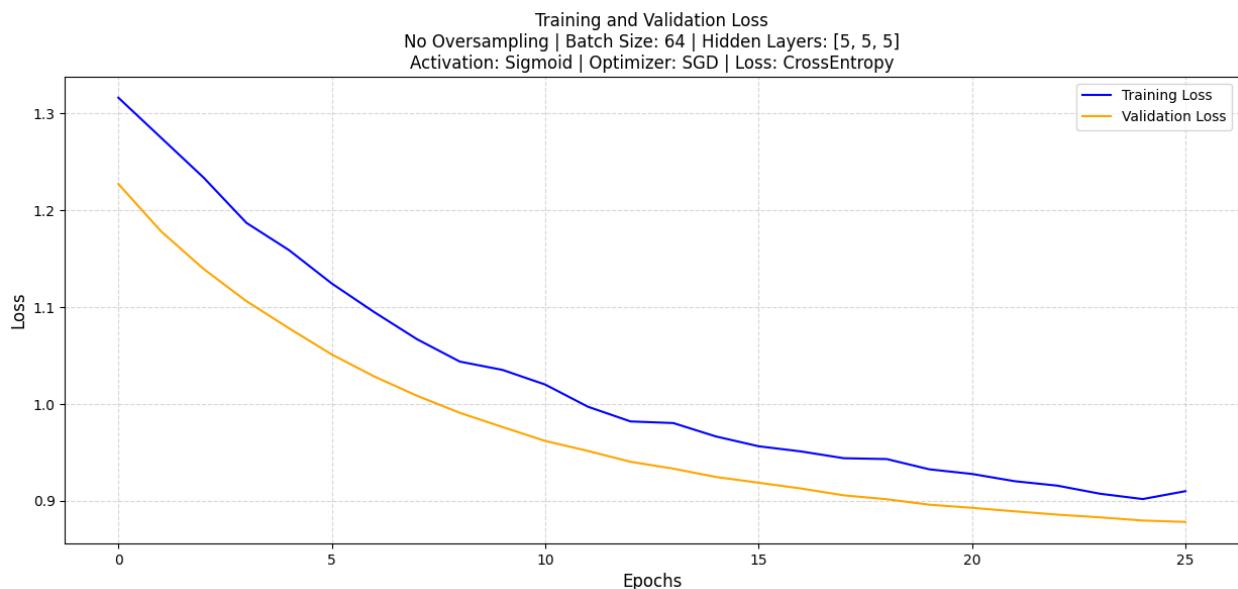
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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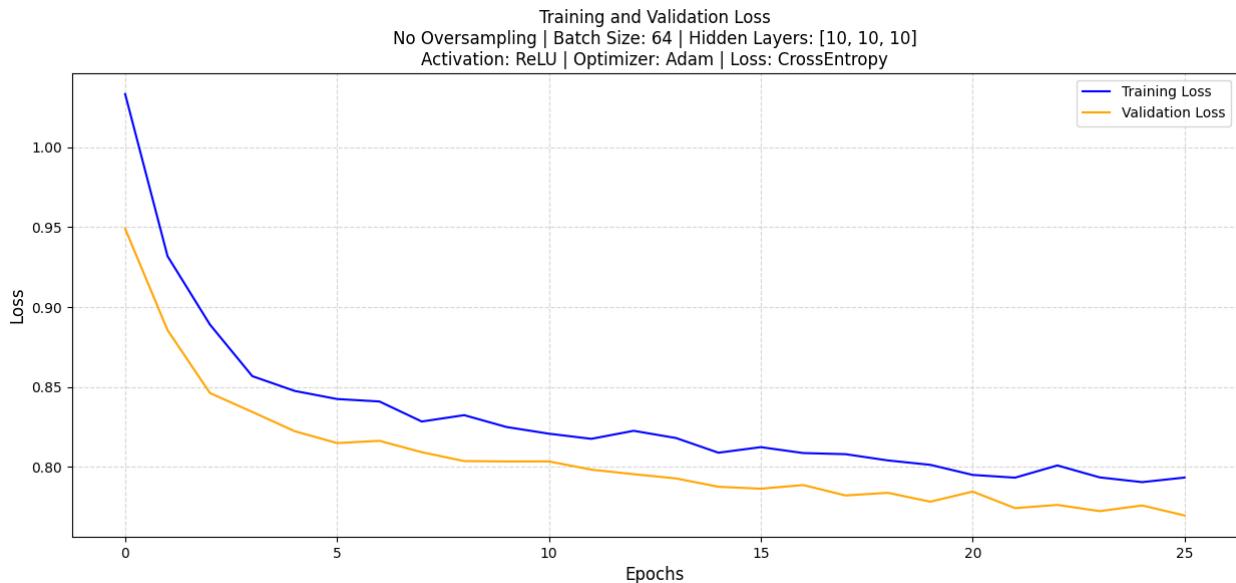
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
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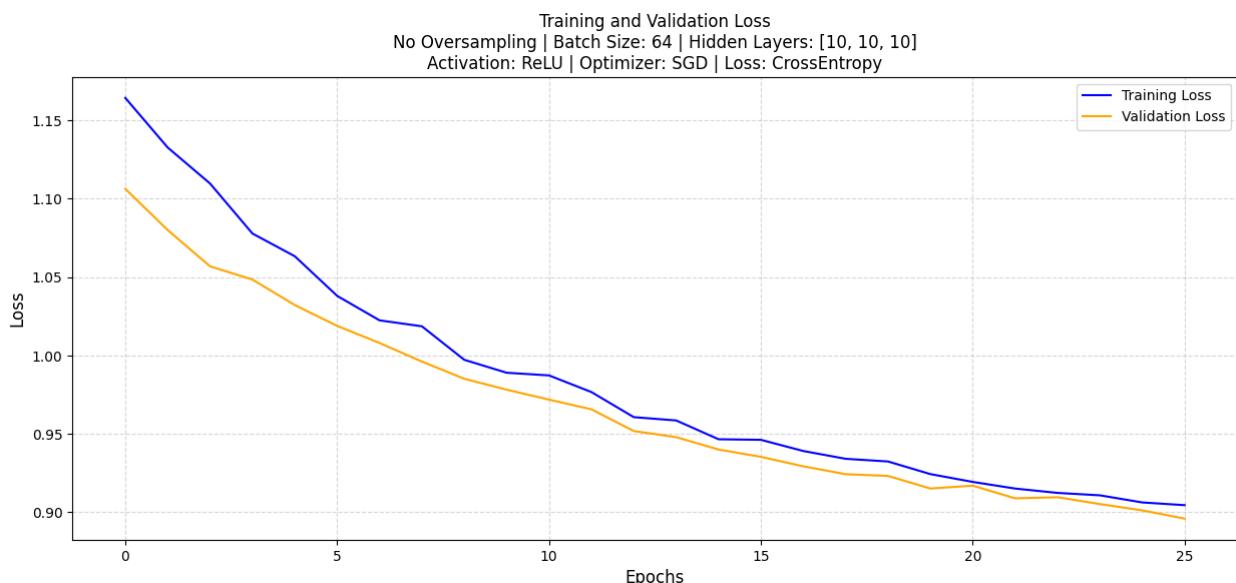
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
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```



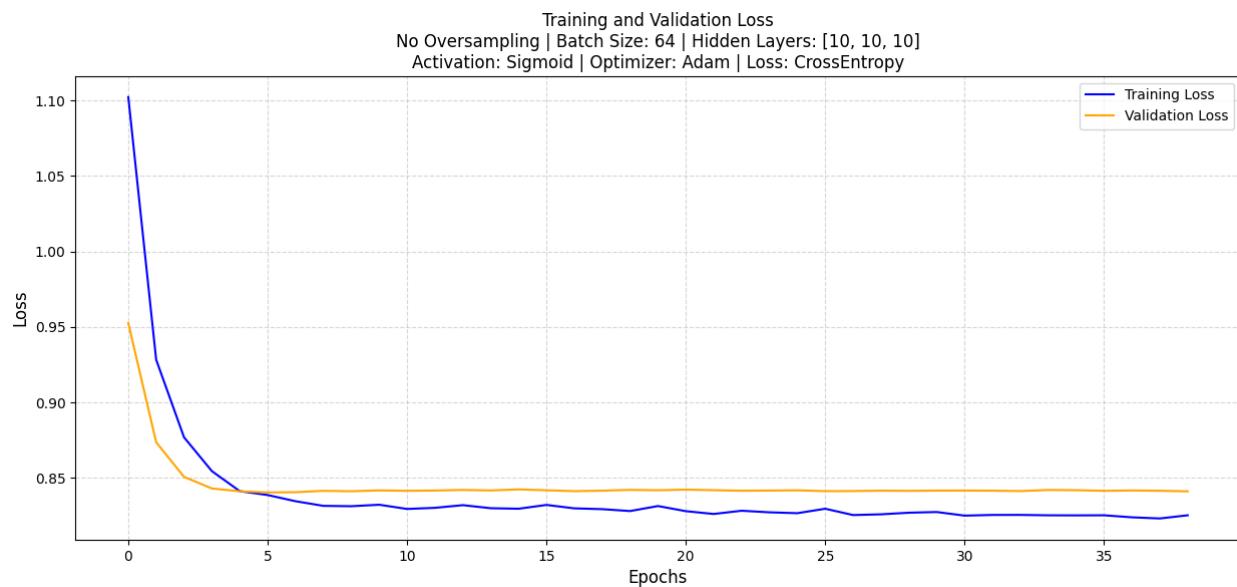
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



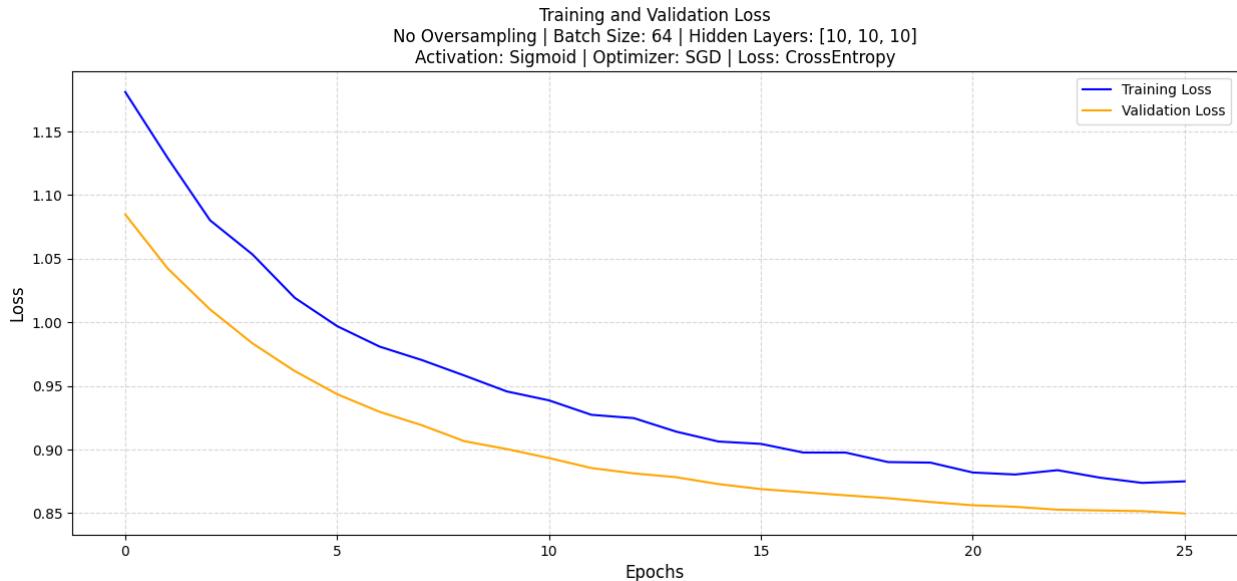
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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```



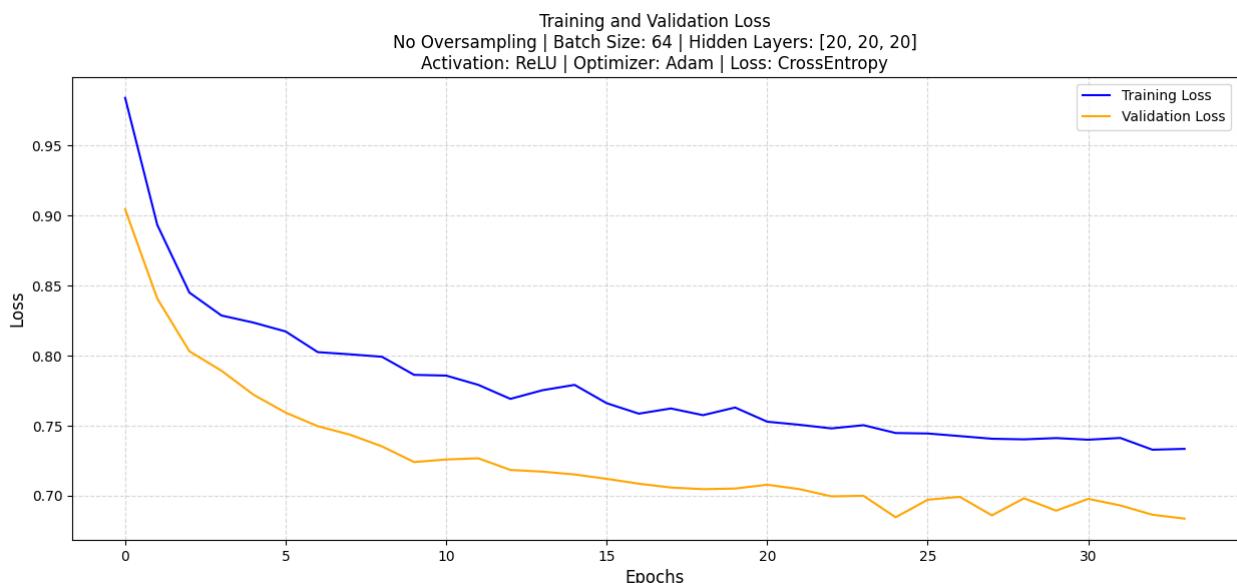
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



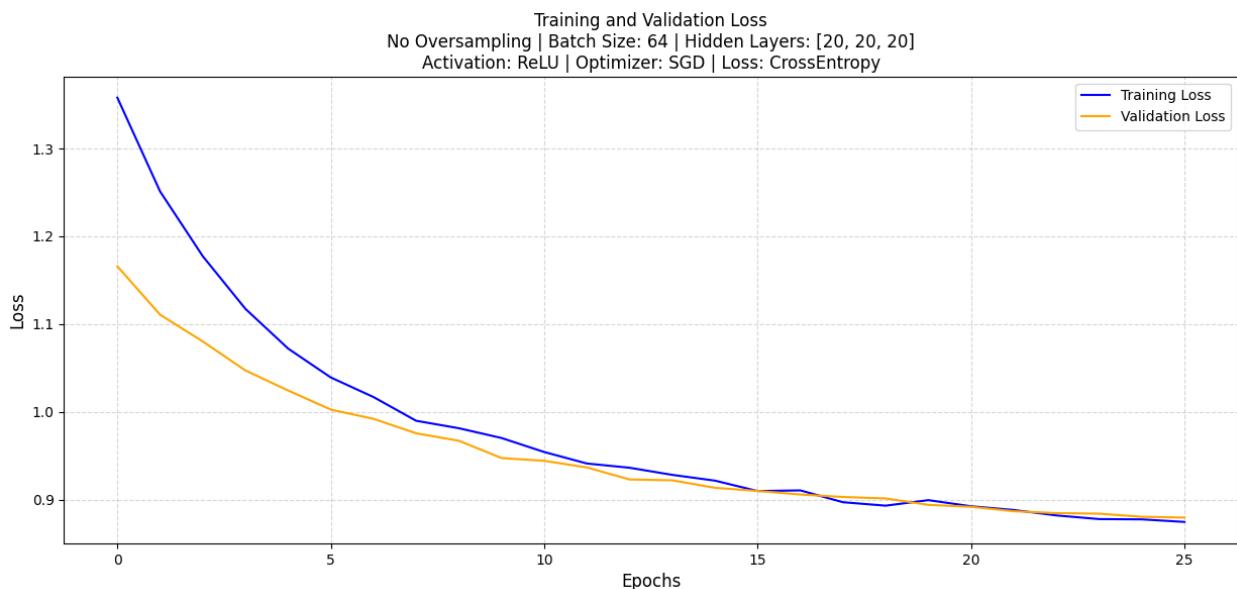
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



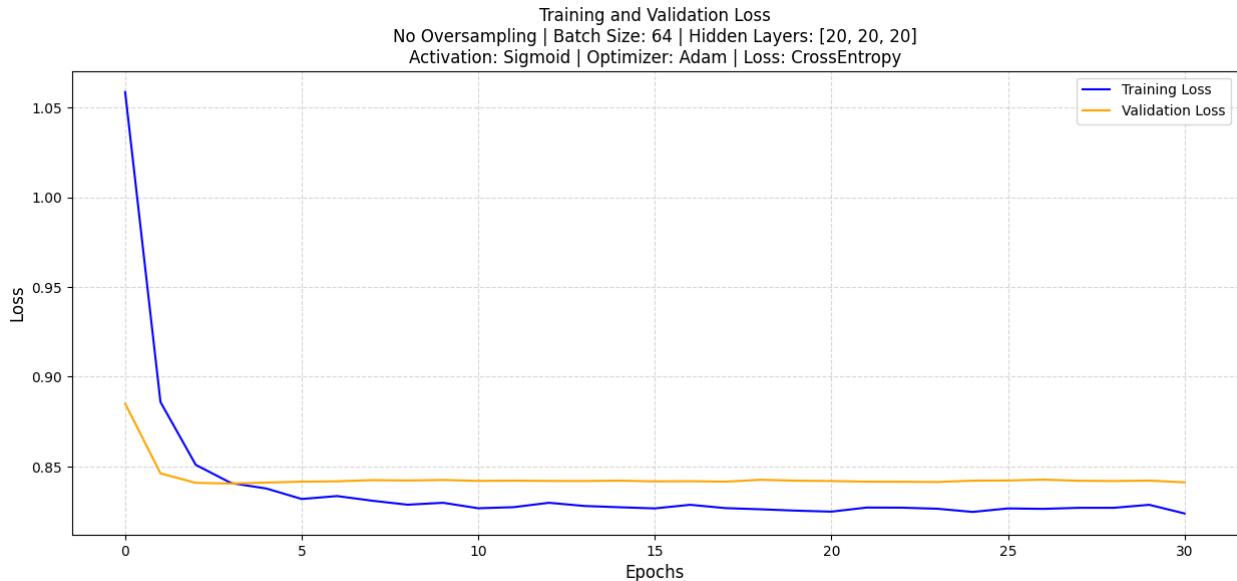
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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len(result))
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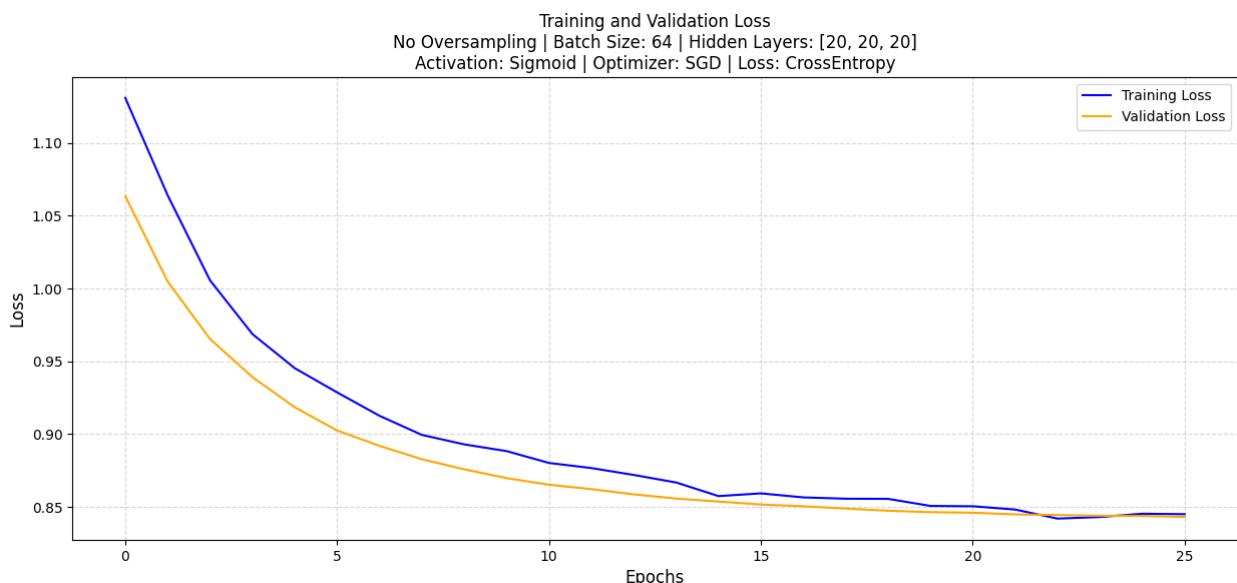
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



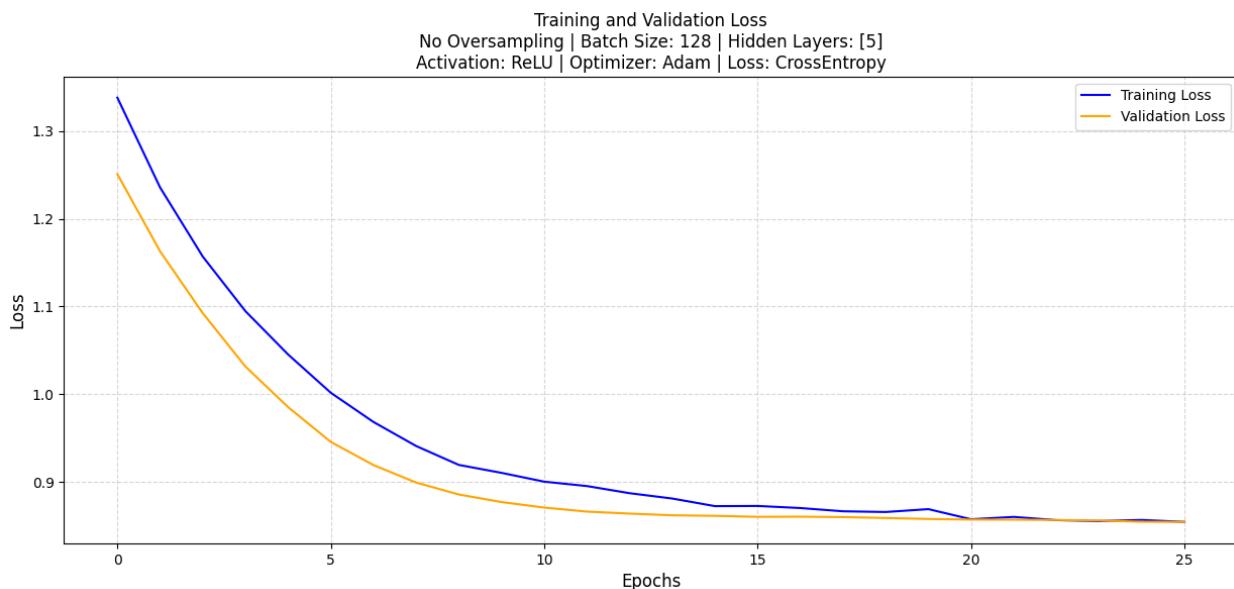
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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len(result))
```



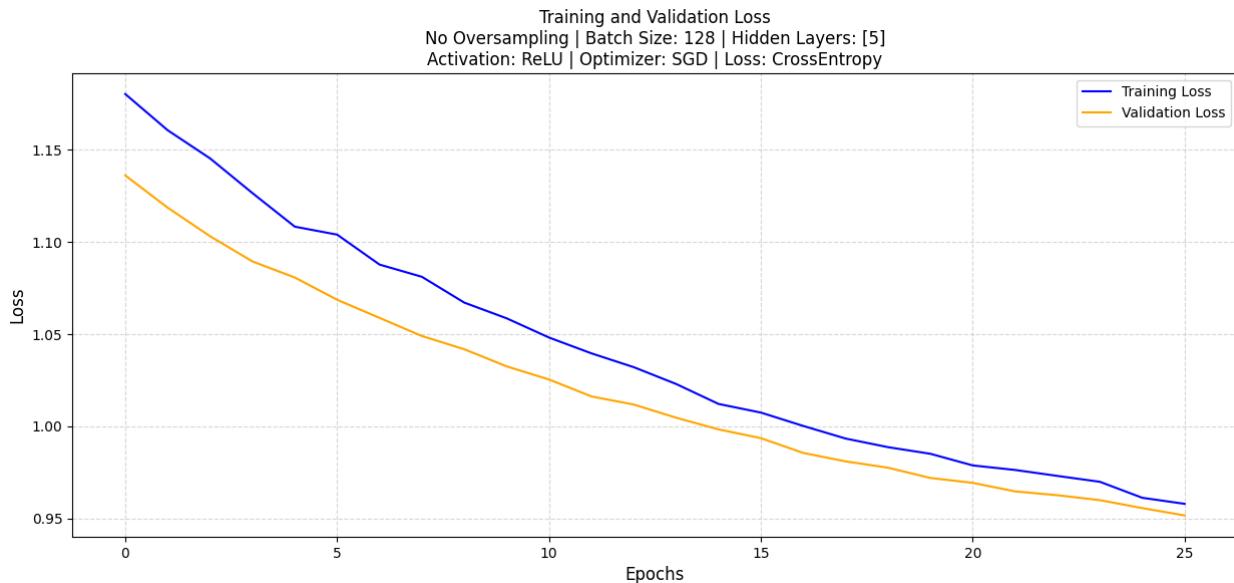
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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```



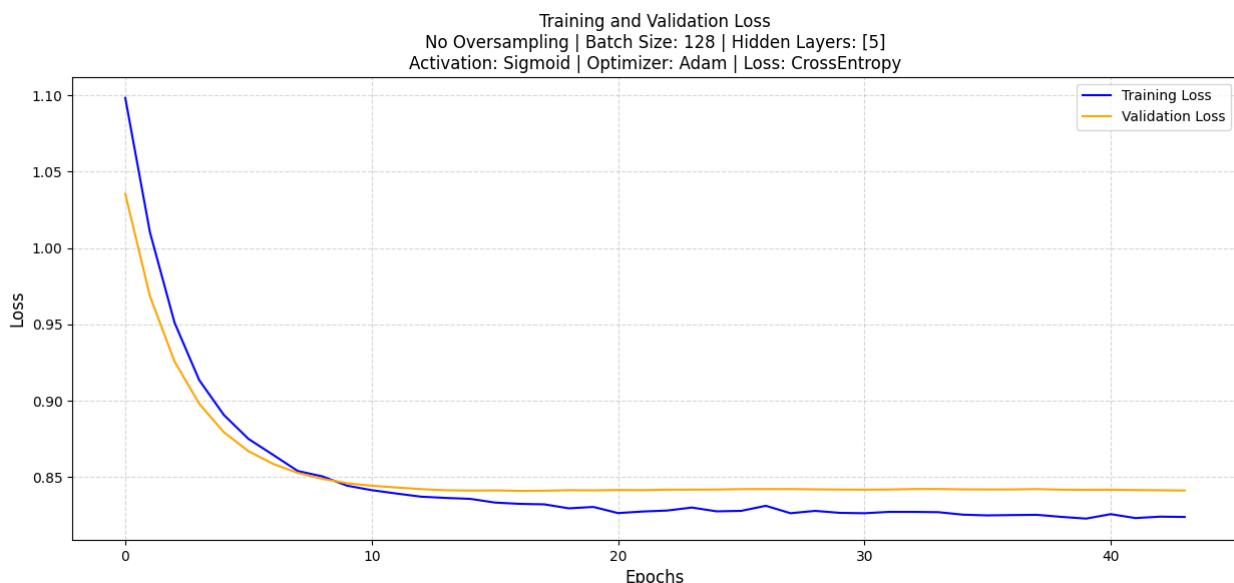
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



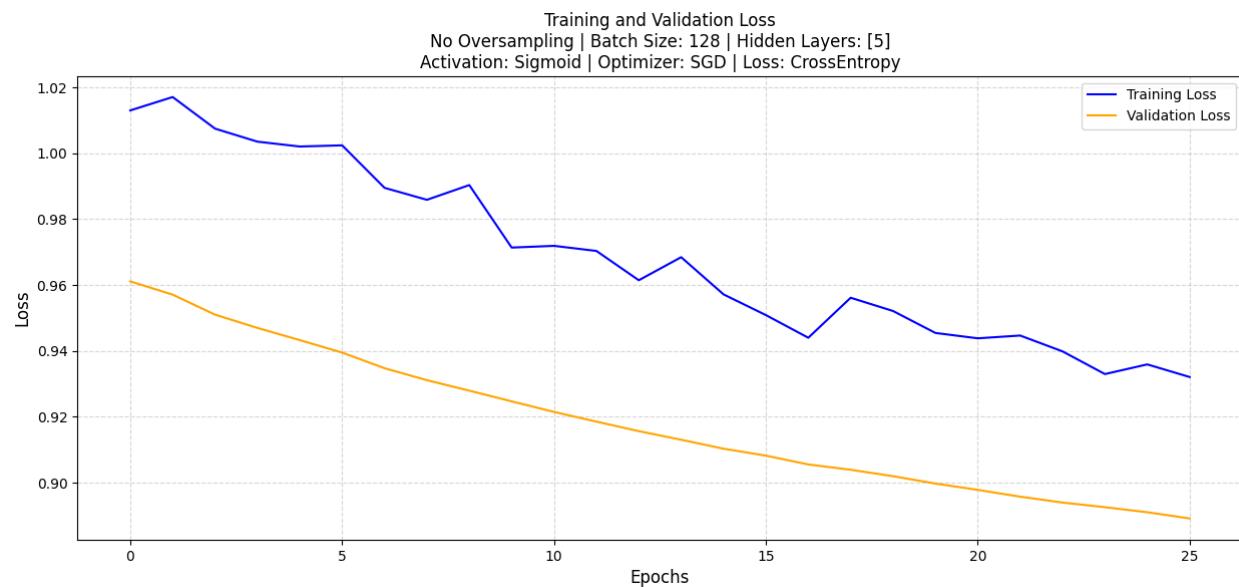
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
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```



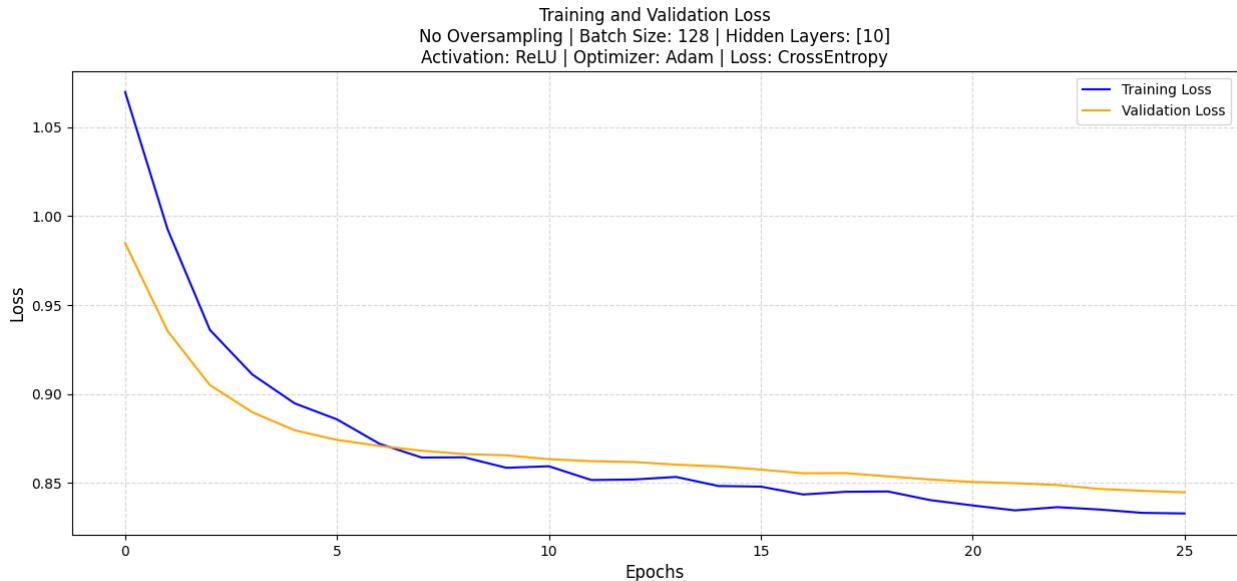
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



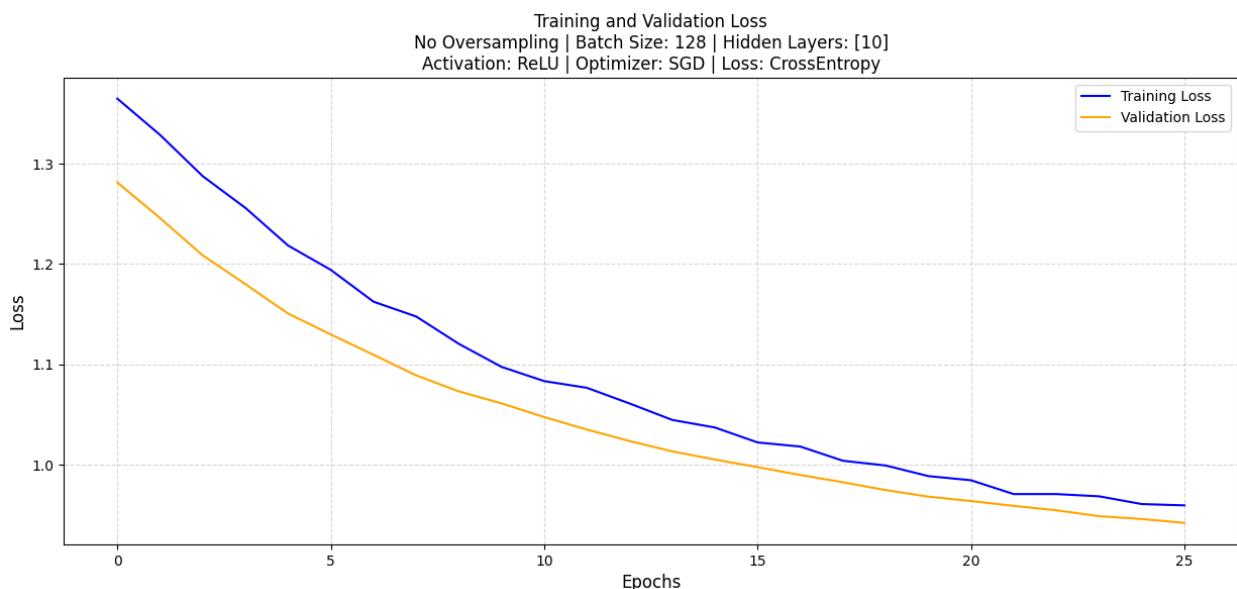
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
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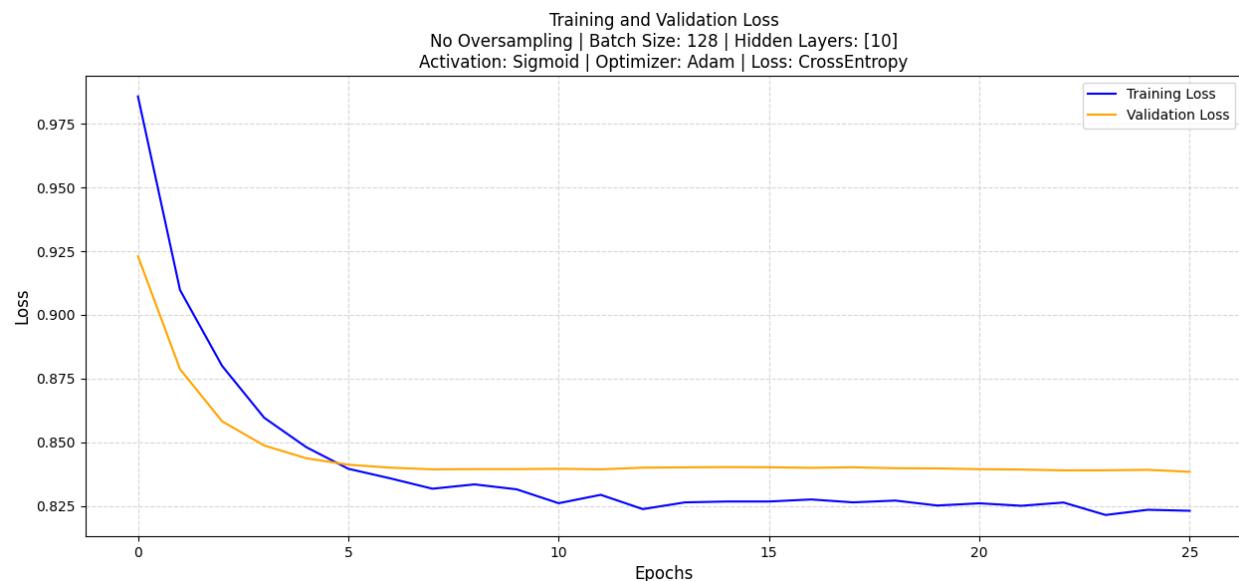
Early stopping triggered

```
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len(result))
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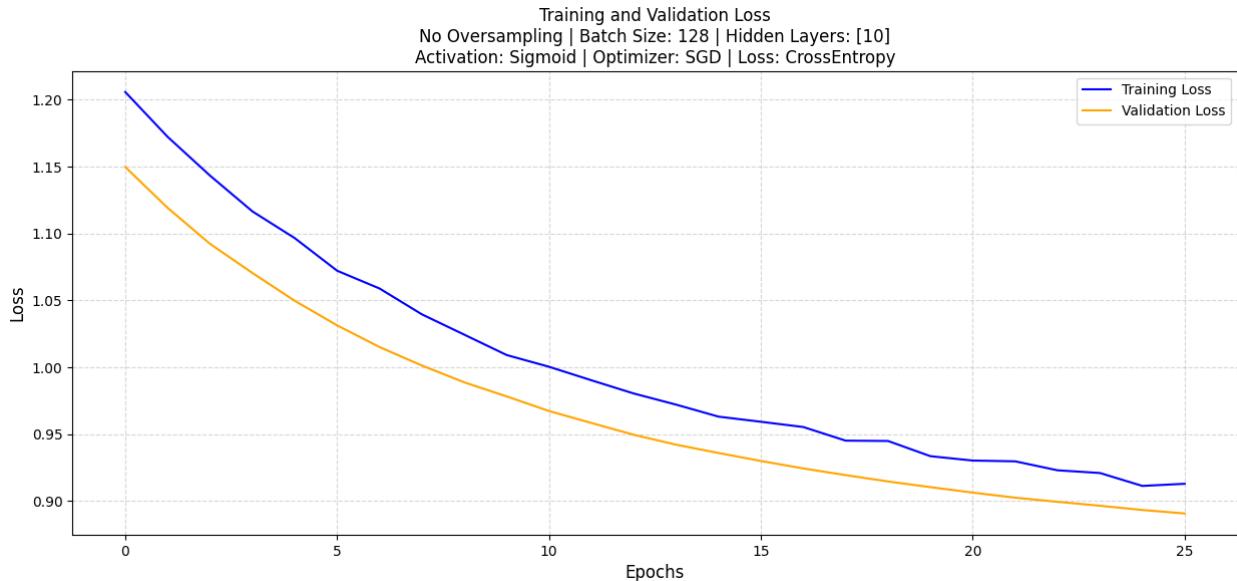
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
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```



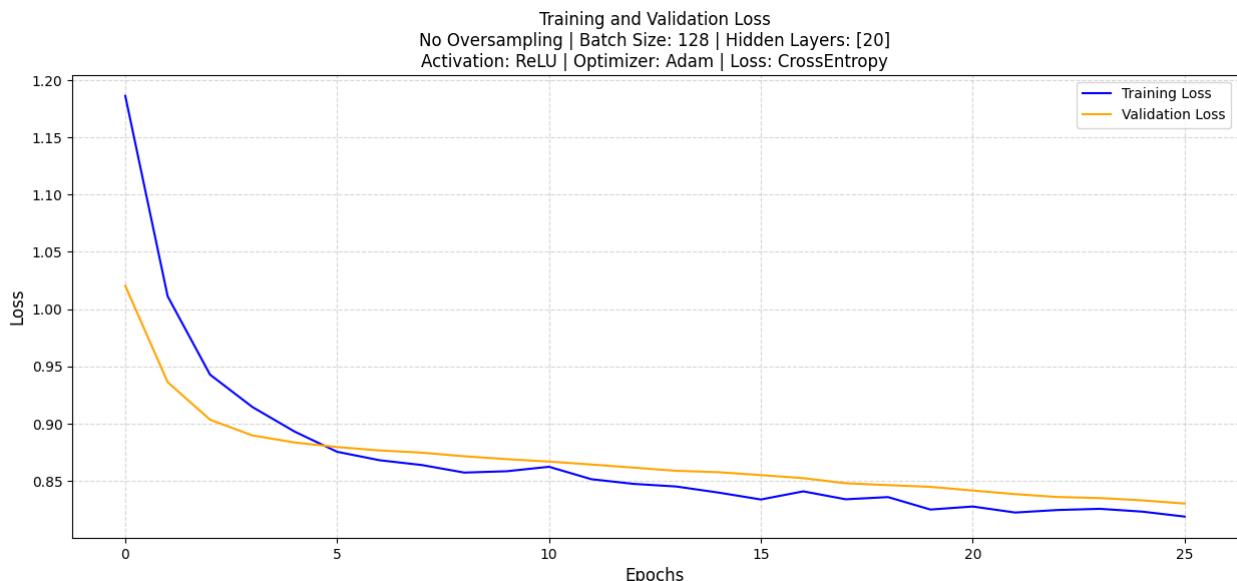
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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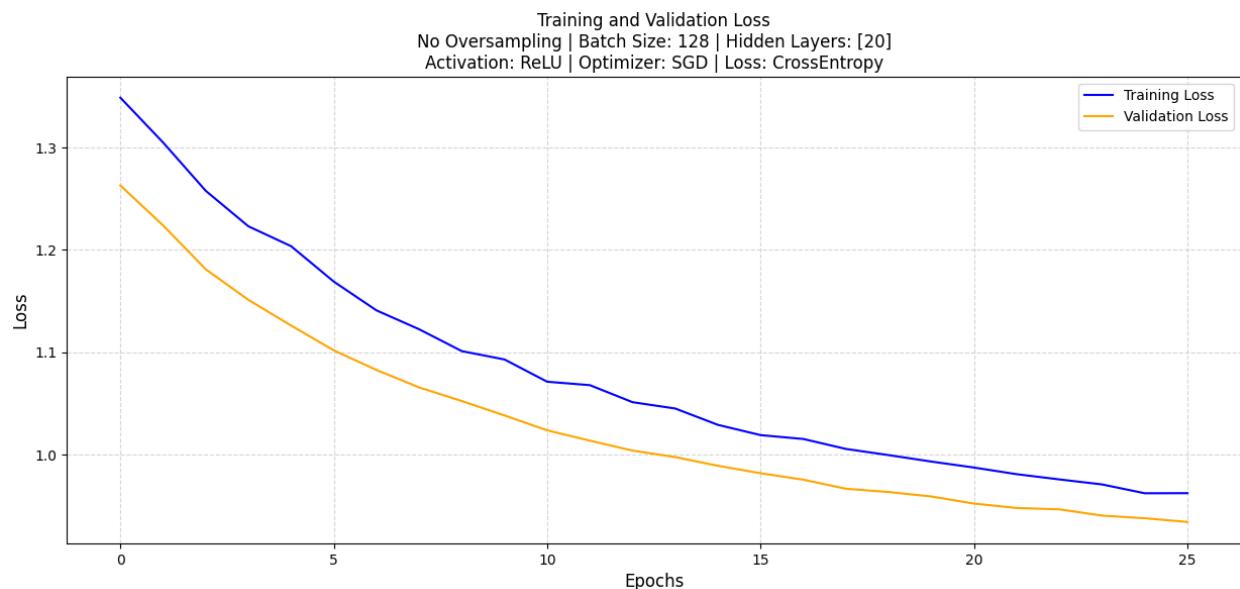
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
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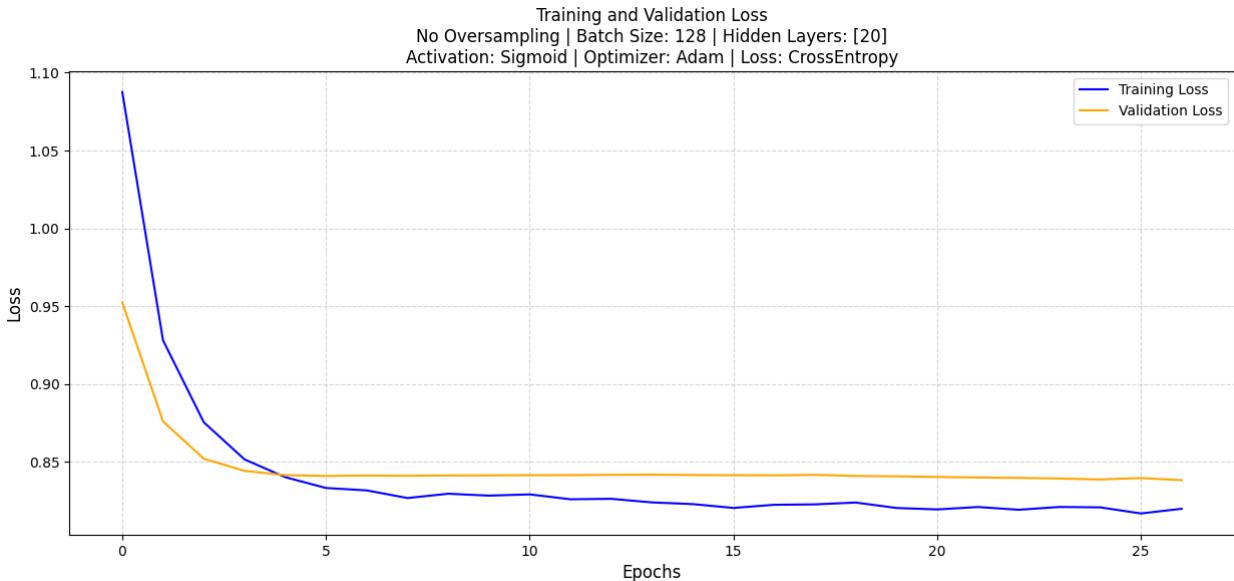
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
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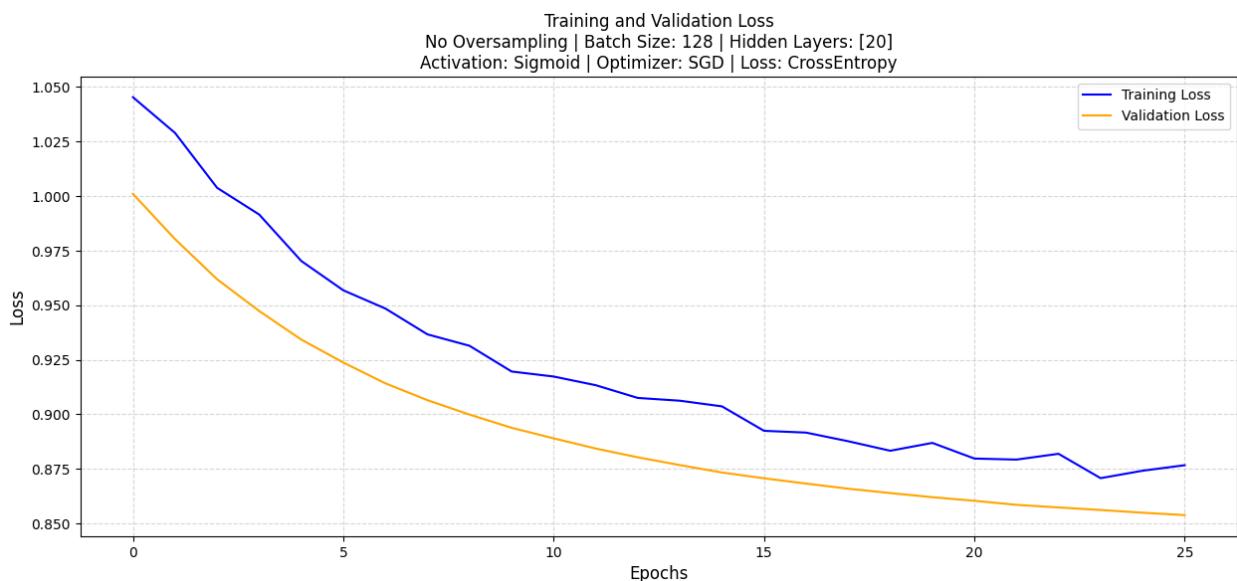
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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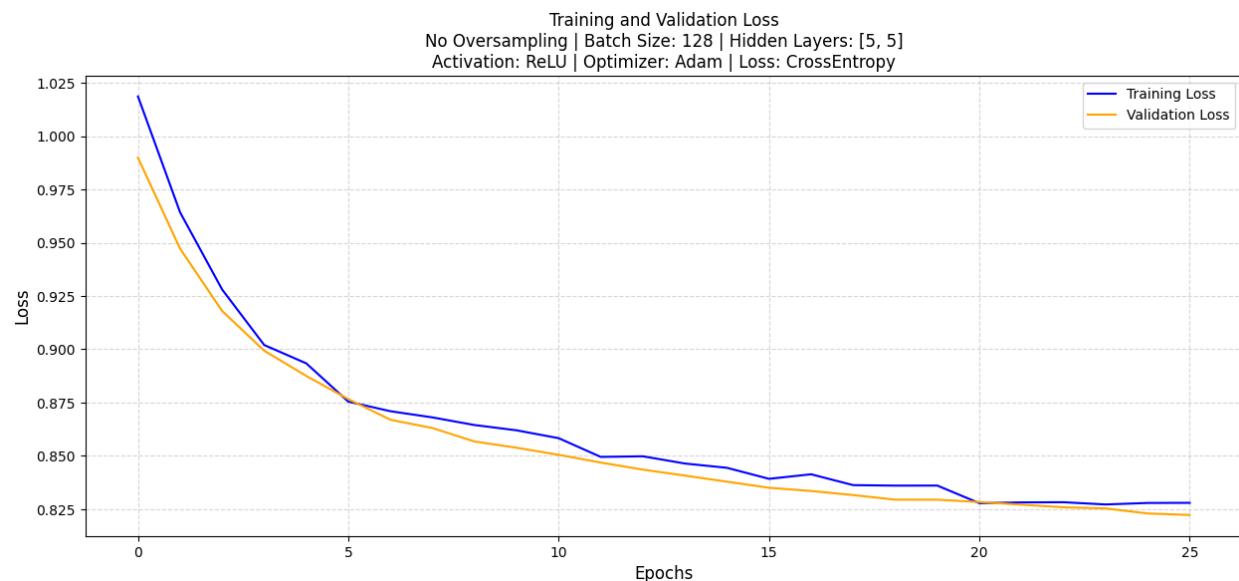
Early stopping triggered

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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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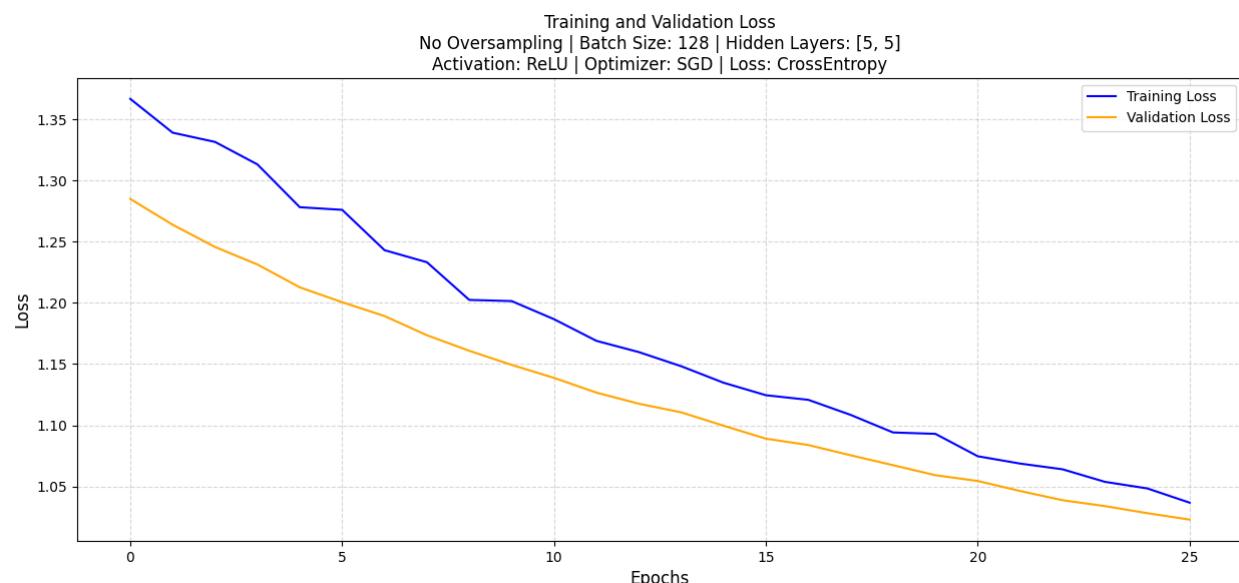


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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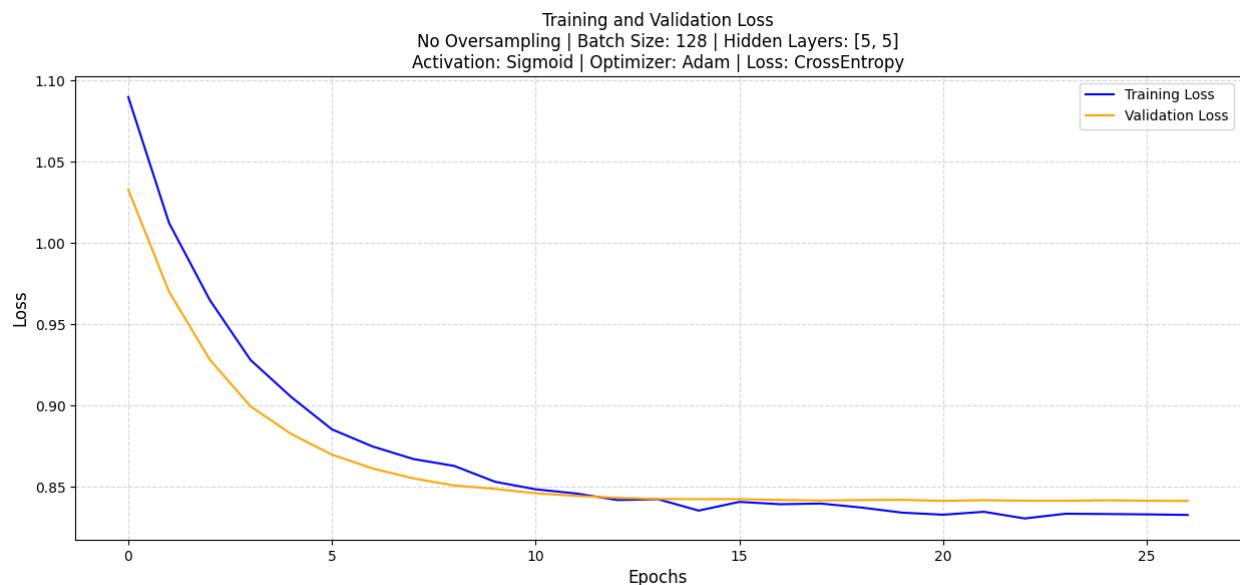


Early stopping triggered



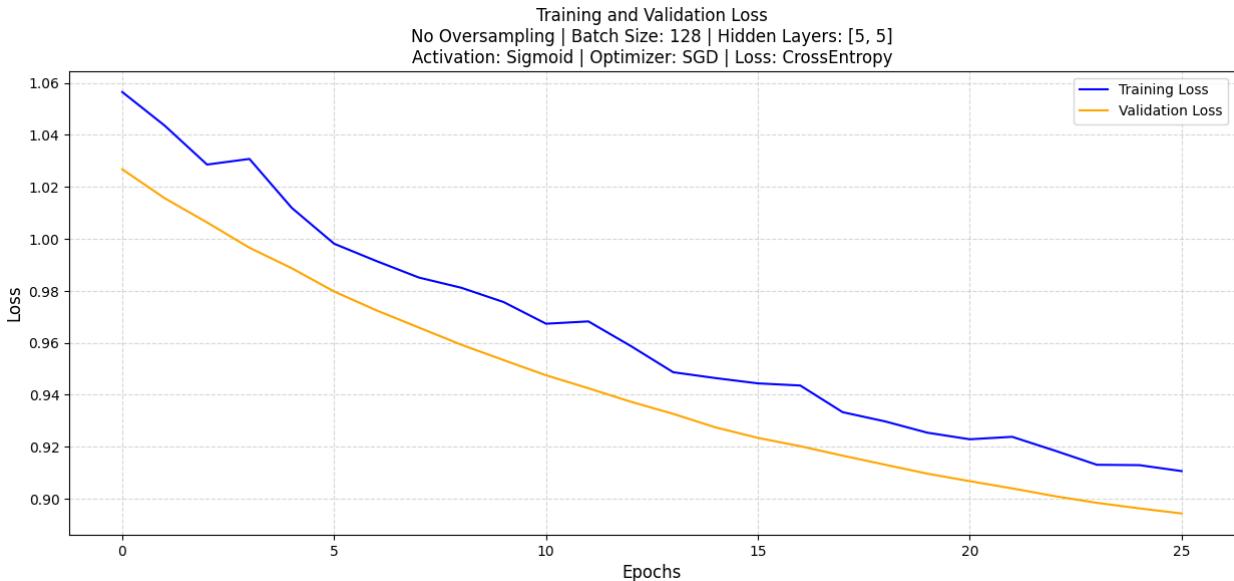
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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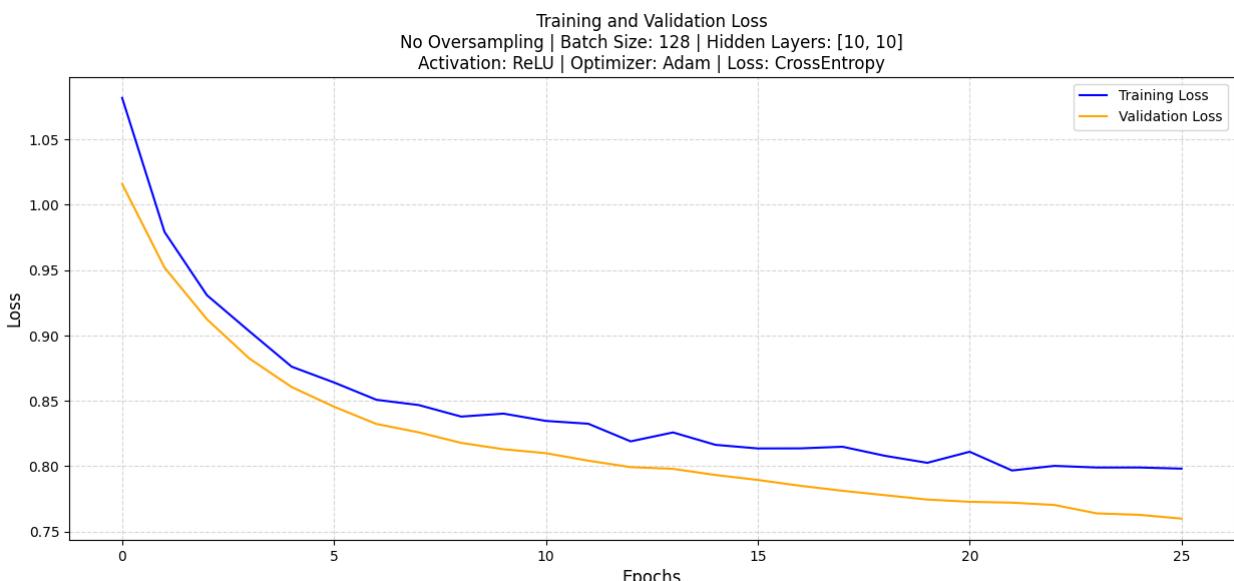
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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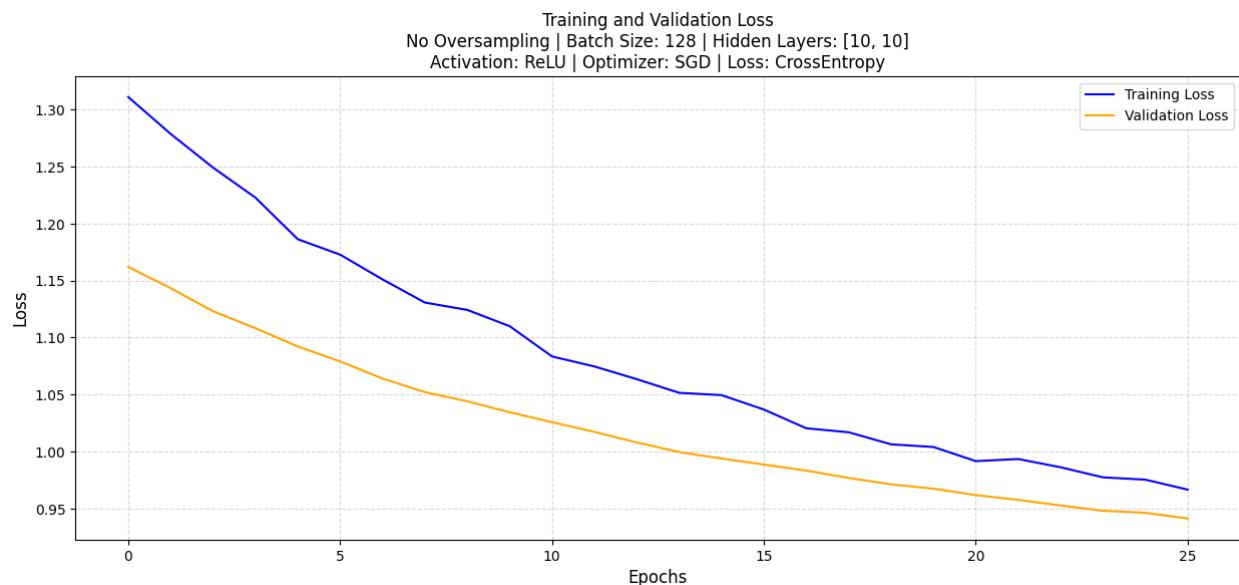
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
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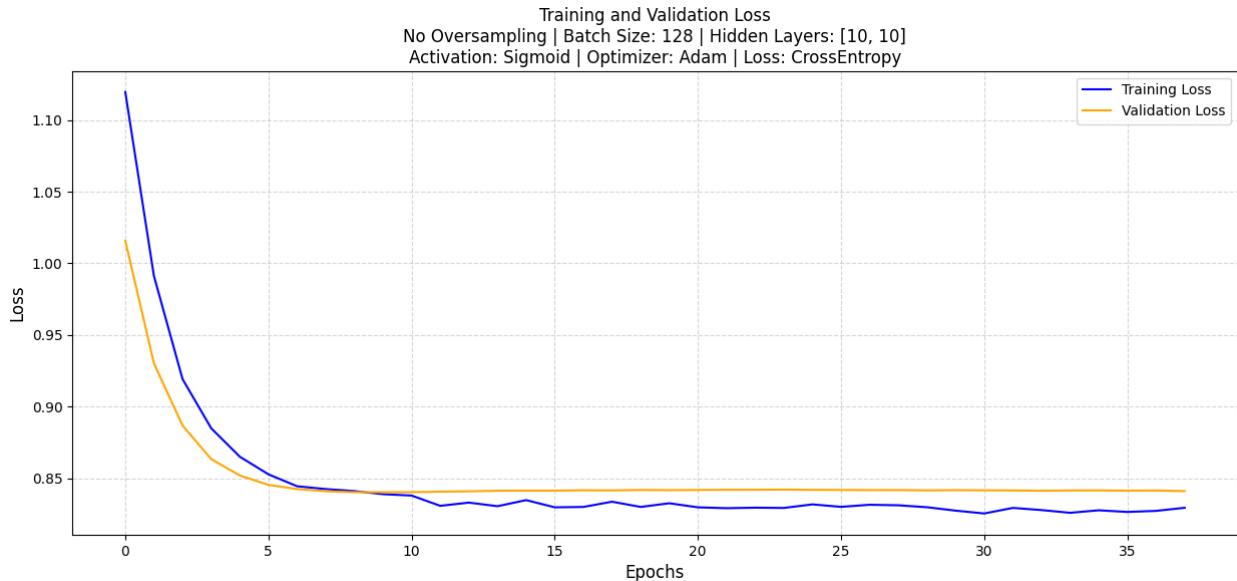
Early stopping triggered

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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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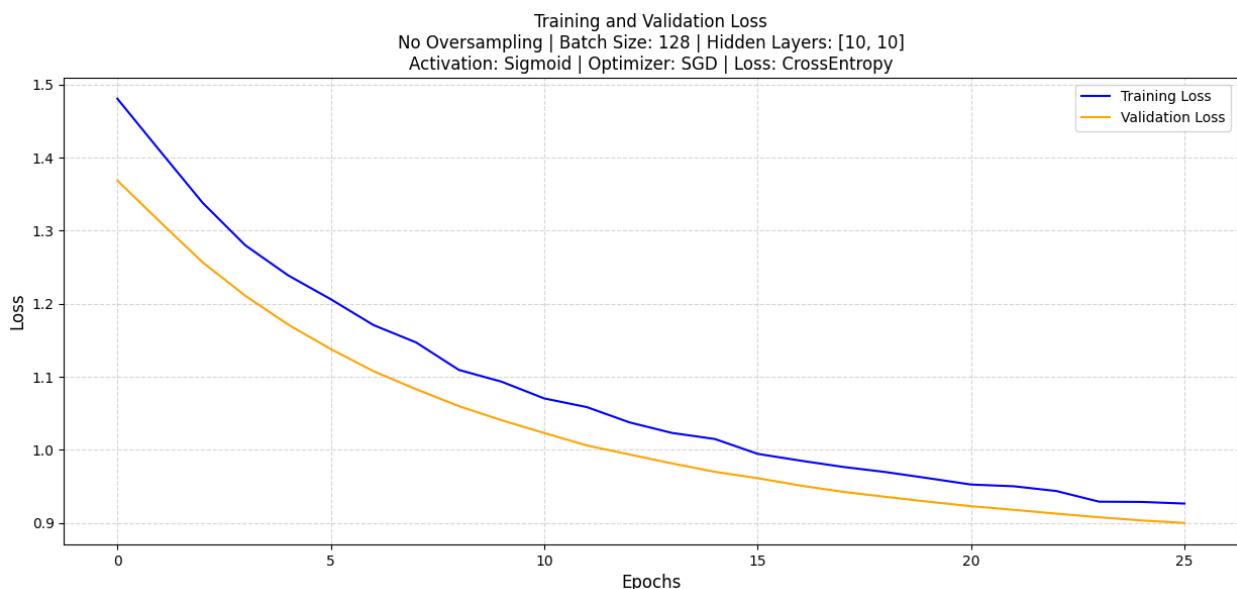
Early stopping triggered

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len(result))
```



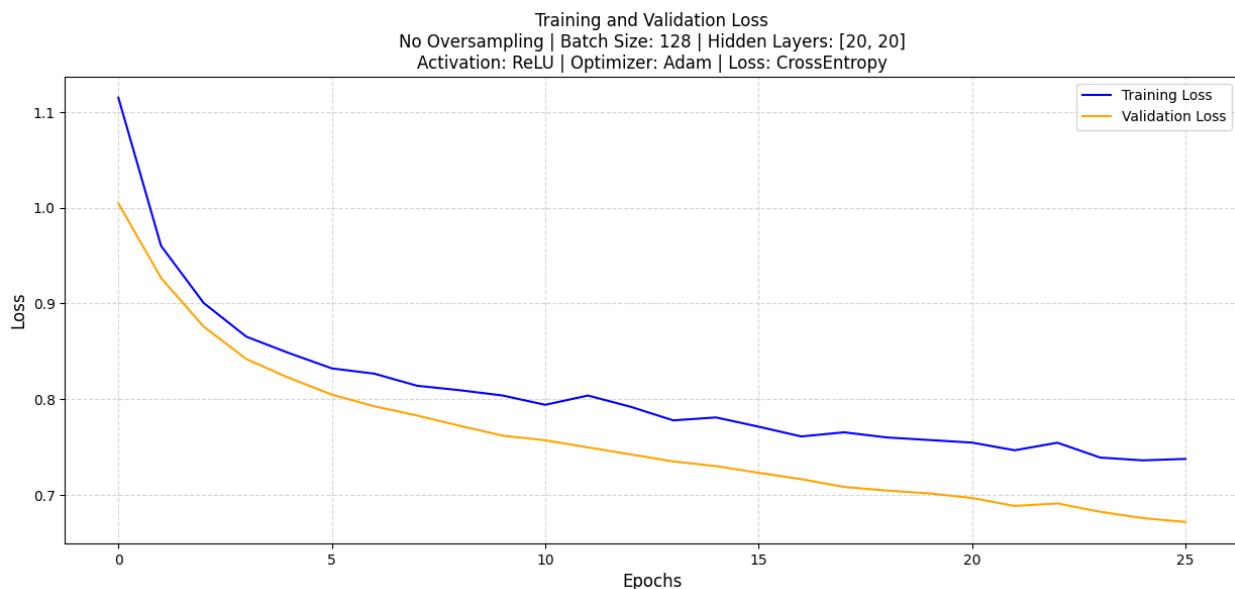
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



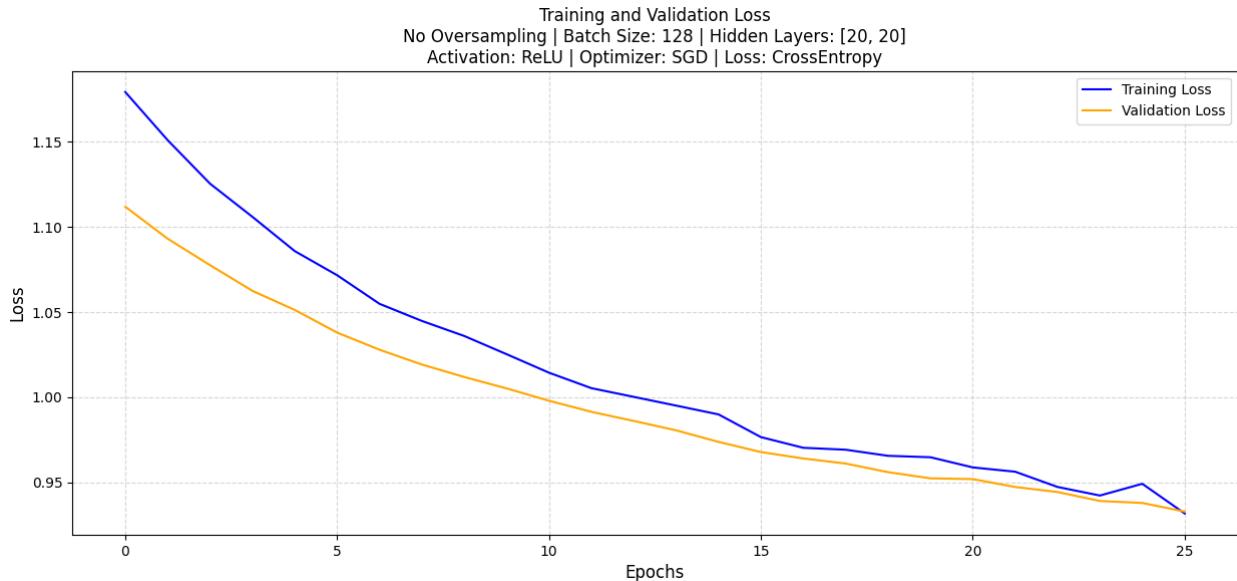
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



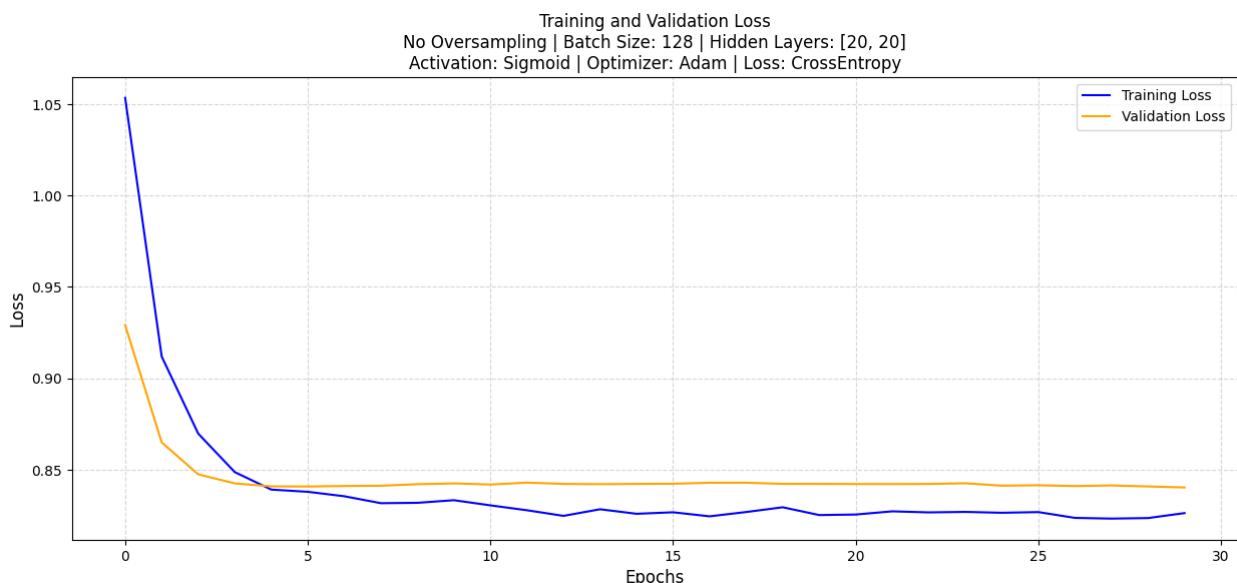
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



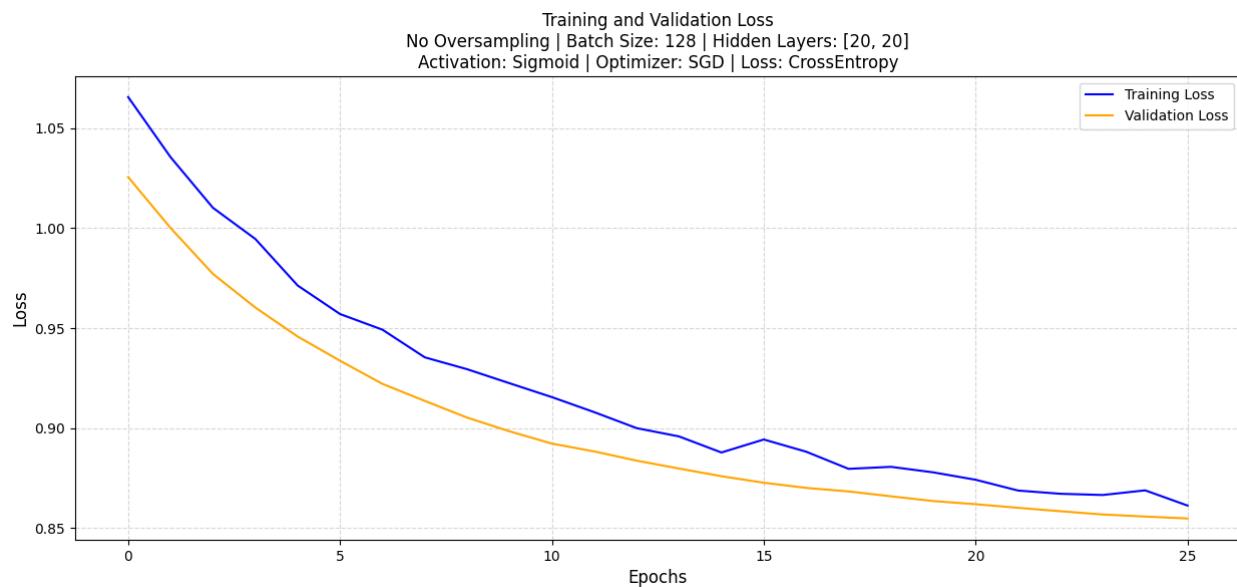
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



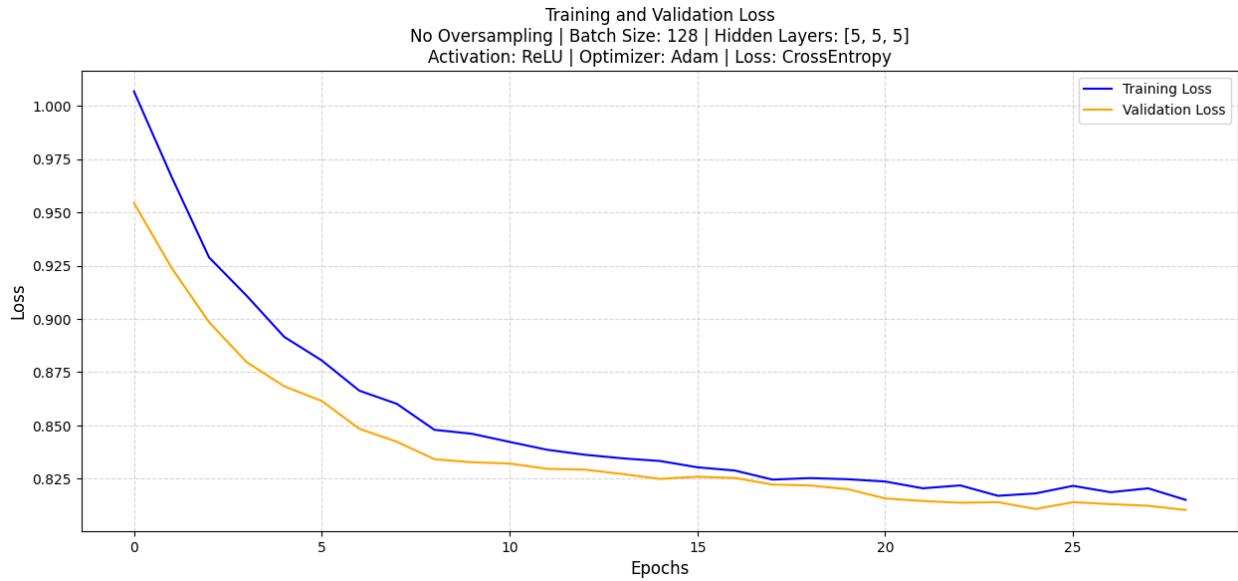
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



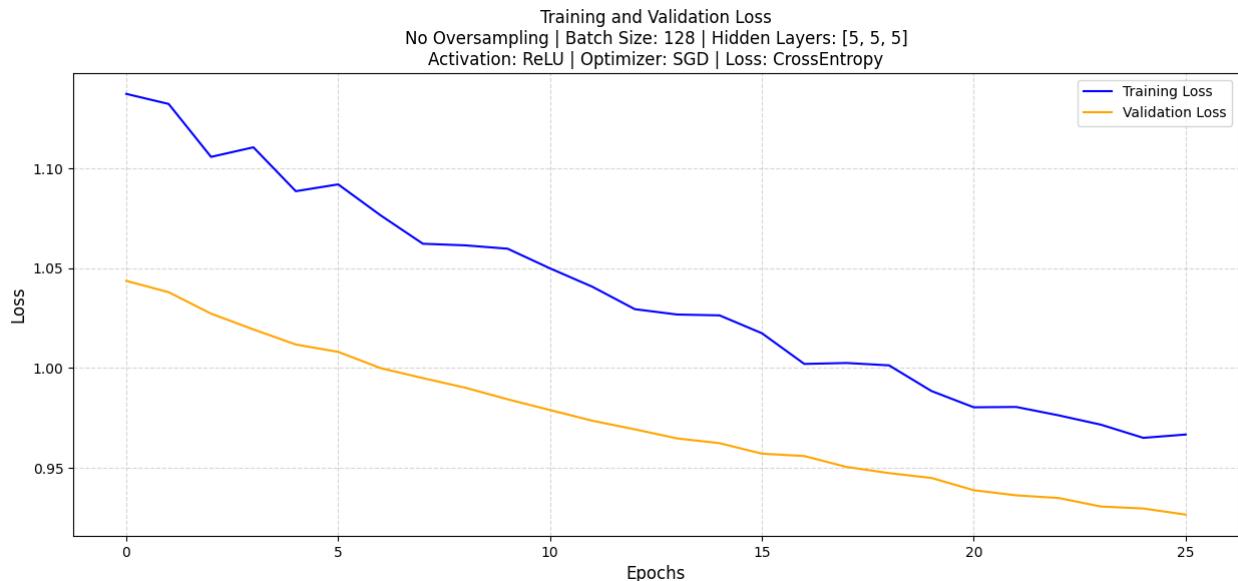
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



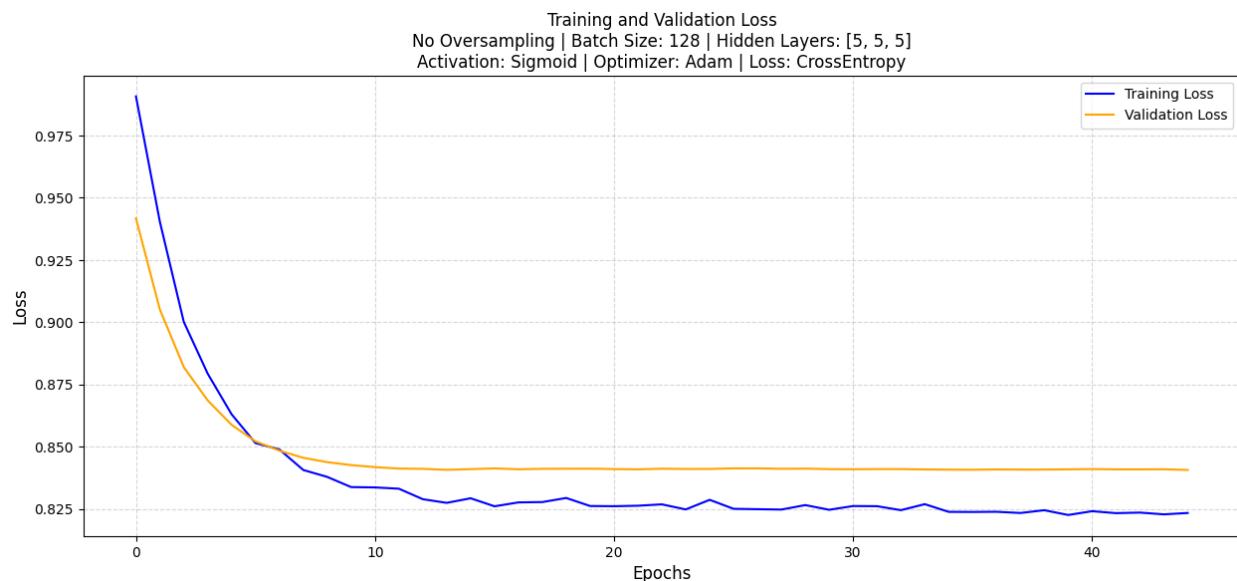
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



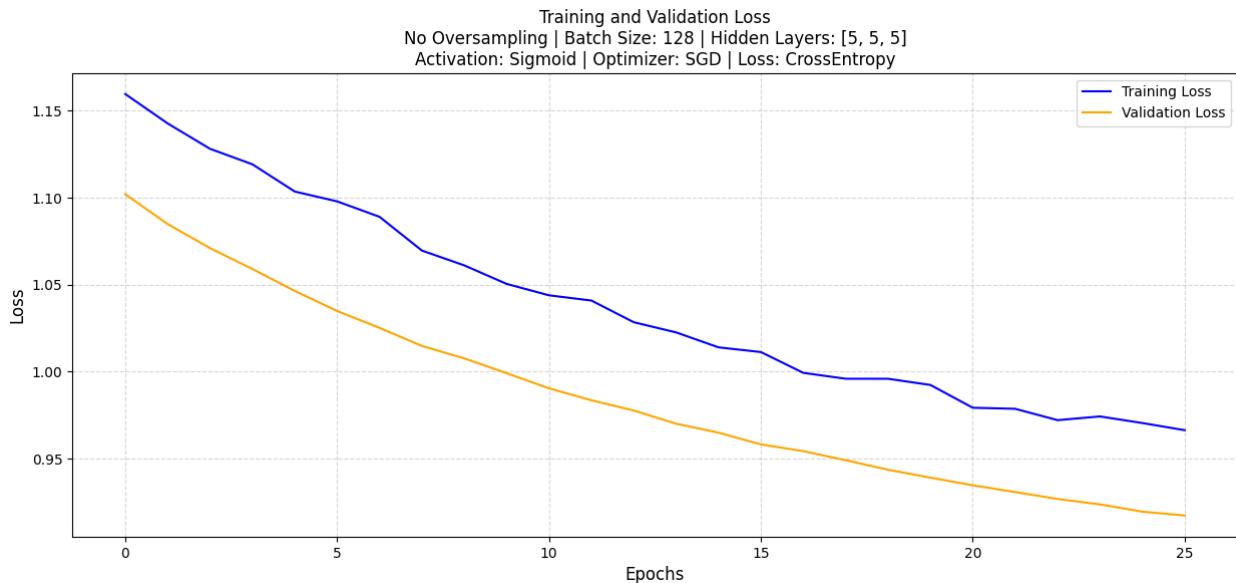
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



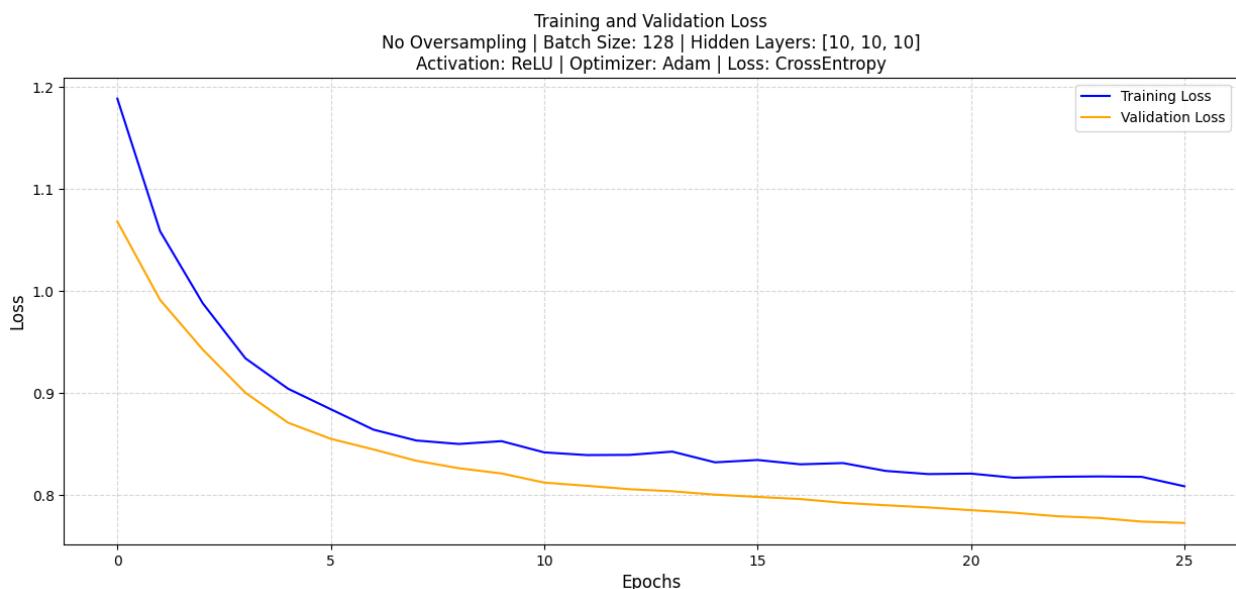
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



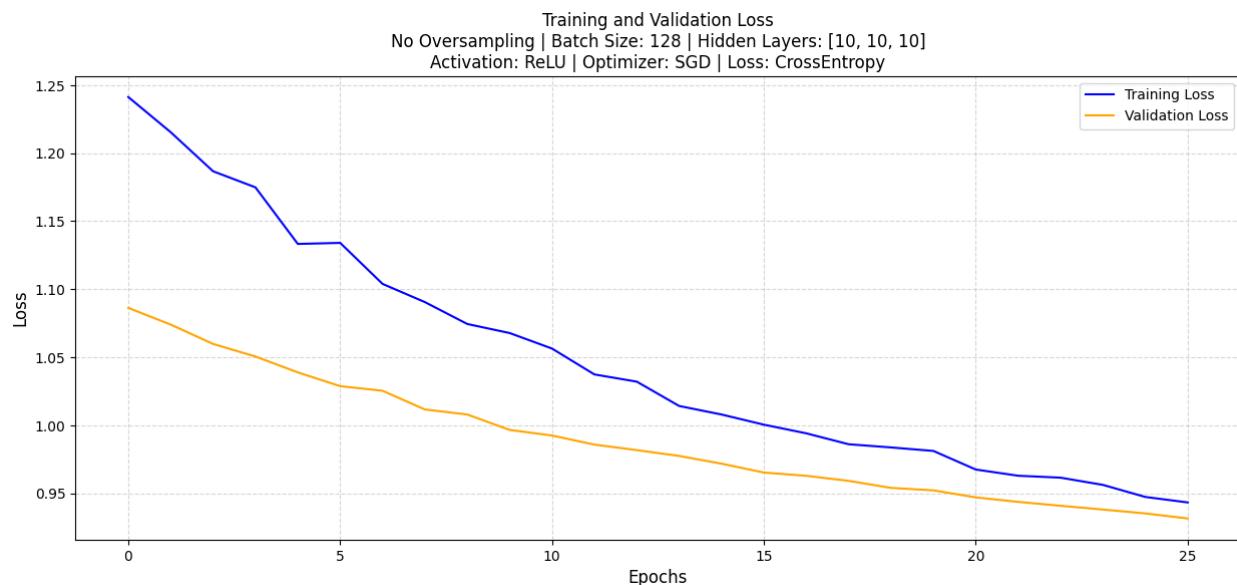
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



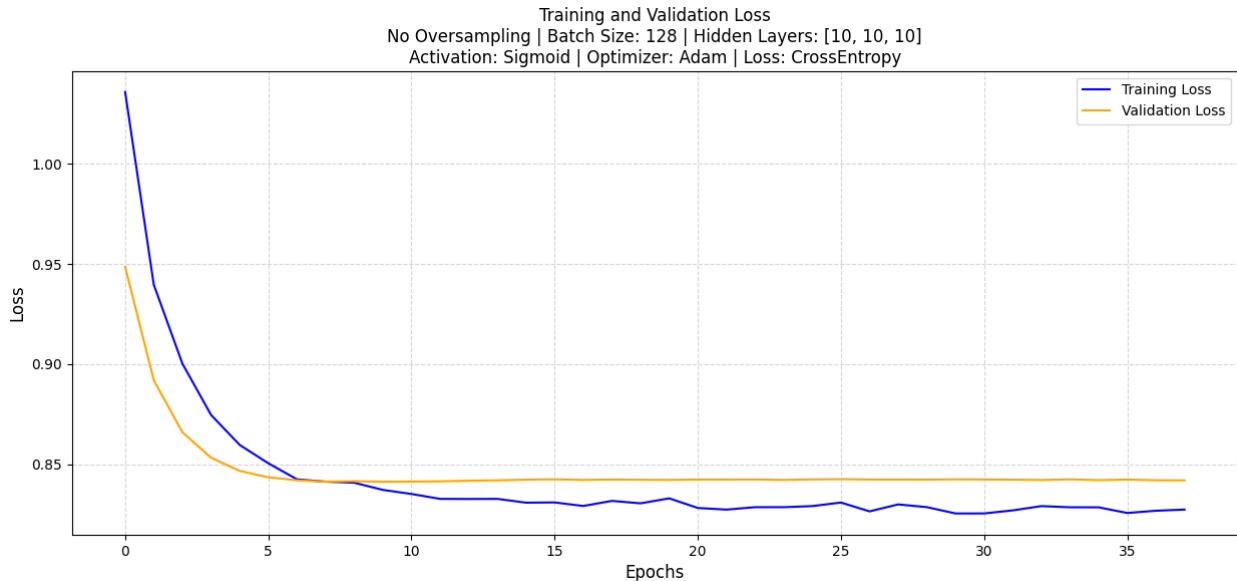
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



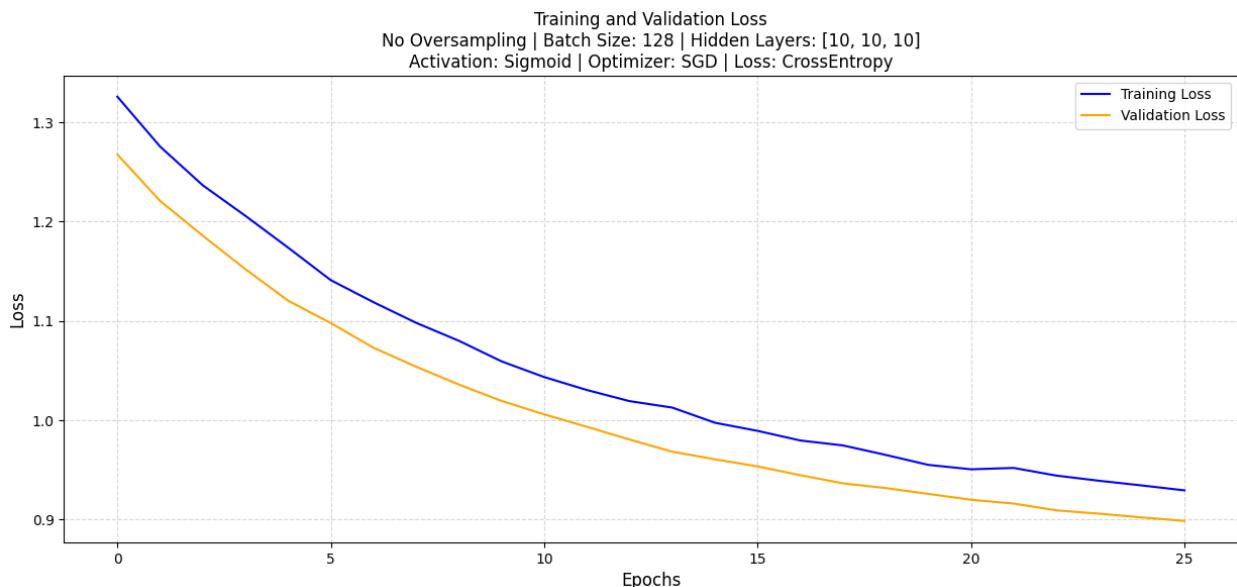
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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len(result))
```



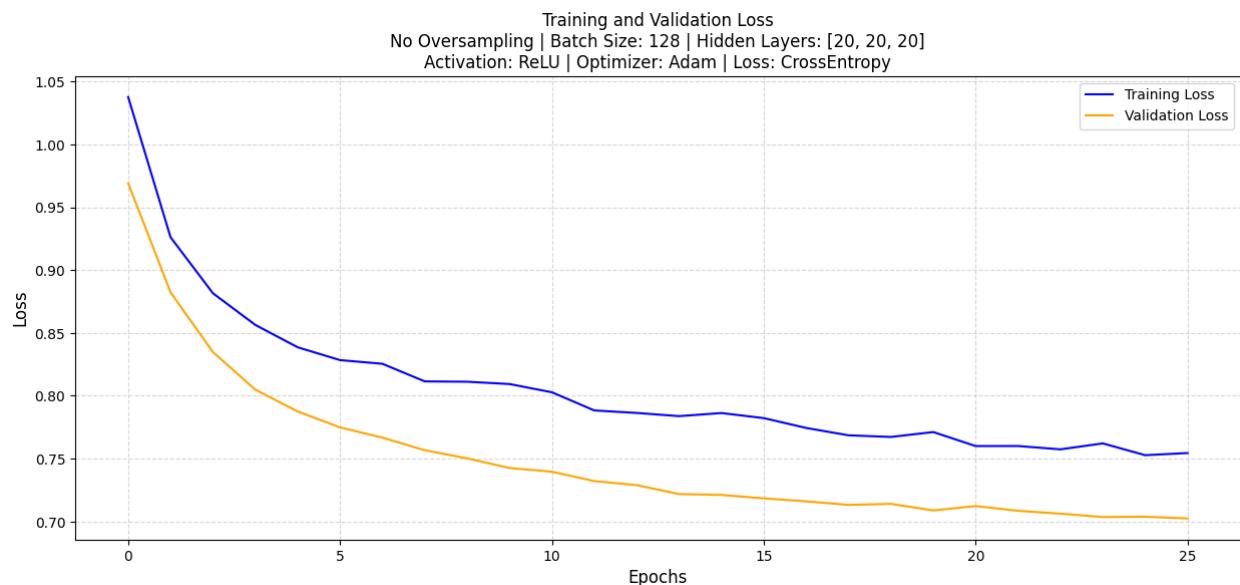
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```



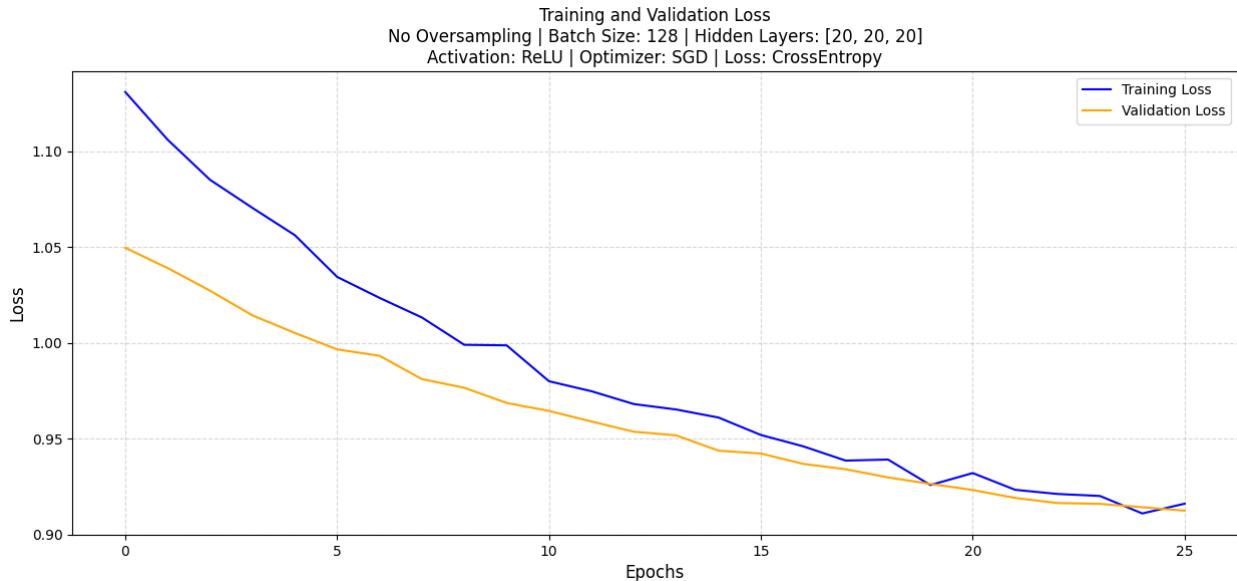
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



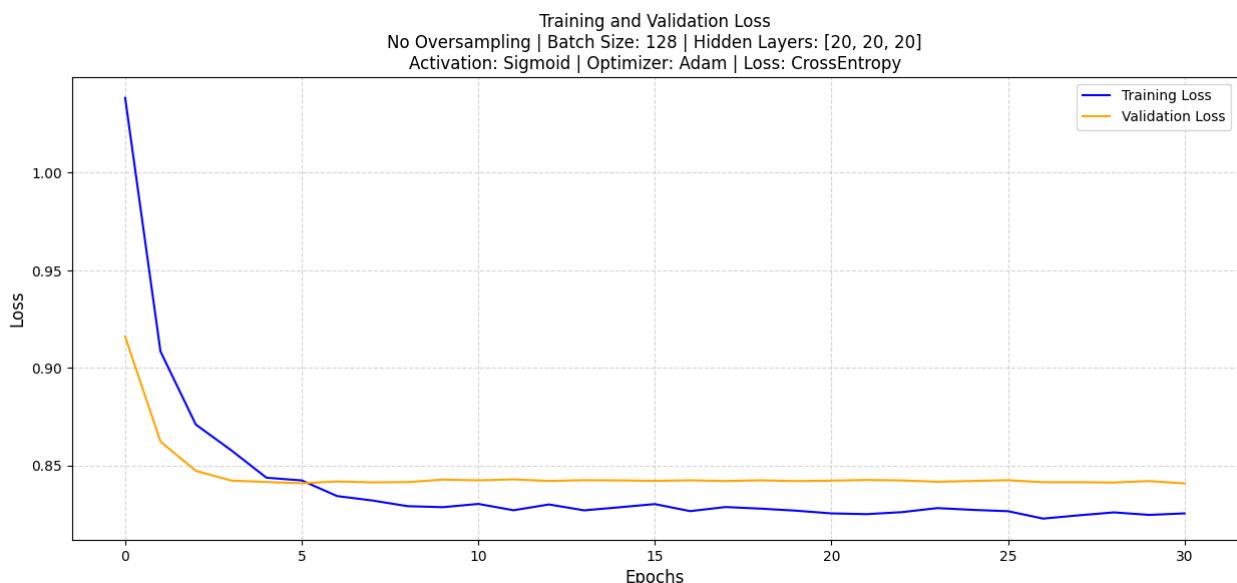
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\metrics\_classification.py:1509:  
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0  
in labels with no predicted samples. Use `zero_division` parameter to  
control this behavior.  
    _warn_prf(average, modifier, f"{metric.capitalize()} is",  
len(result))
```



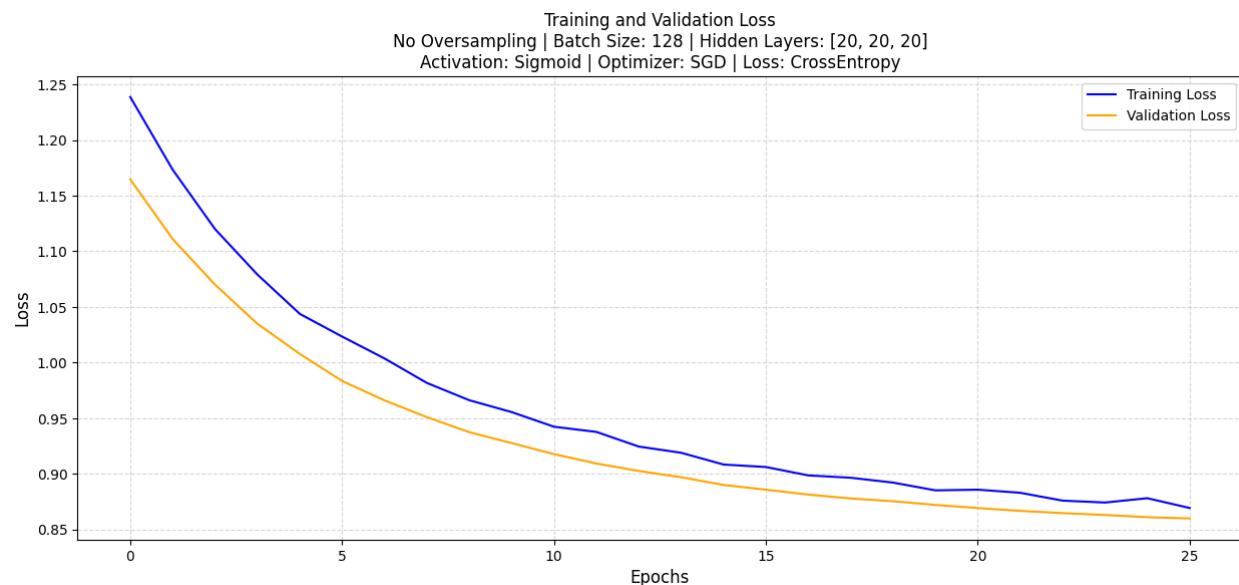
Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```

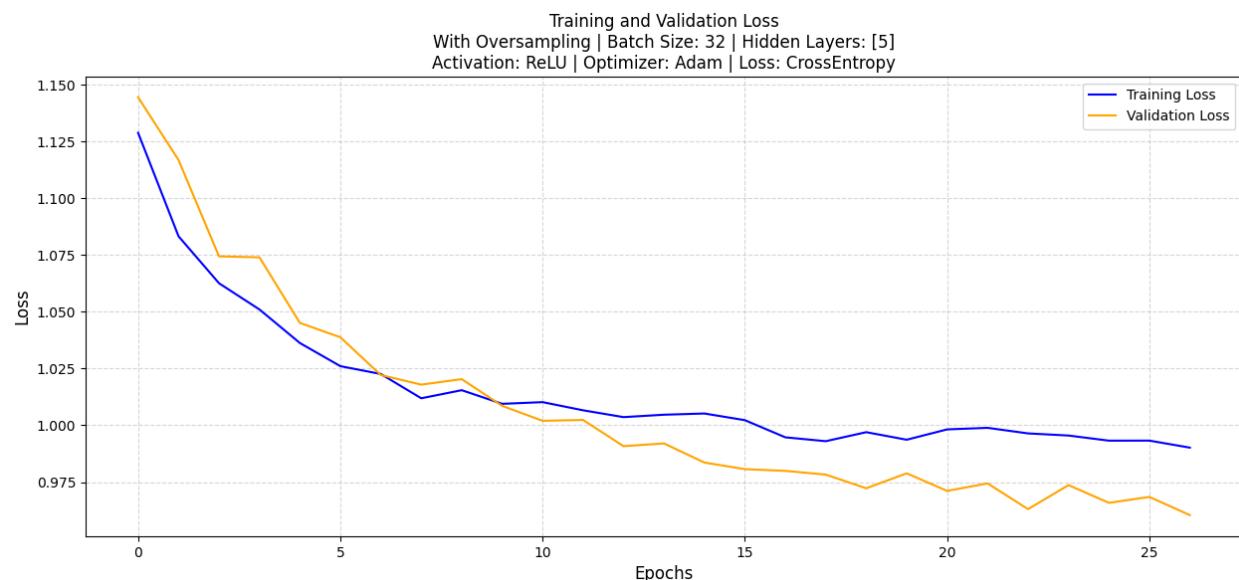


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```

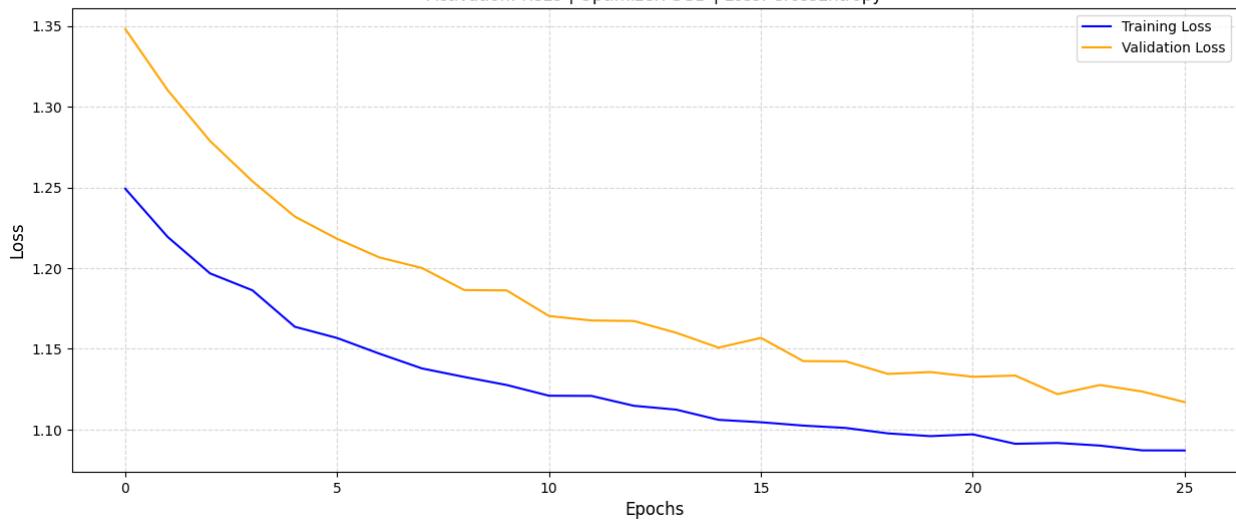


Early stopping triggered



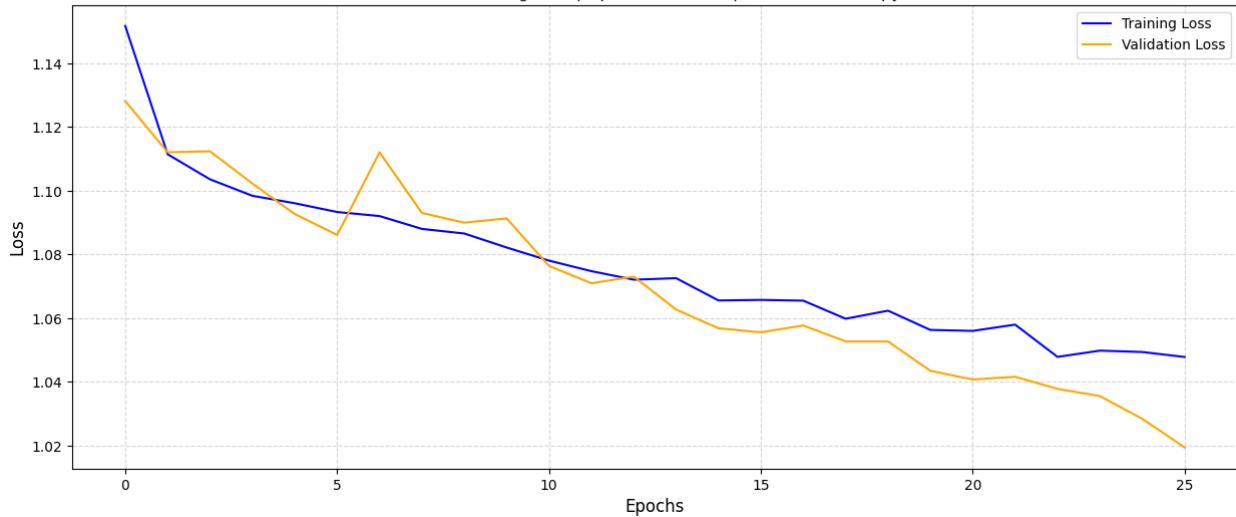
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



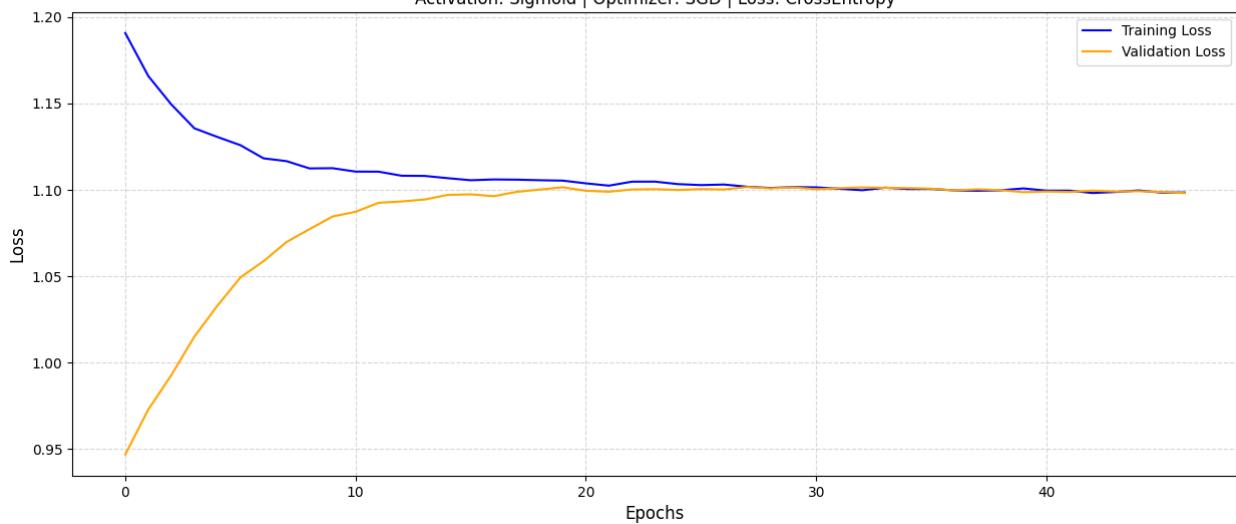
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



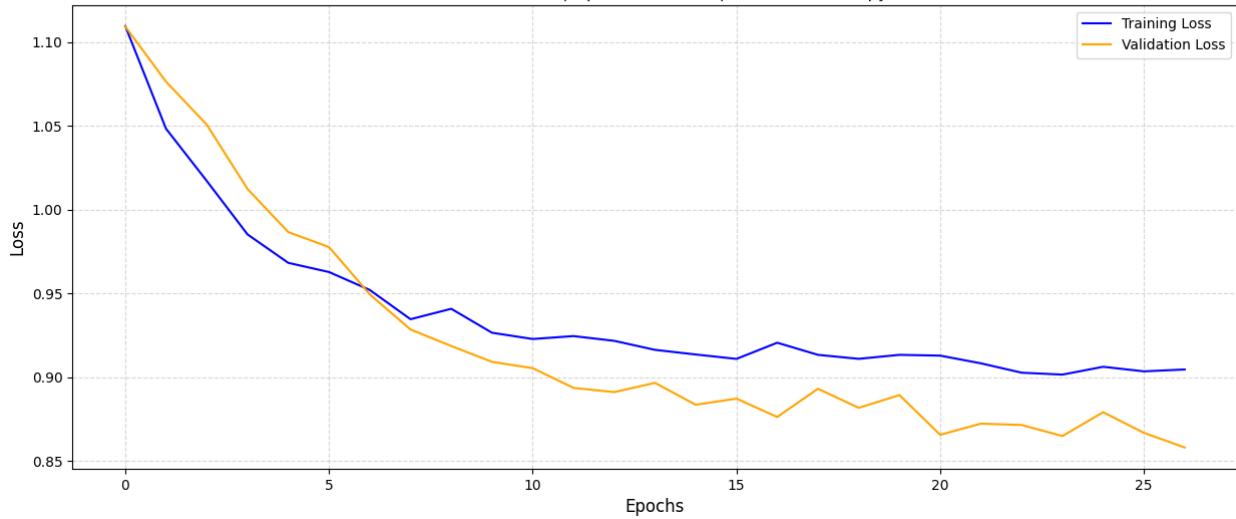
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



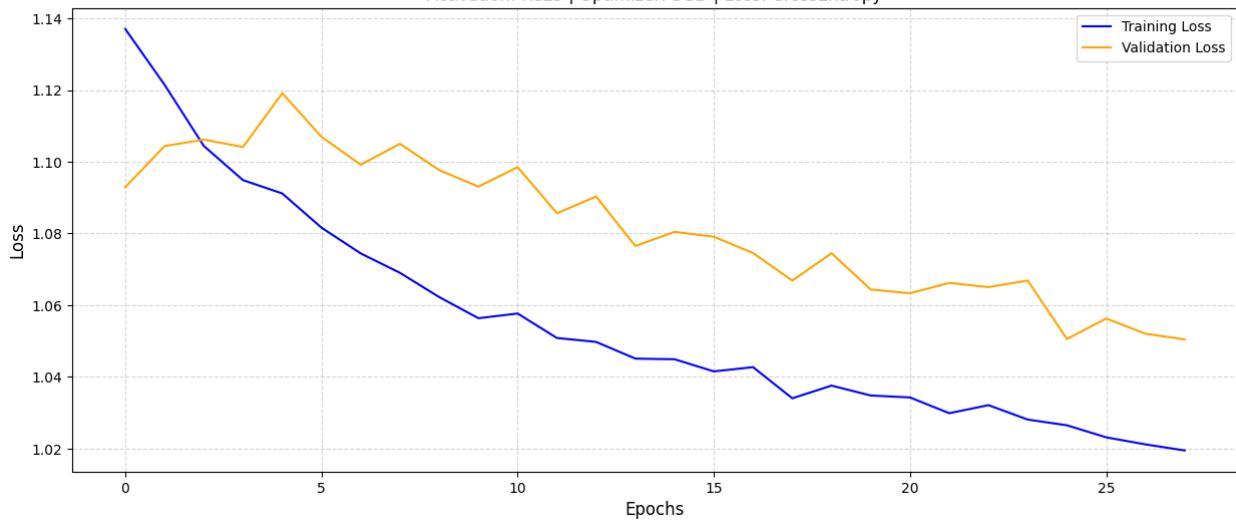
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



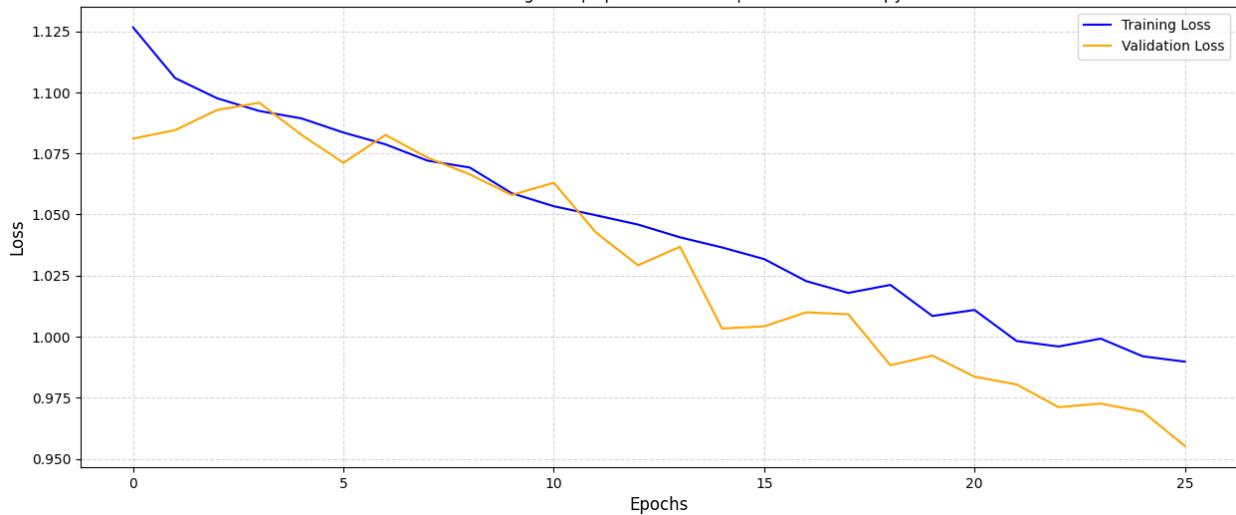
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



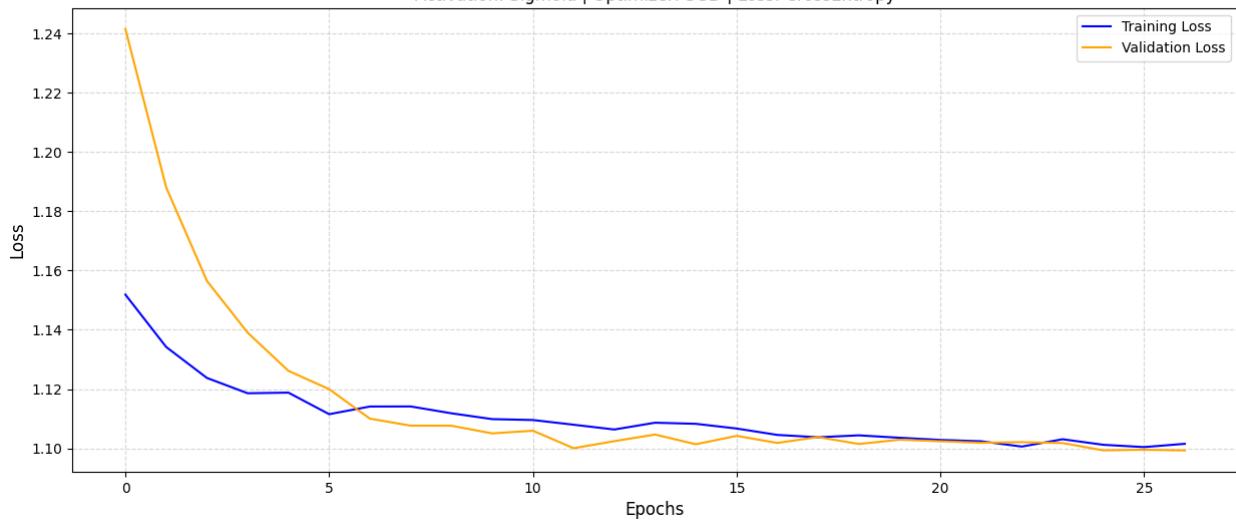
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



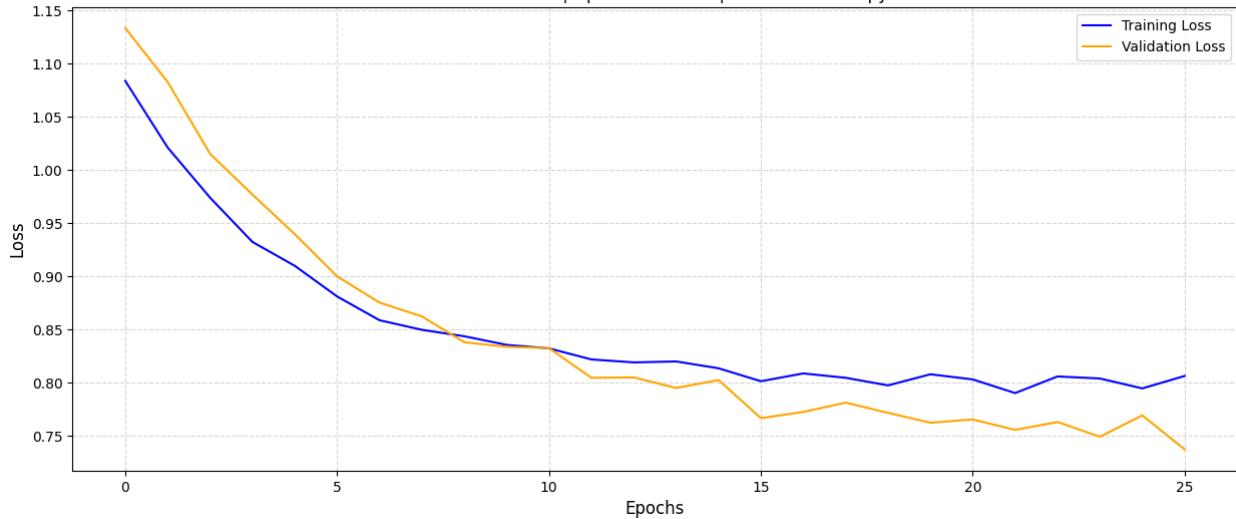
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



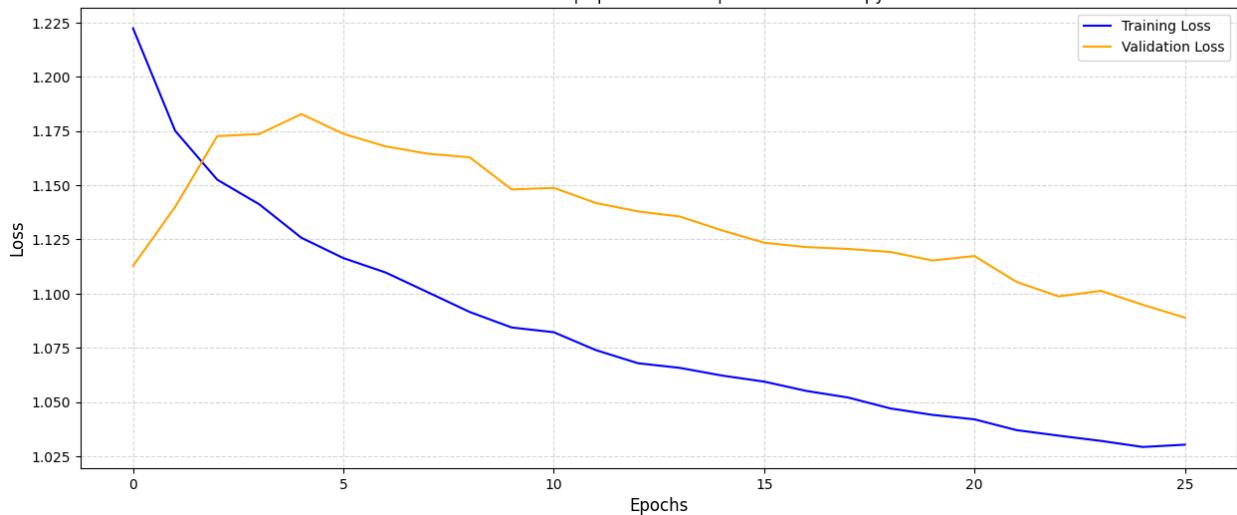
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



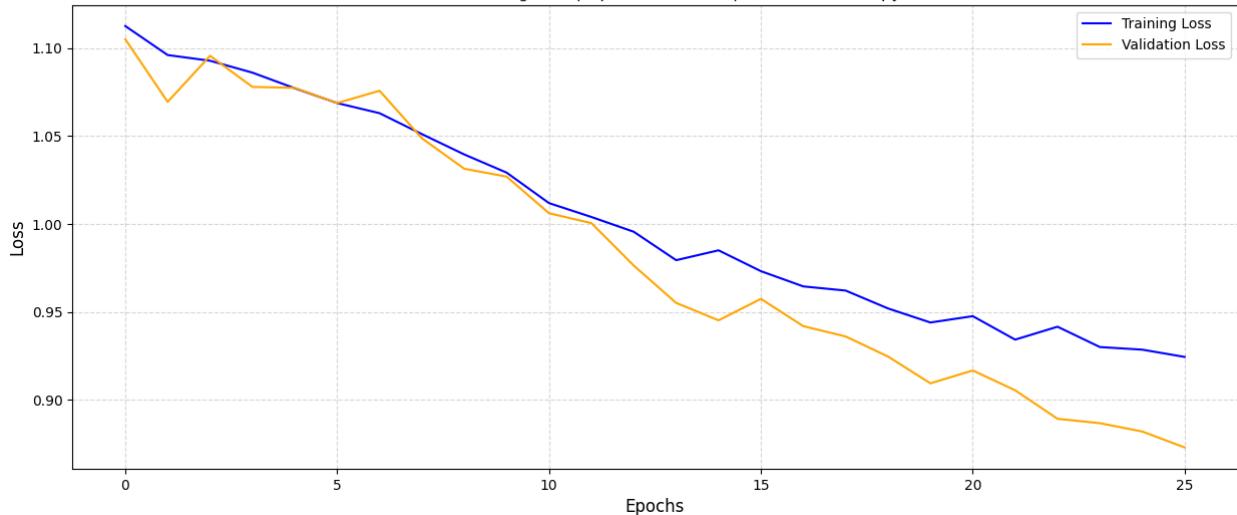
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

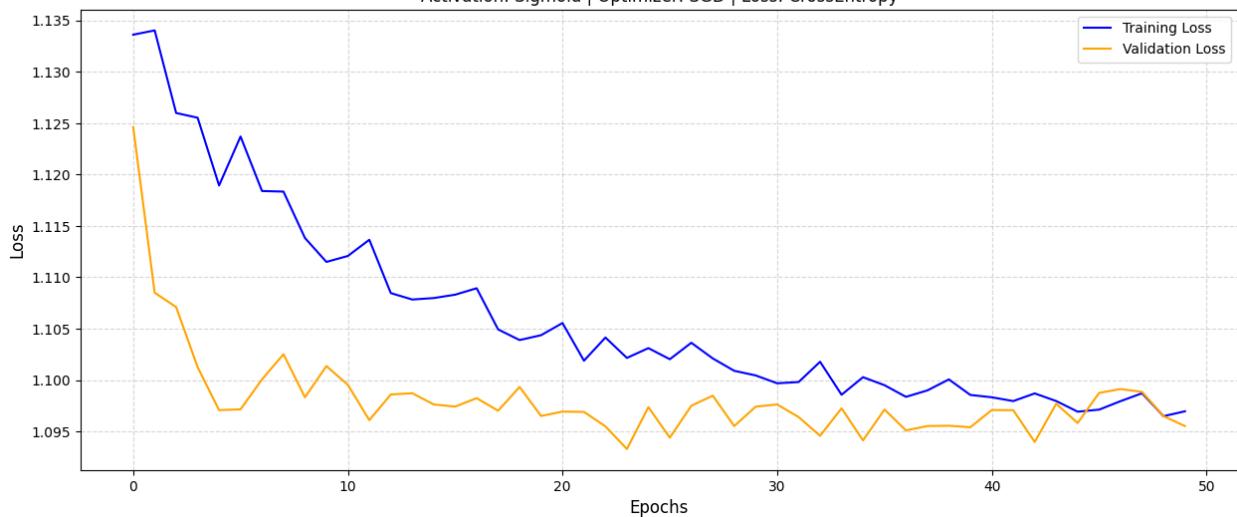


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy

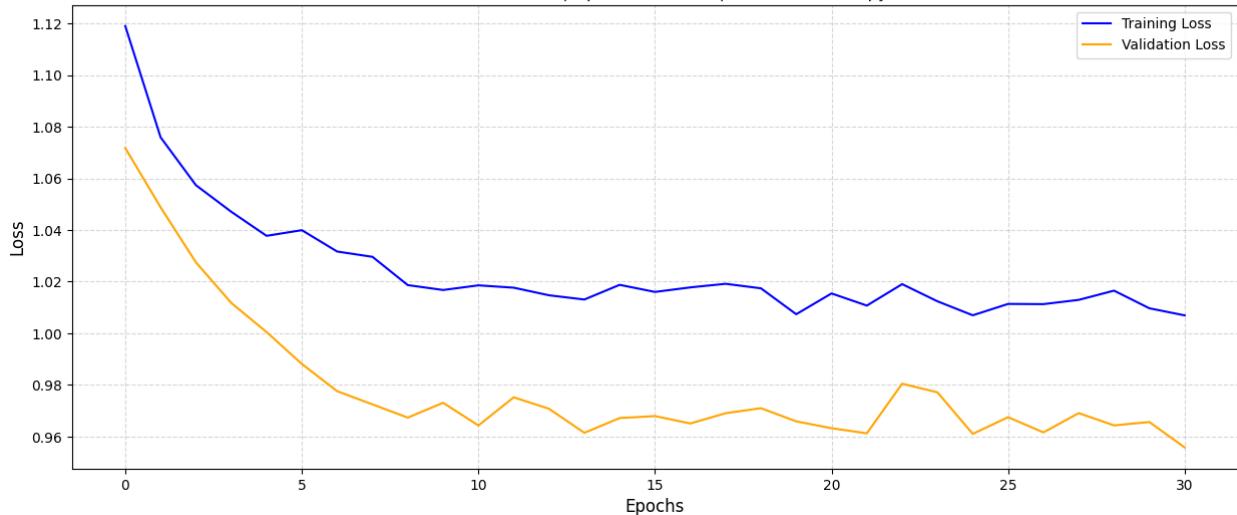


Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



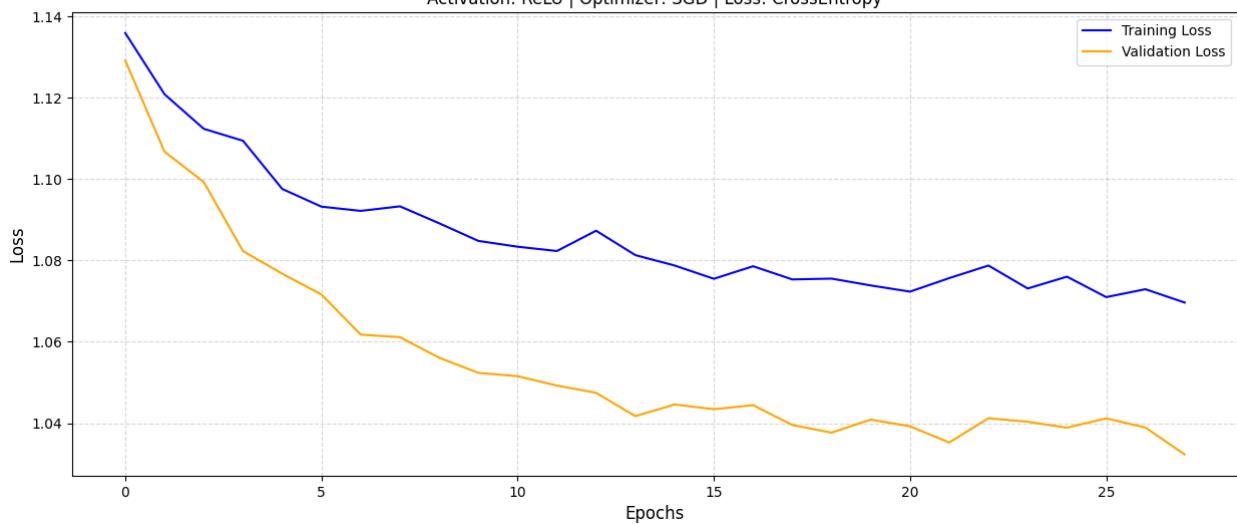
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5, 5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



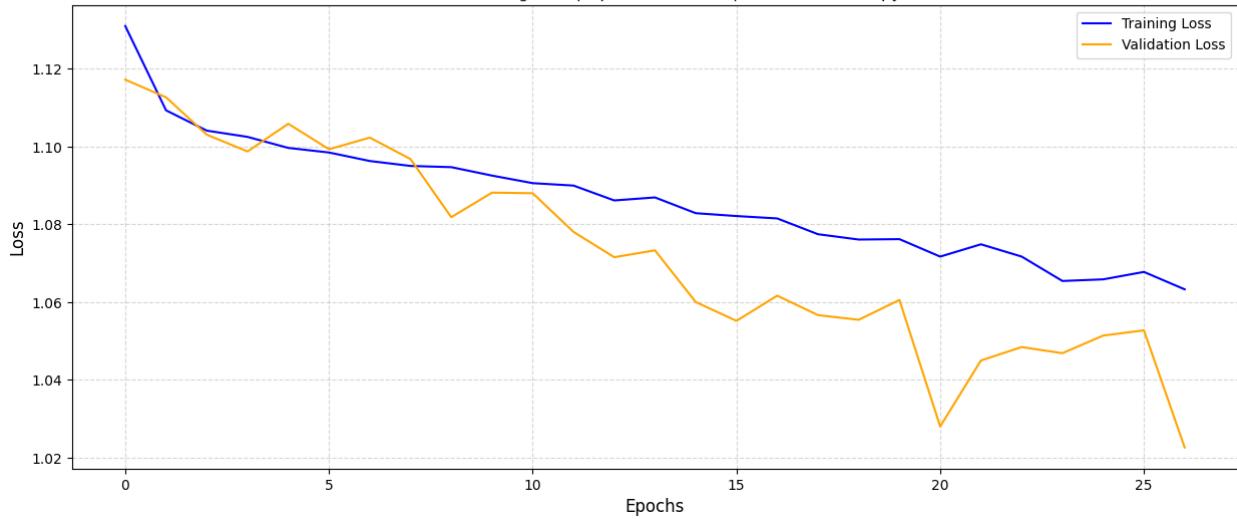
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5, 5]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



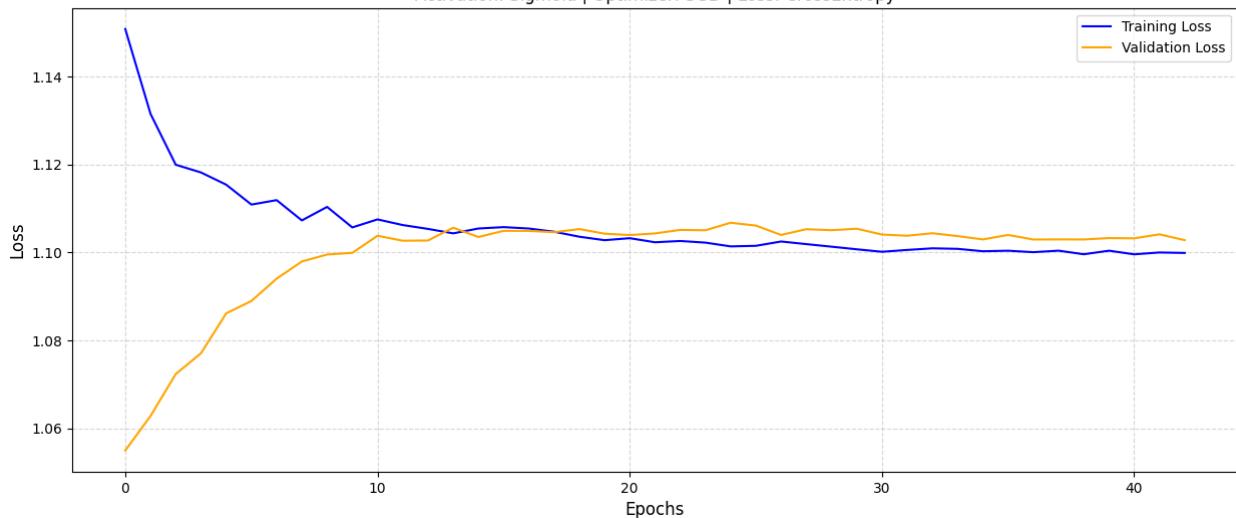
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5, 5]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



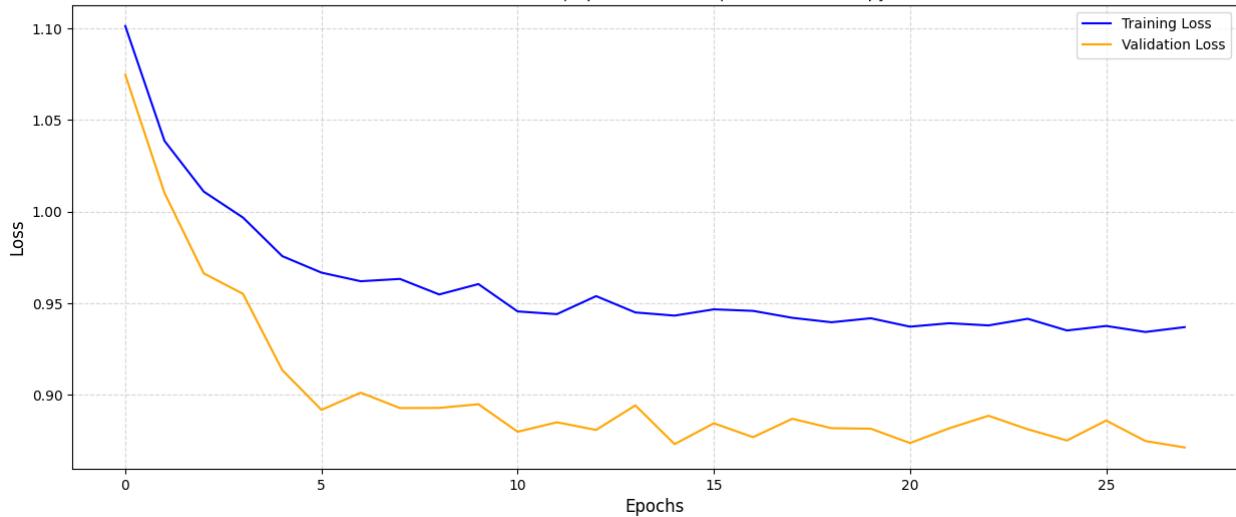
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [5, 5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

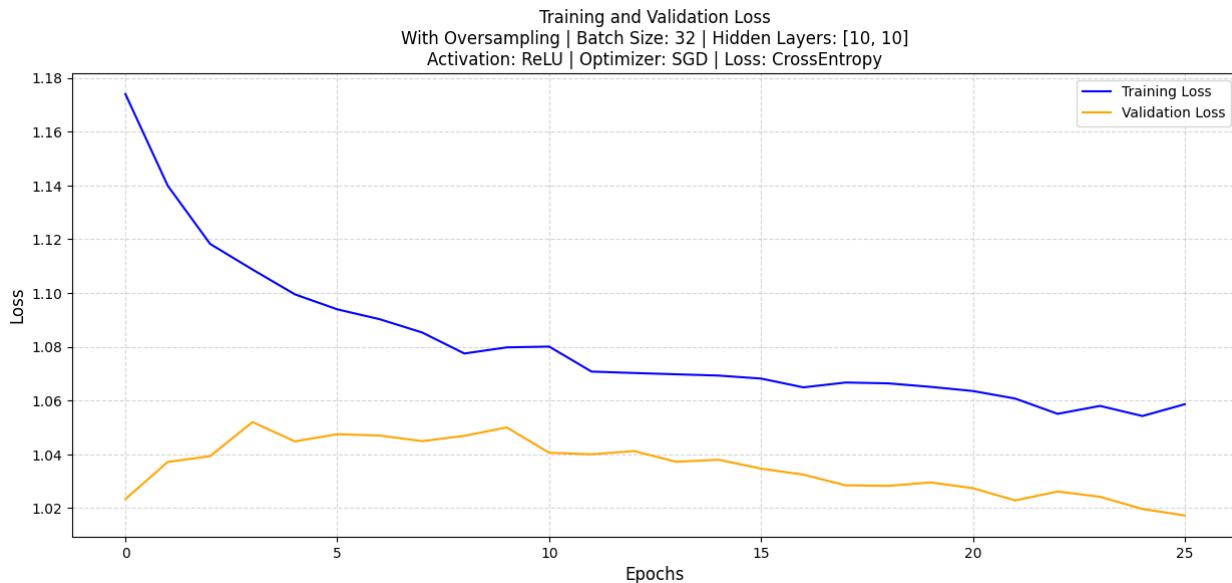


Early stopping triggered

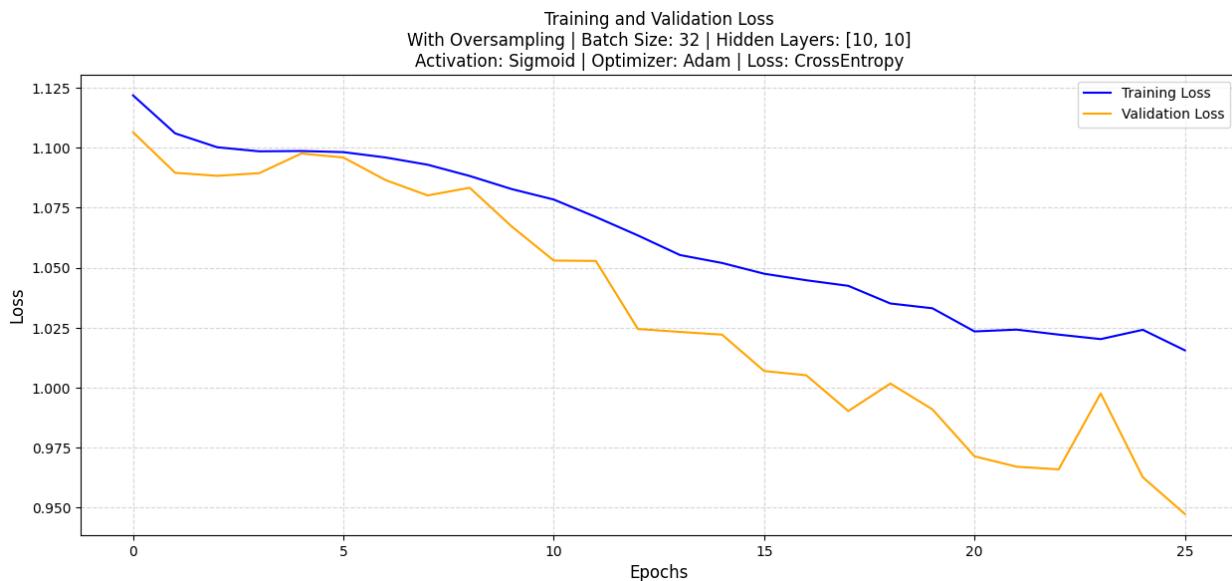
Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10, 10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered

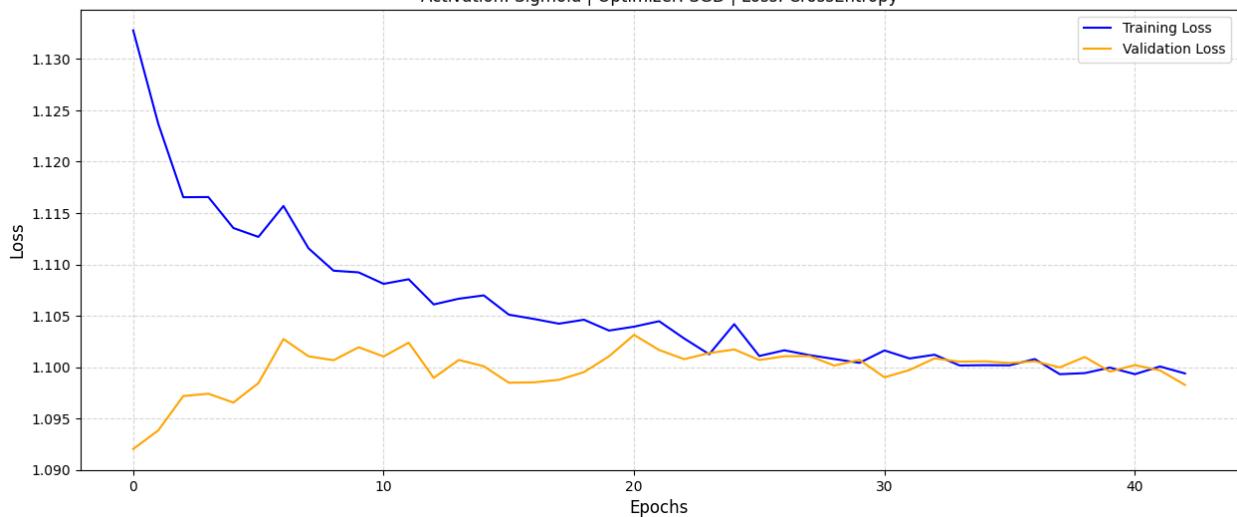


Early stopping triggered



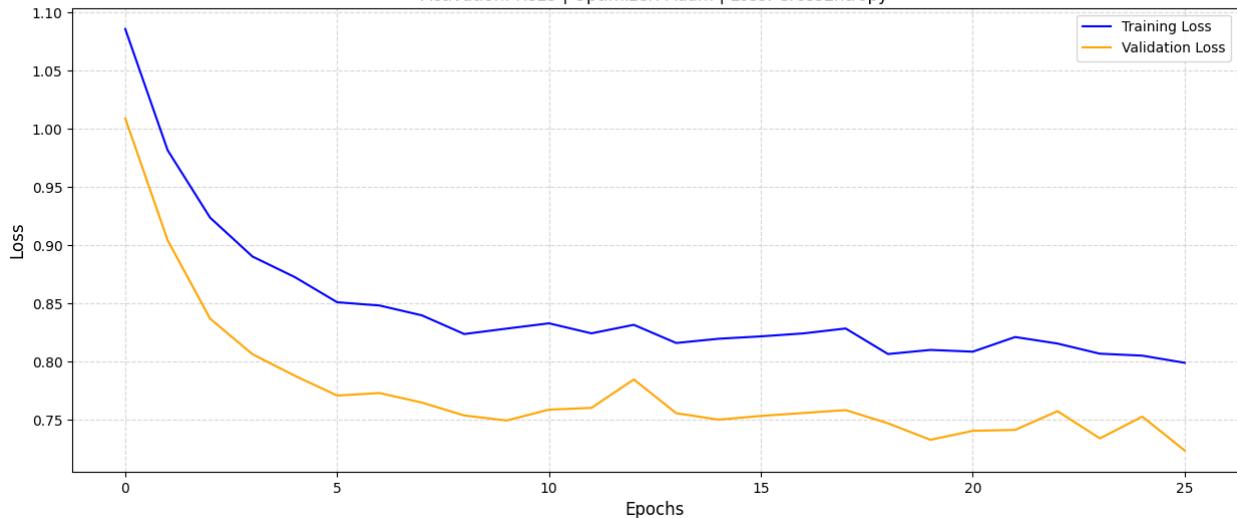
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10, 10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



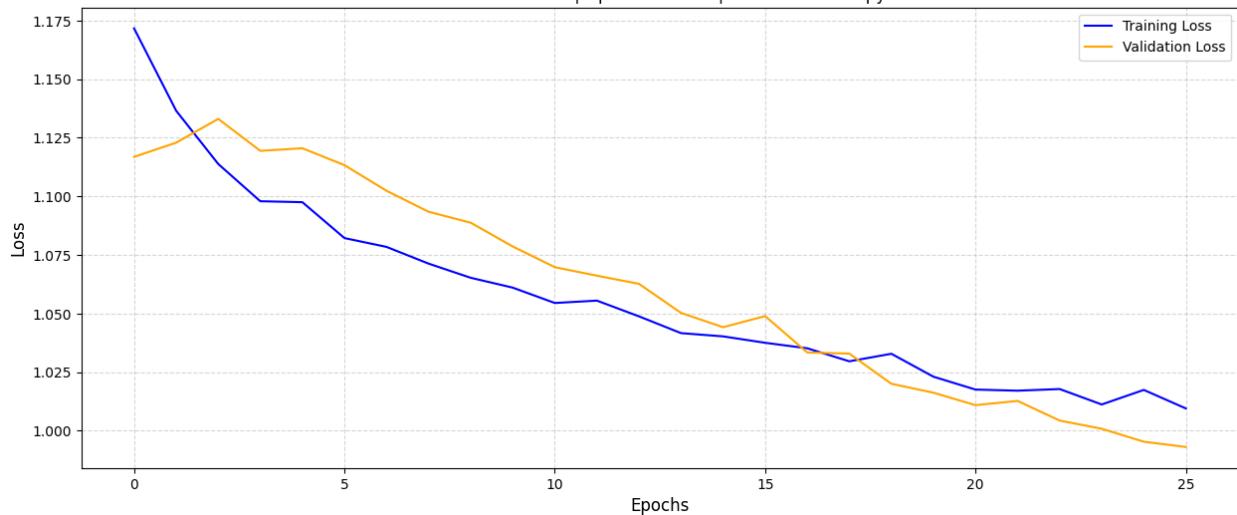
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20, 20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



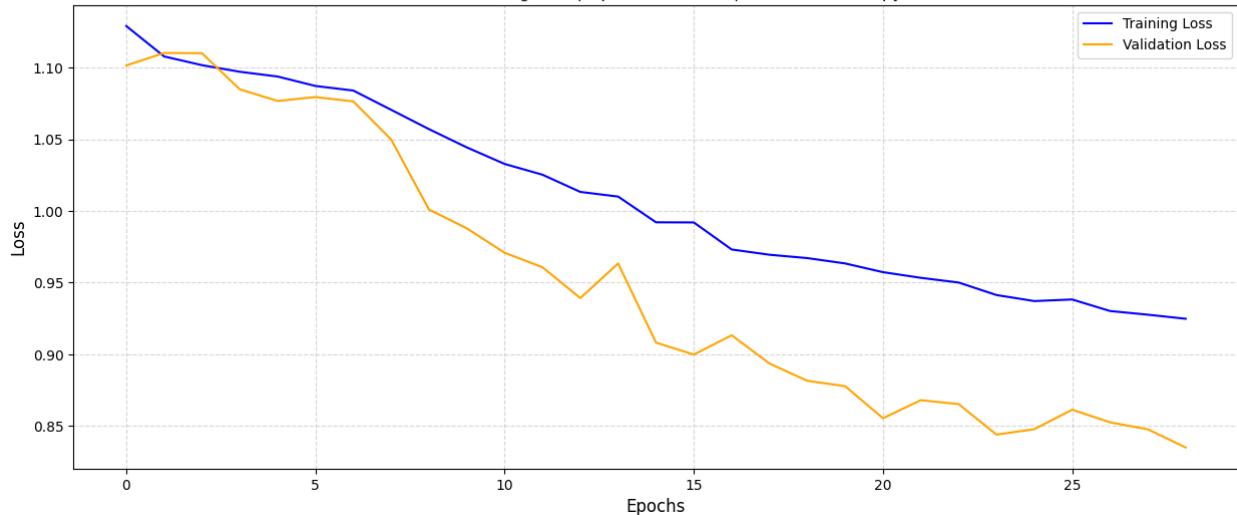
Early stopping triggered

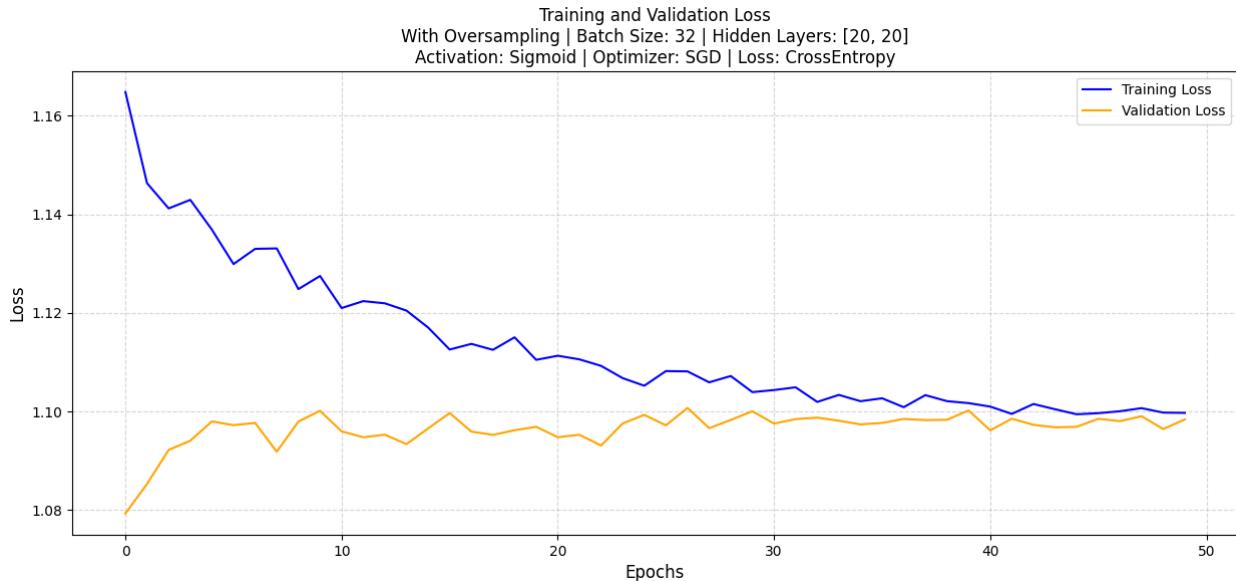
Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20, 20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



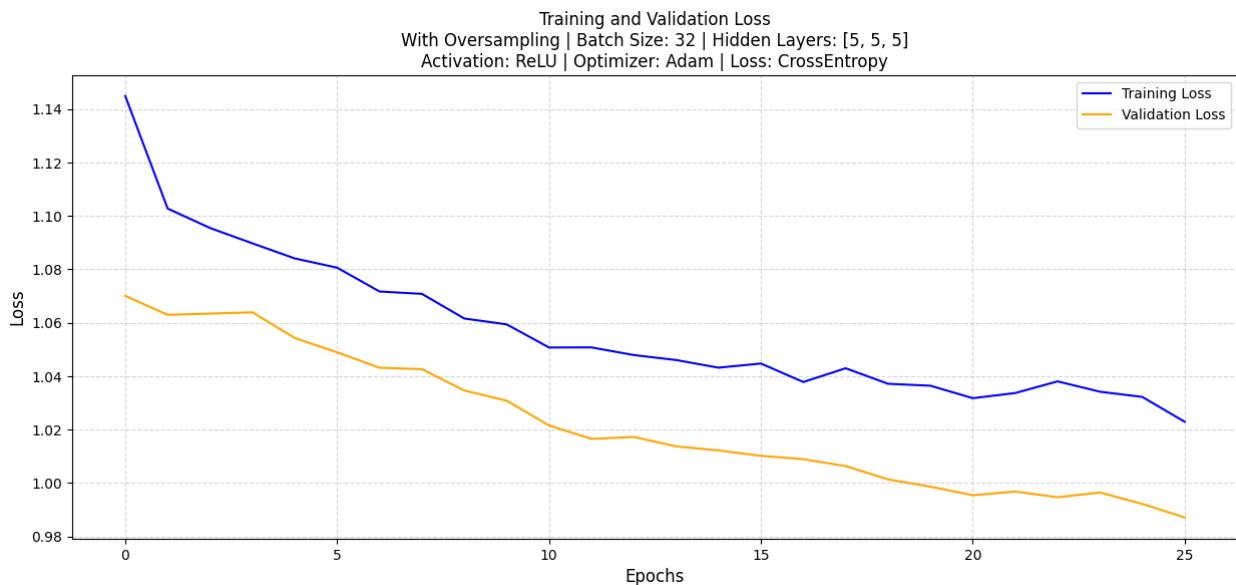
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20, 20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



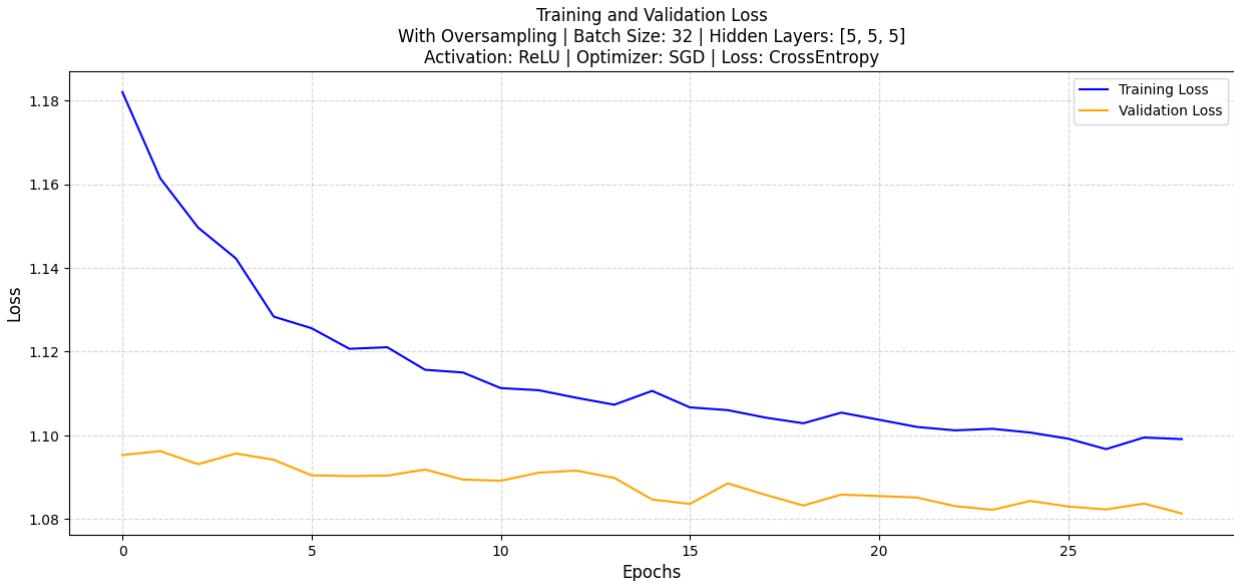


Early stopping triggered

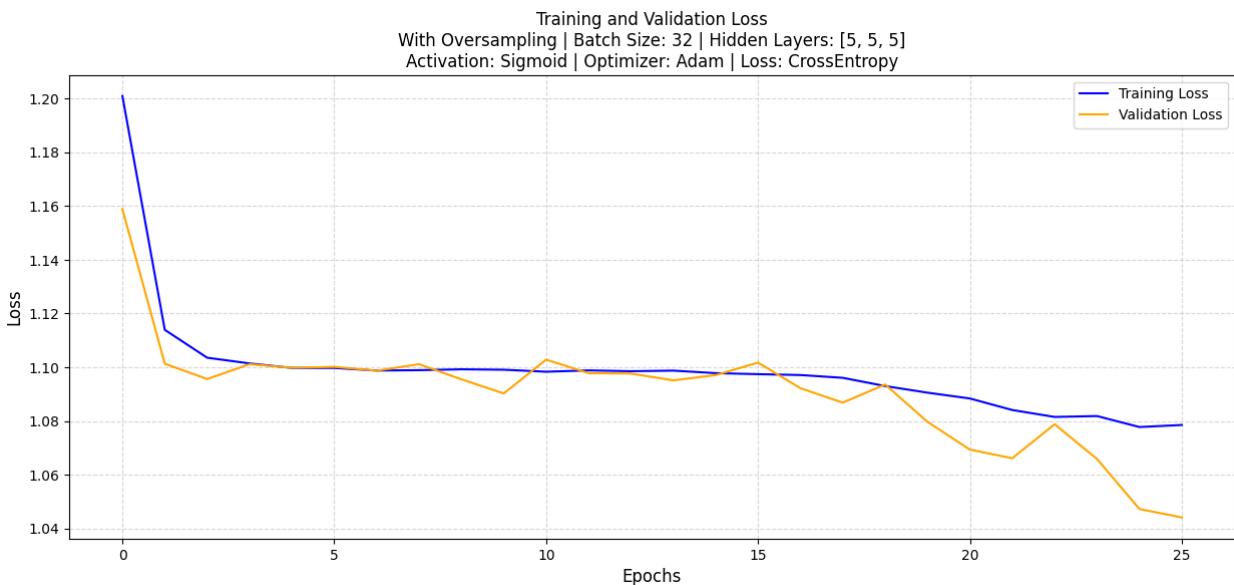


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
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```

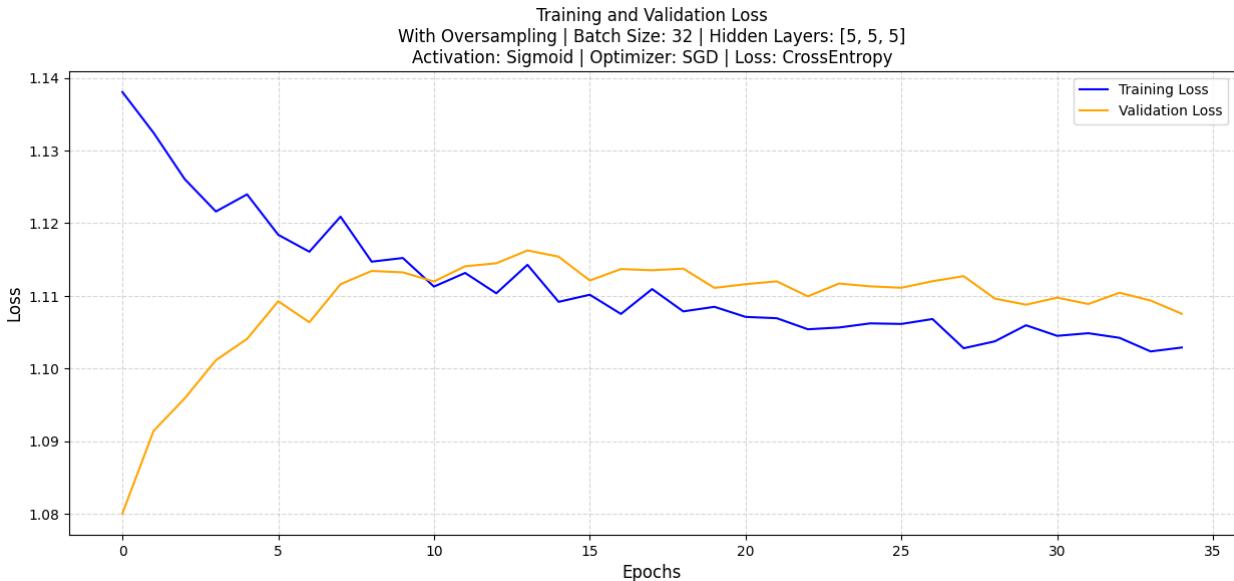


Early stopping triggered

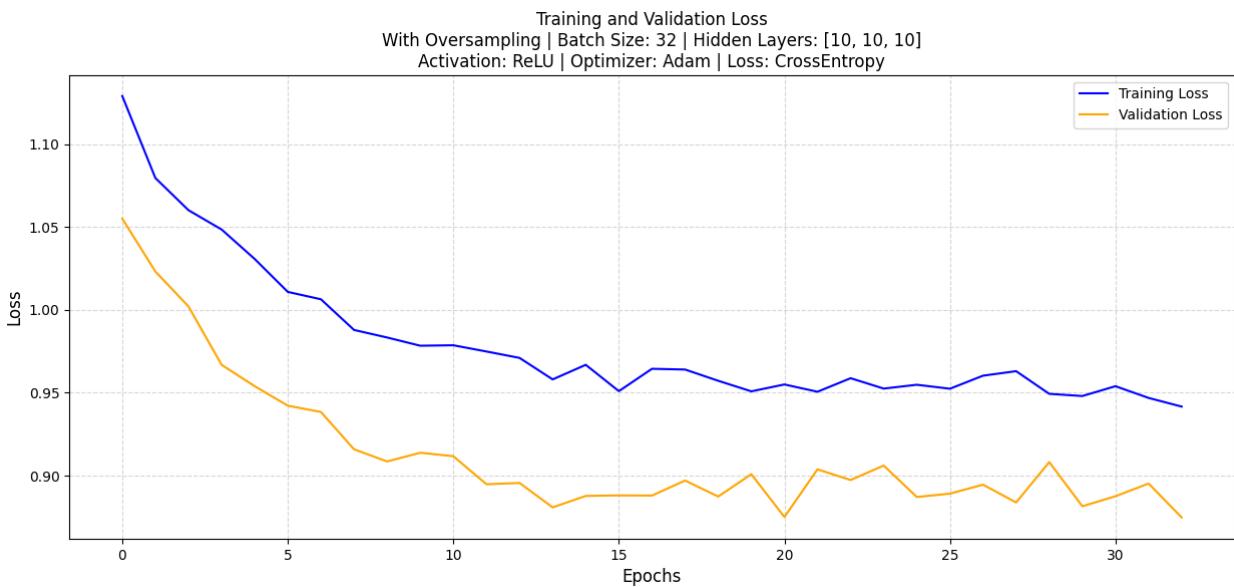


Early stopping triggered

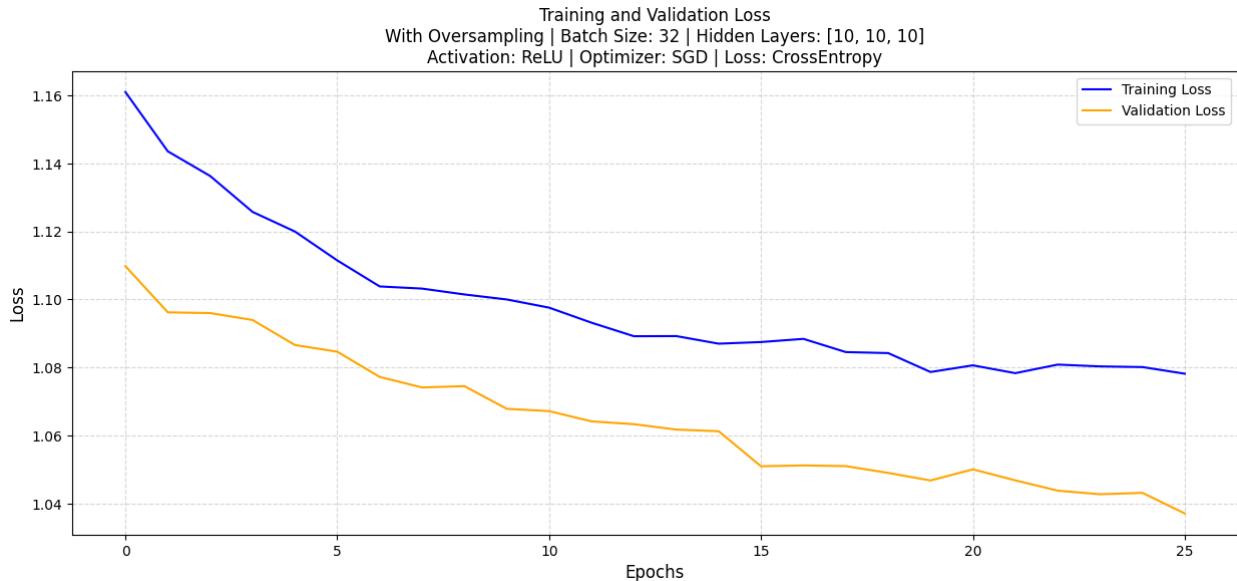
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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
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UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
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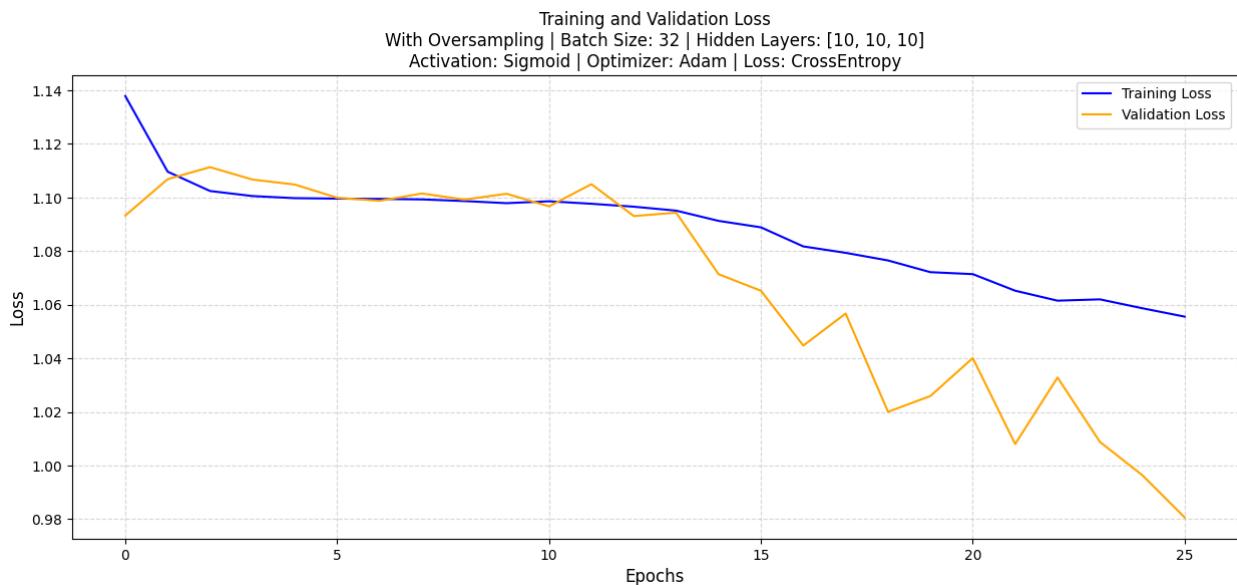
Early stopping triggered



Early stopping triggered



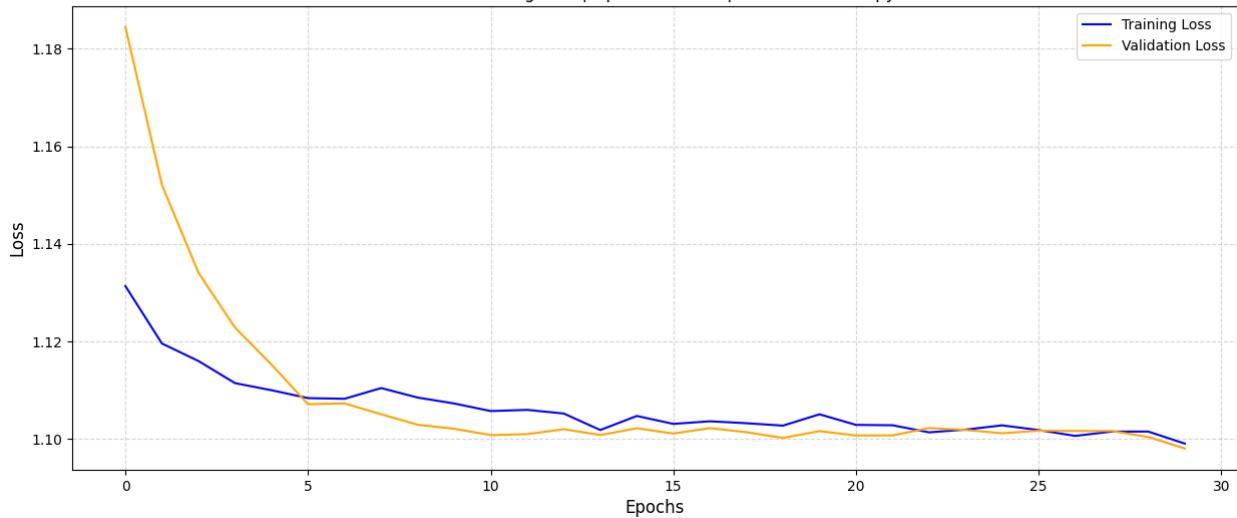
Early stopping triggered



Early stopping triggered

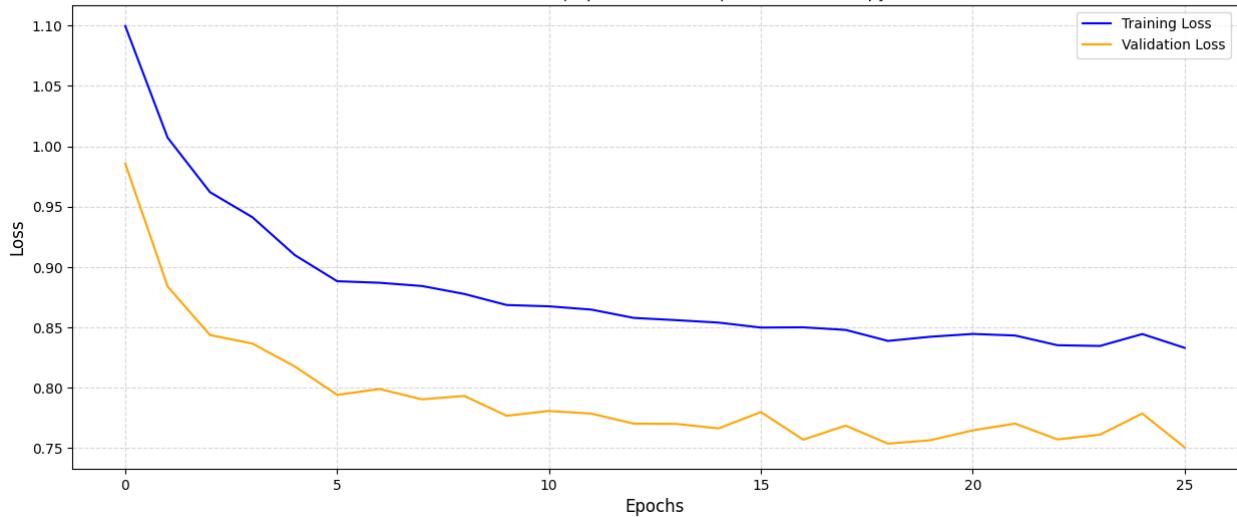
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c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
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    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [10, 10, 10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

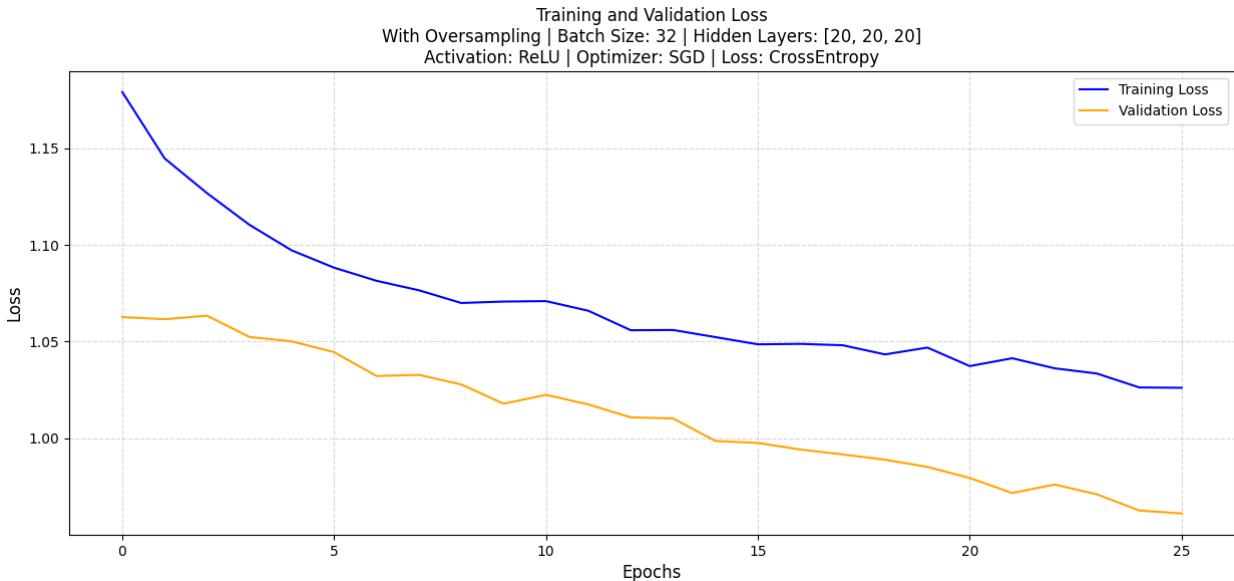


Early stopping triggered

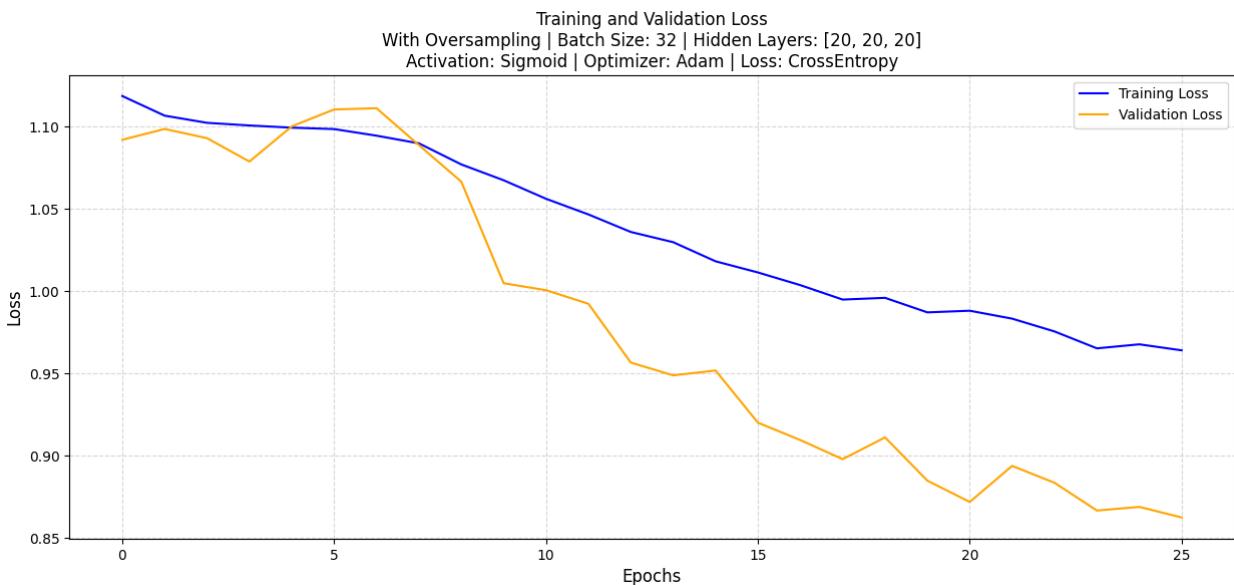
Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20, 20, 20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered



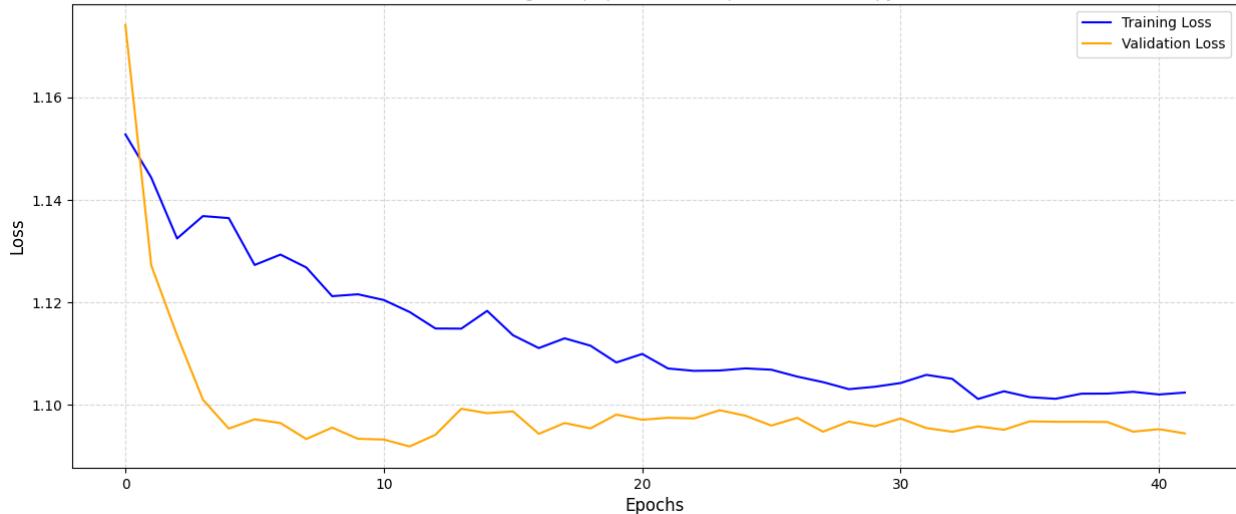
Early stopping triggered



Early stopping triggered

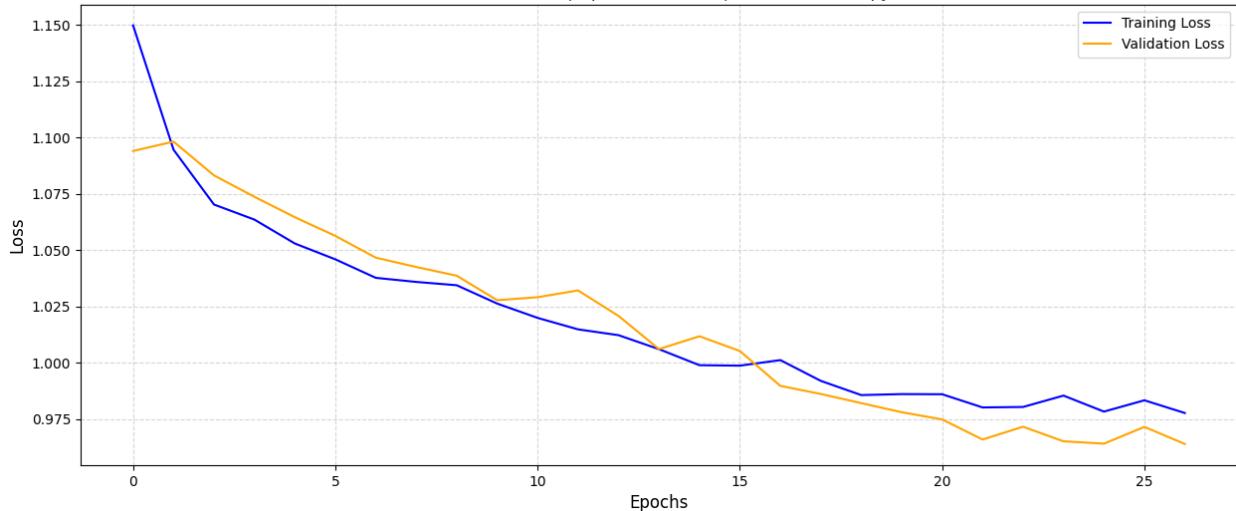
```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```

Training and Validation Loss
With Oversampling | Batch Size: 32 | Hidden Layers: [20, 20, 20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

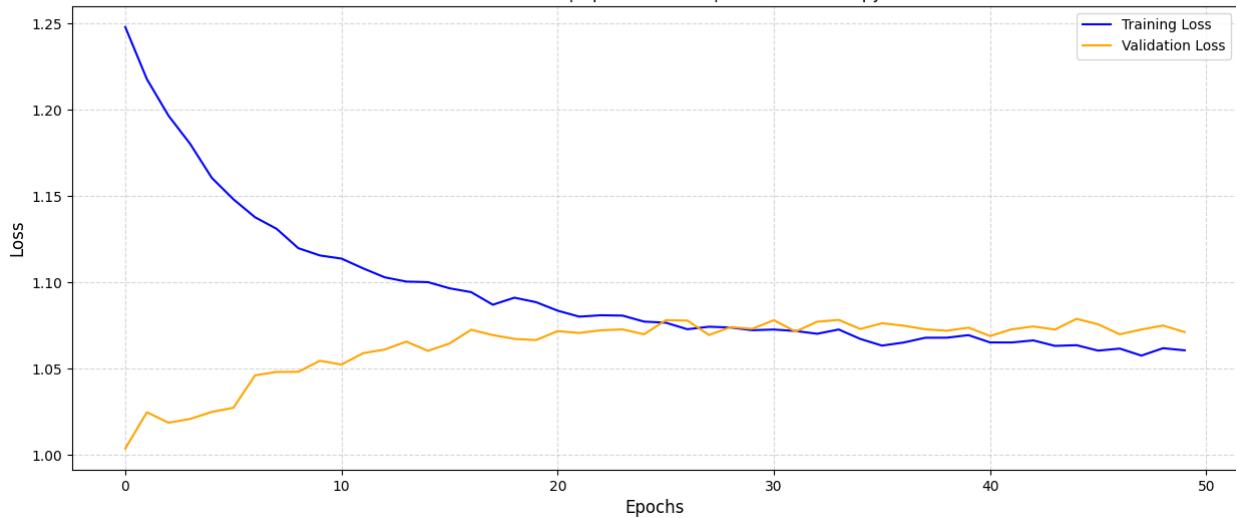


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy

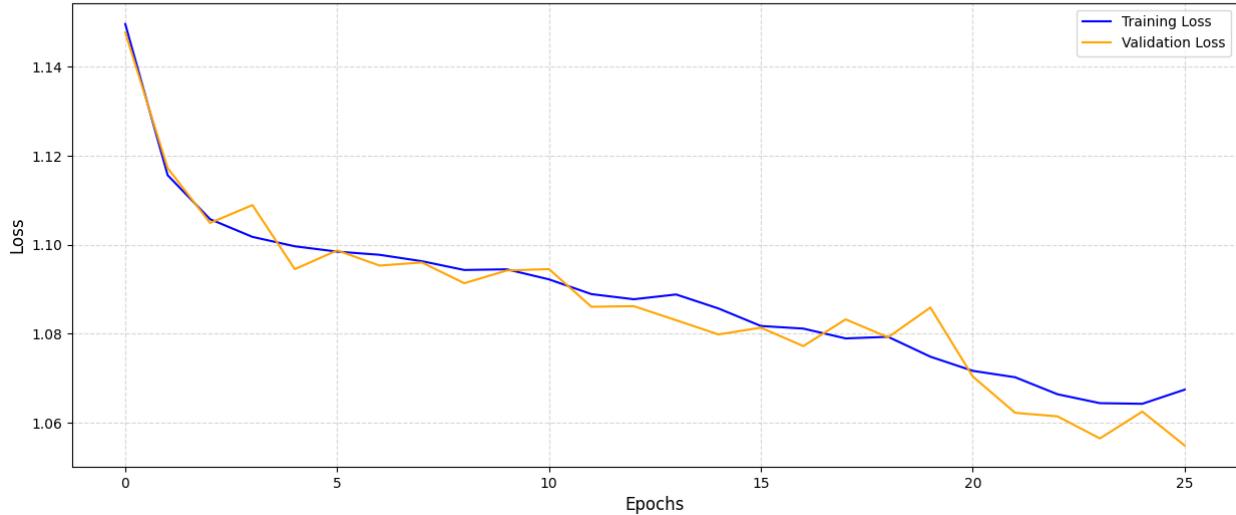


Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

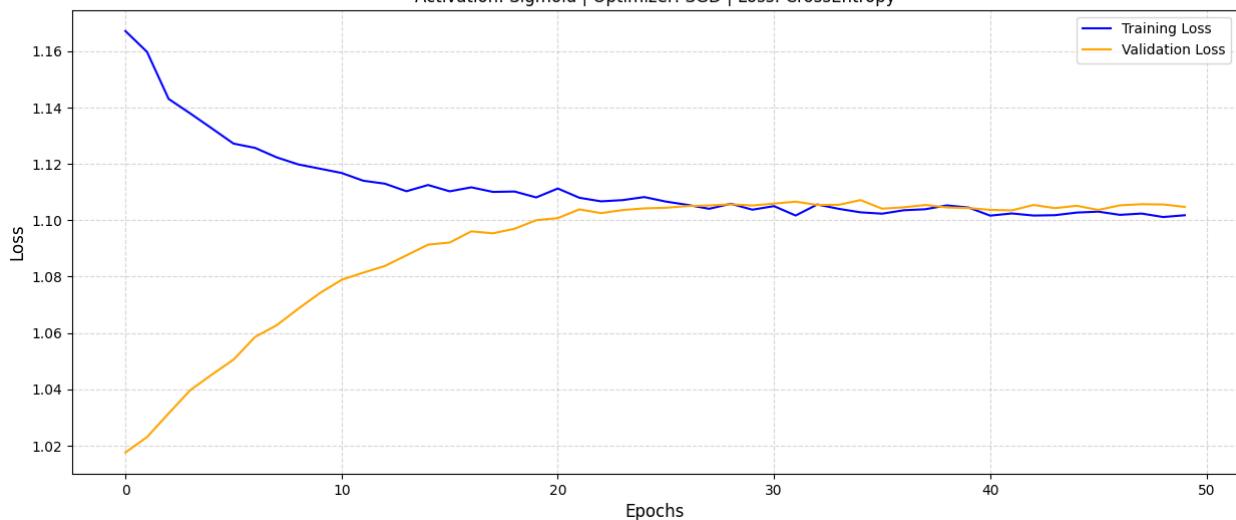


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy

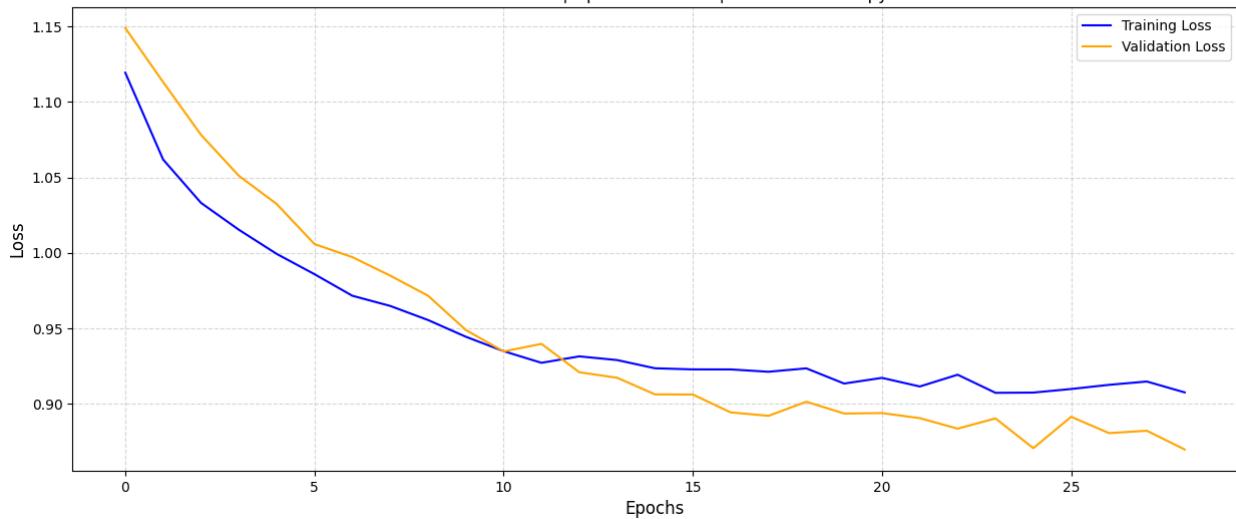


Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



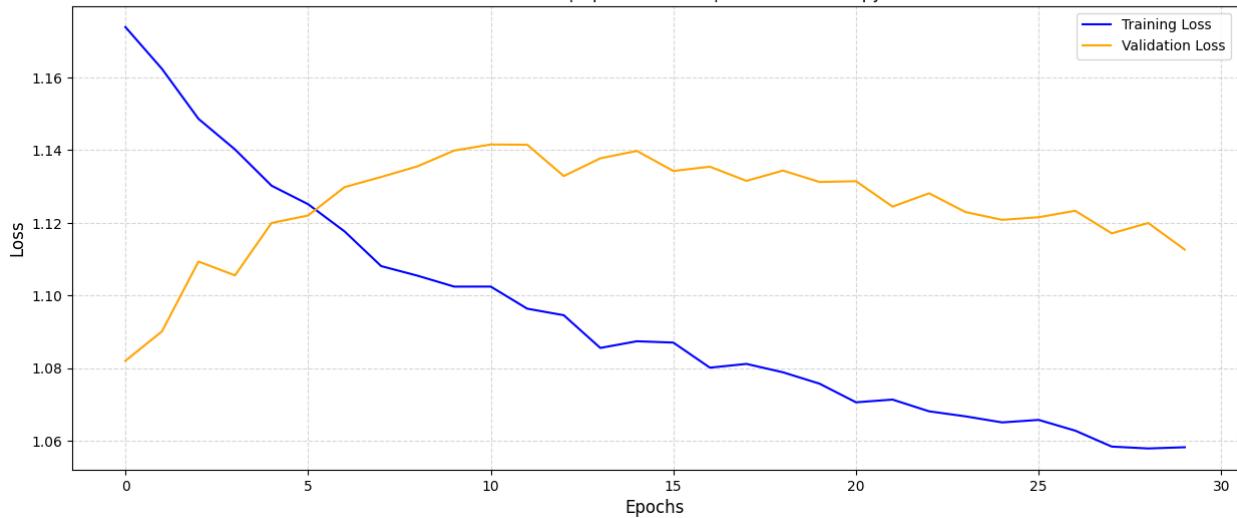
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



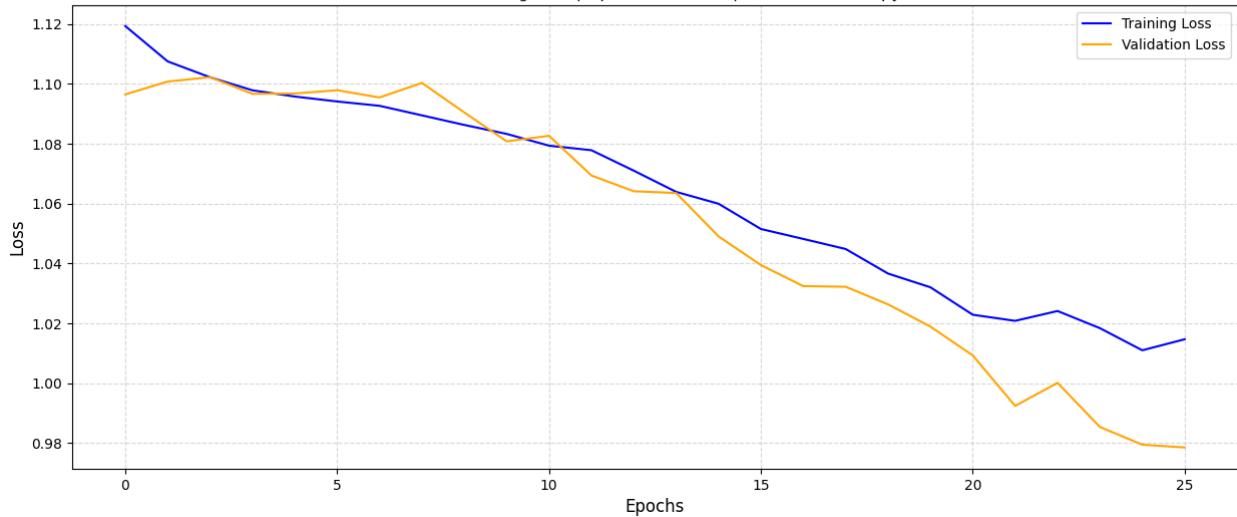
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



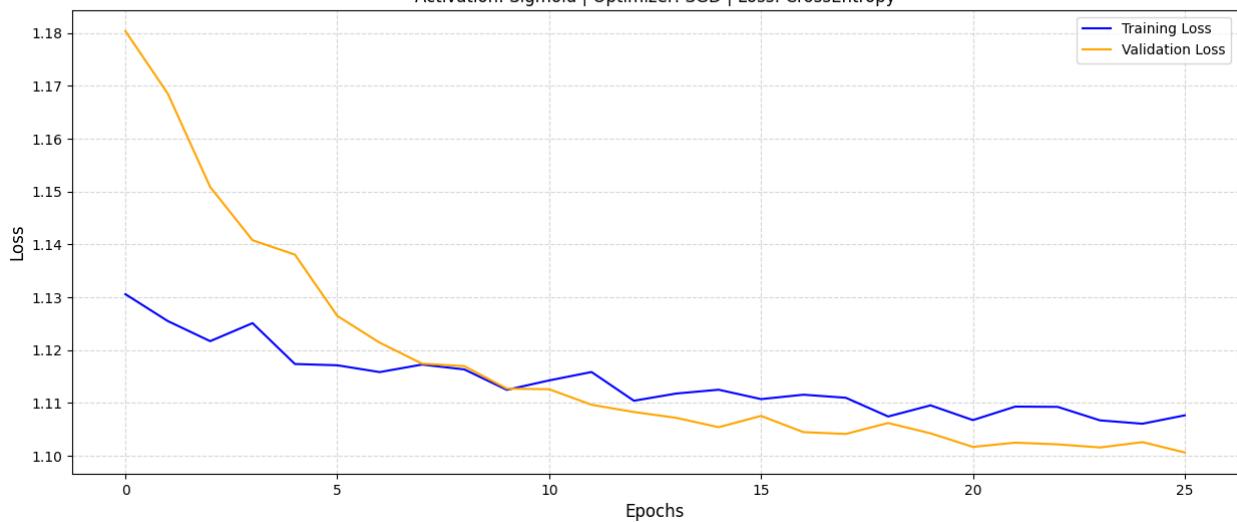
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



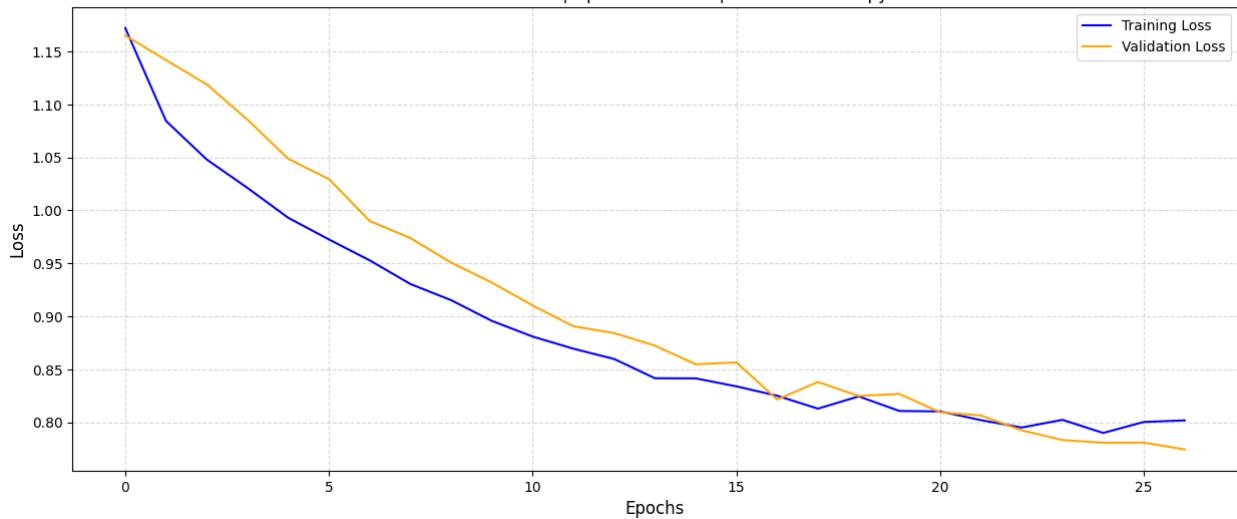
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



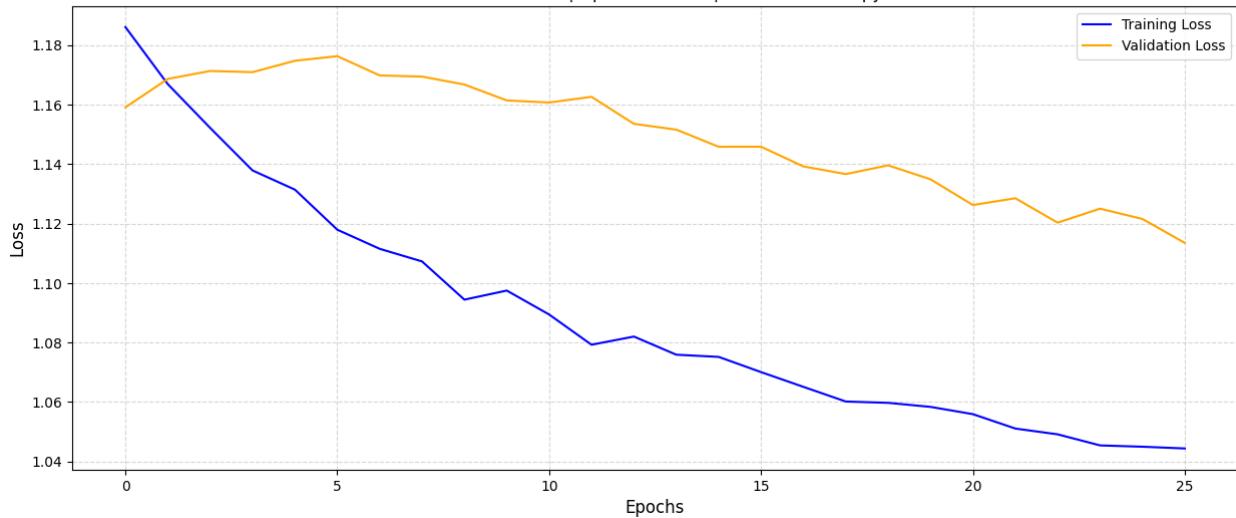
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



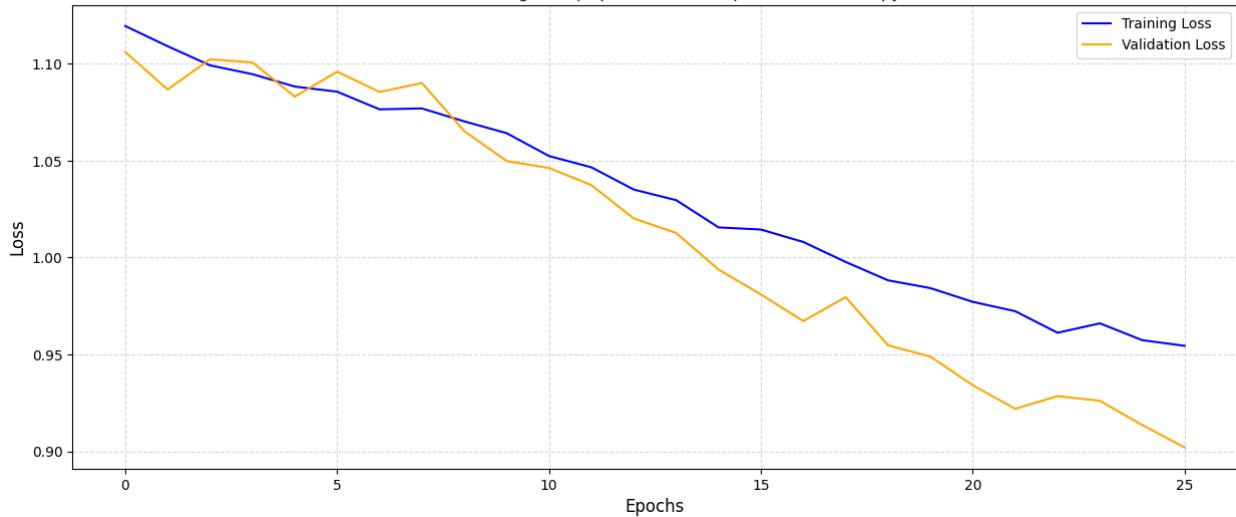
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



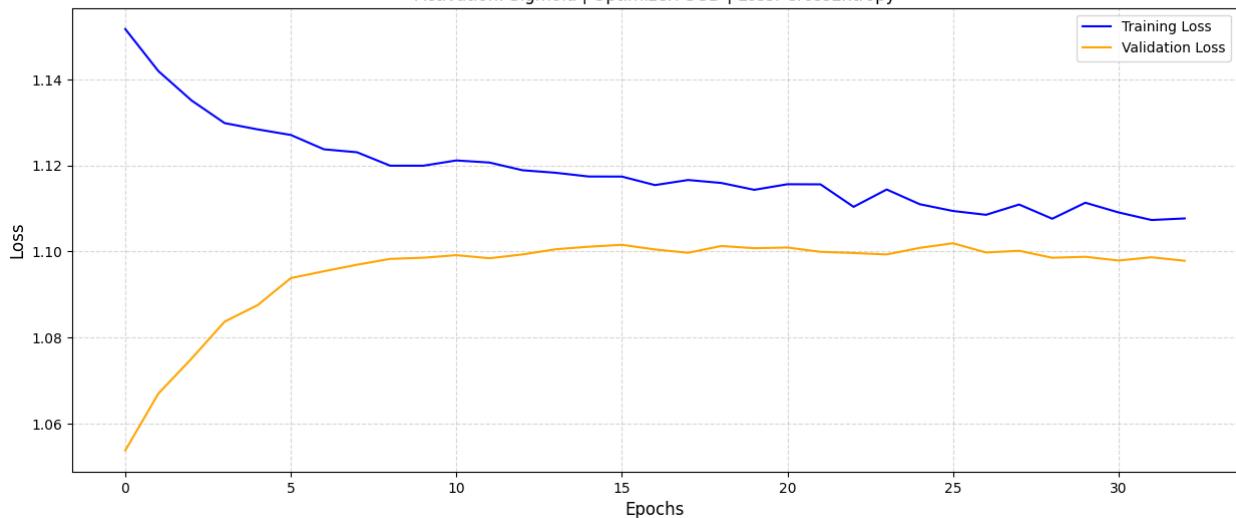
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



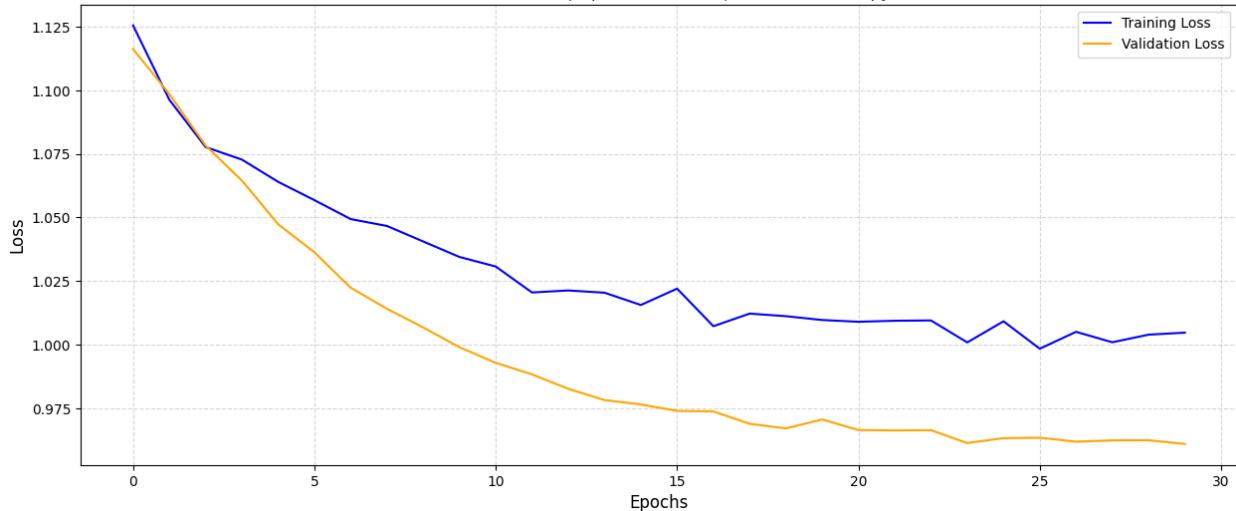
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

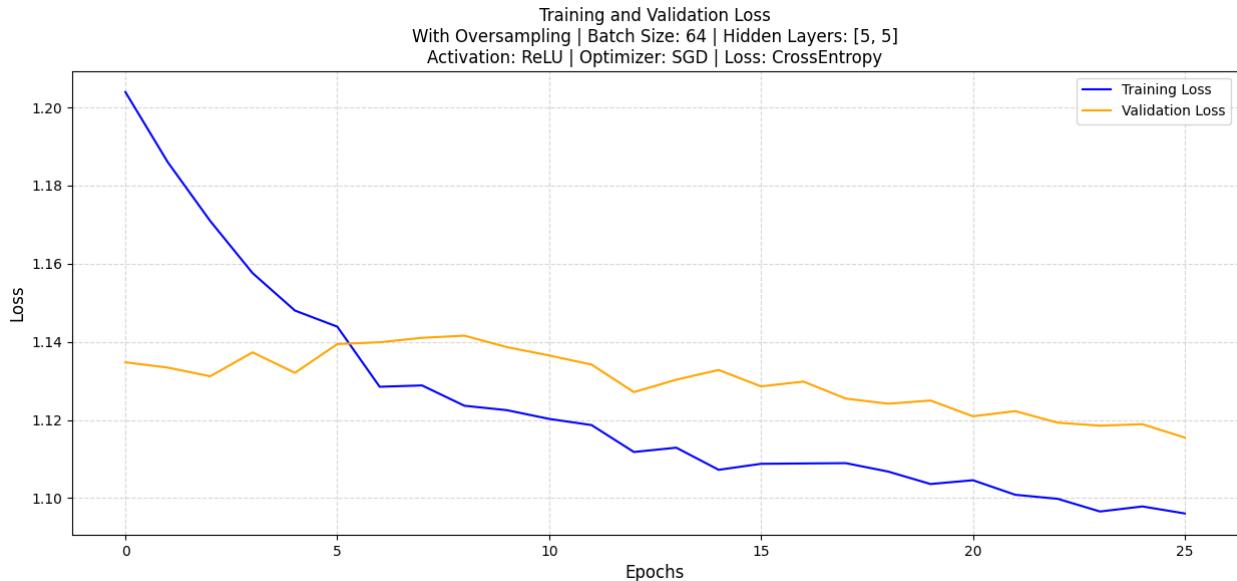


Early stopping triggered

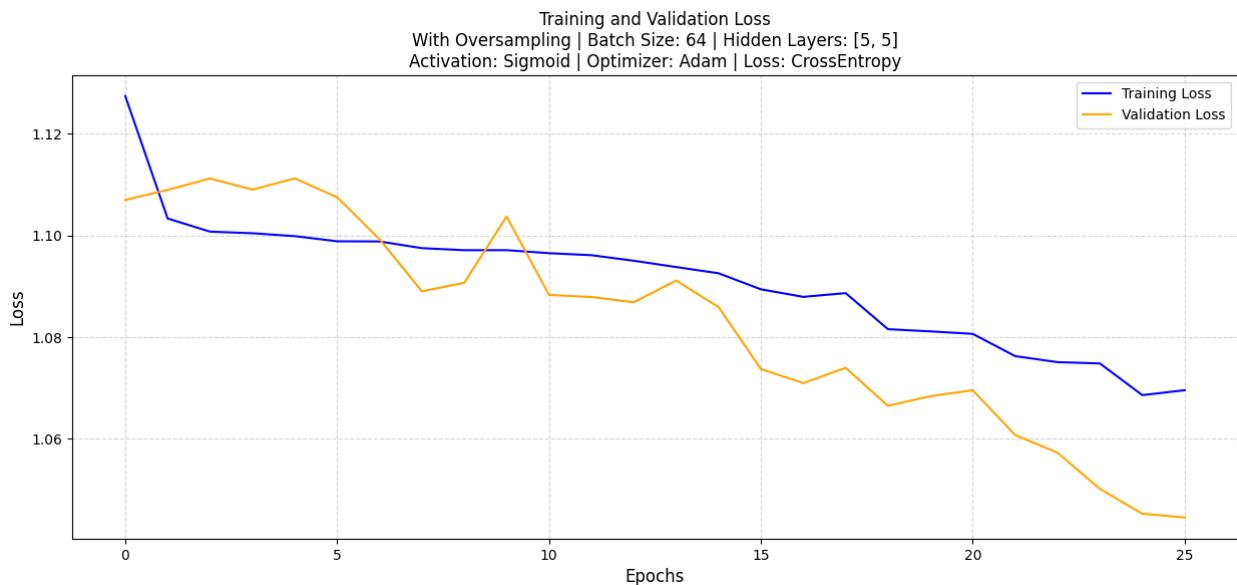
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5, 5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered

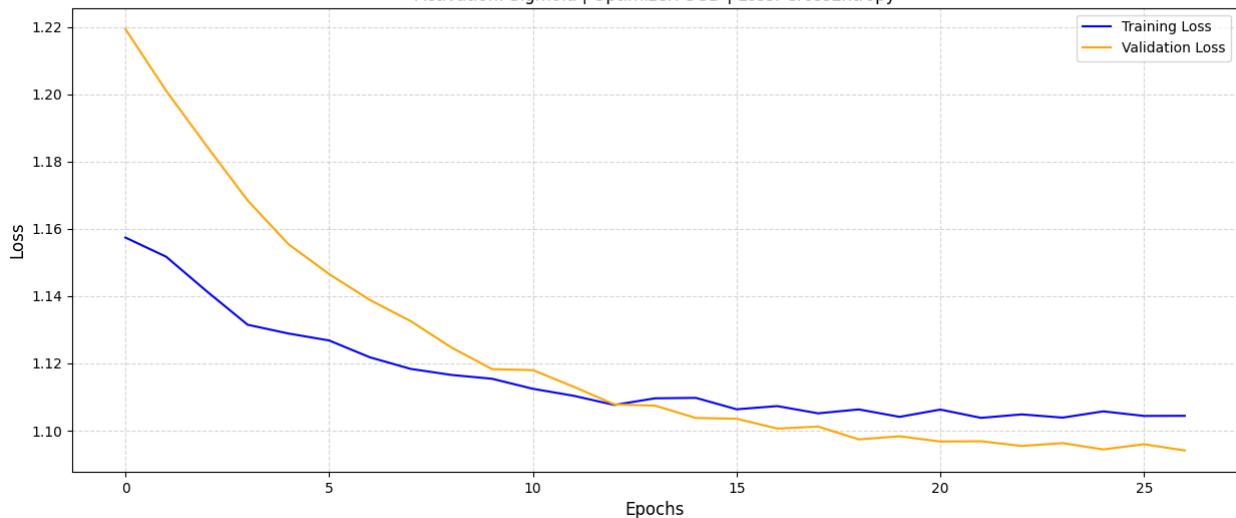


Early stopping triggered



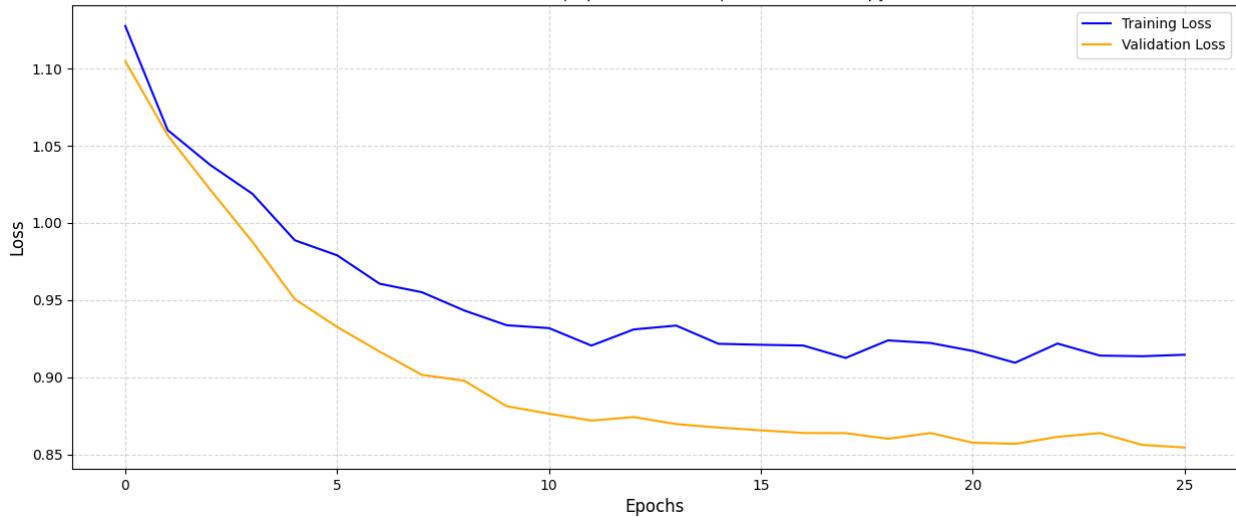
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5, 5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



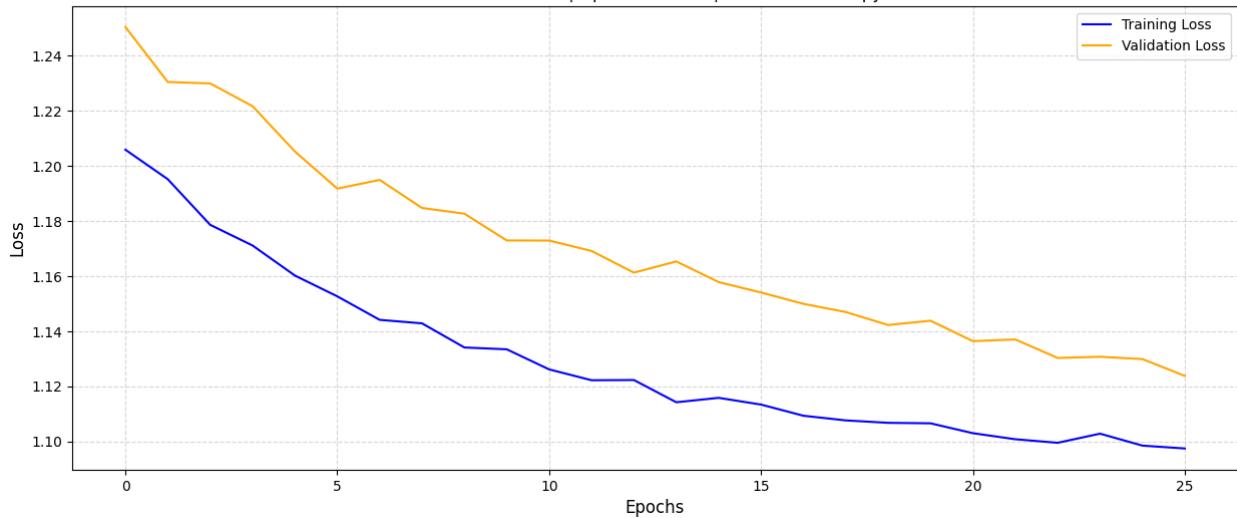
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10, 10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



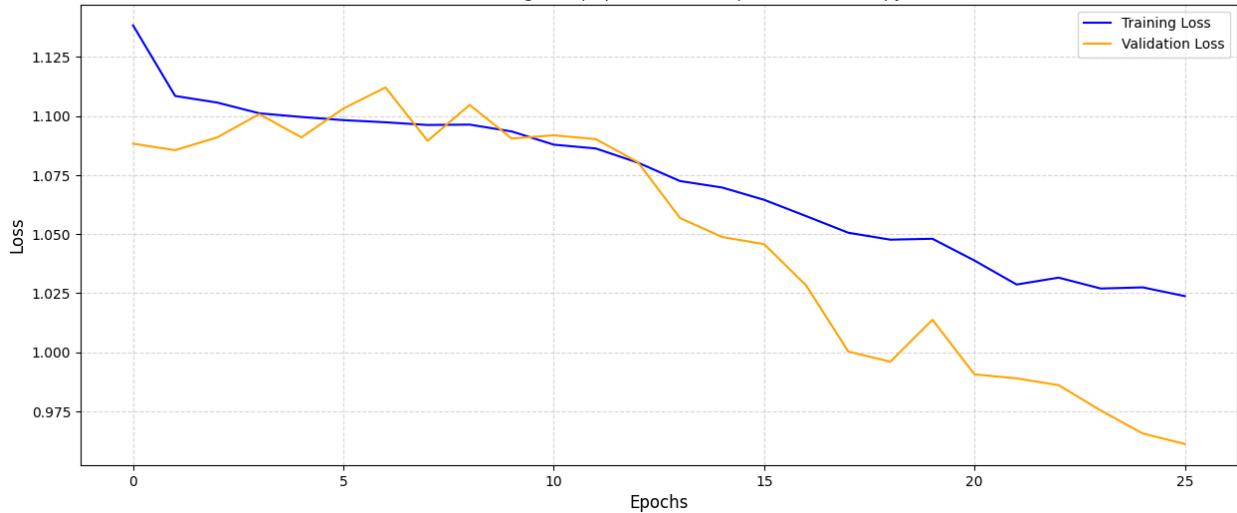
Early stopping triggered

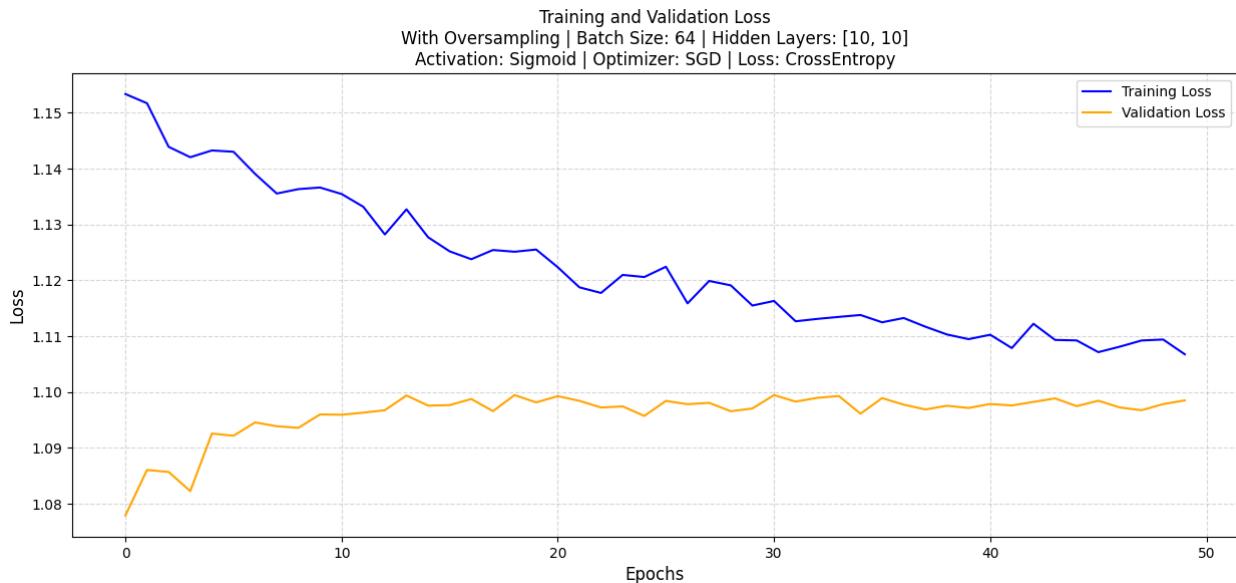
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10, 10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



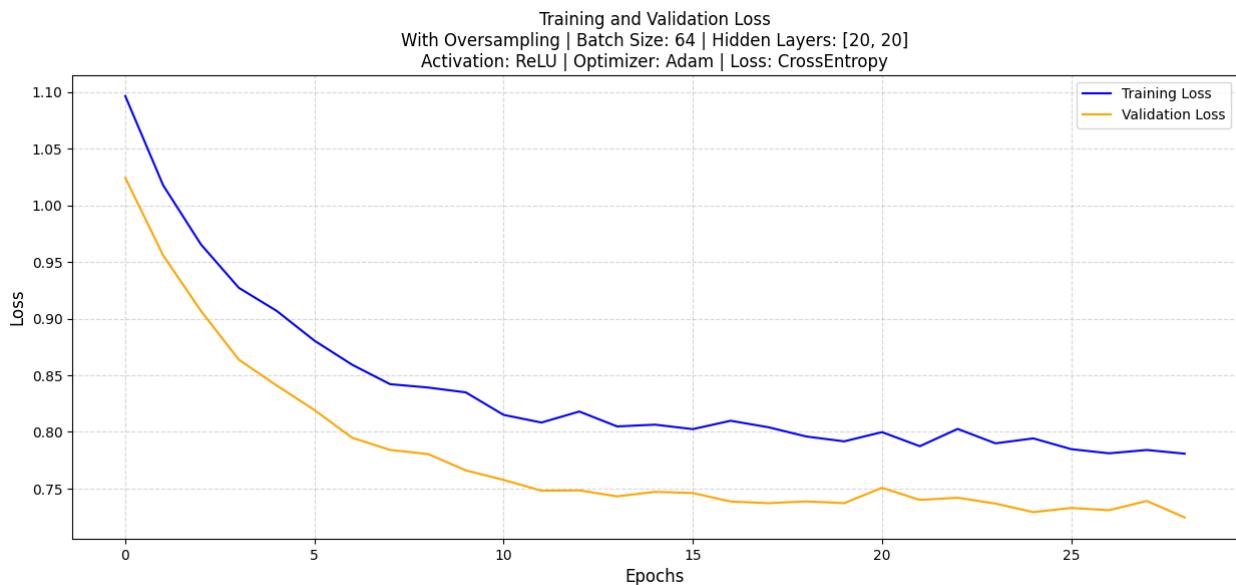
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10, 10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy

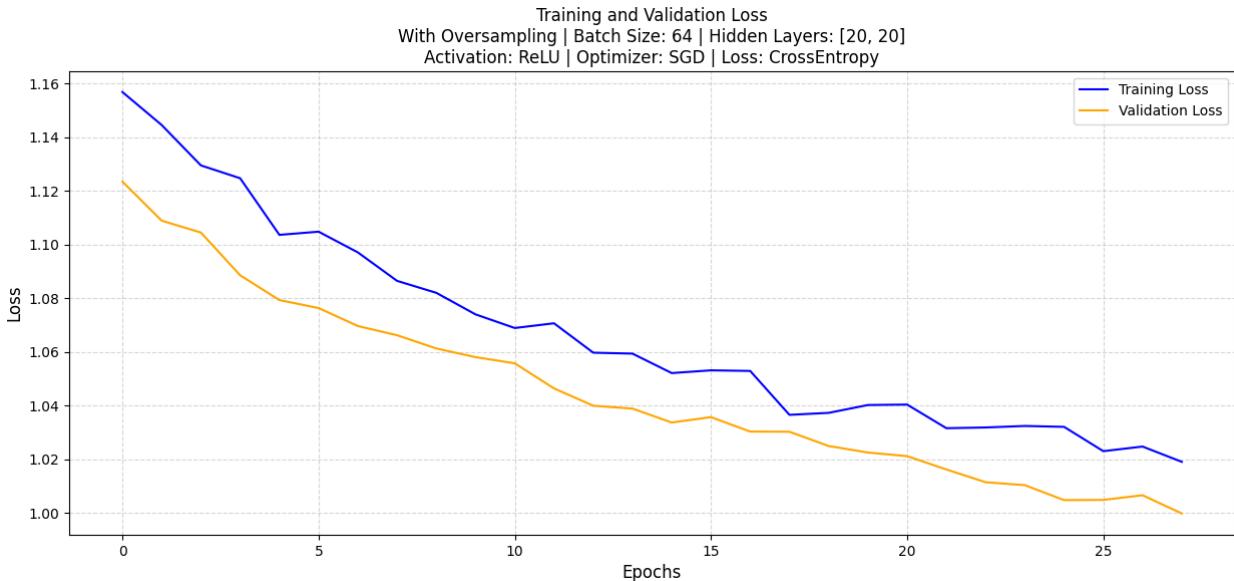




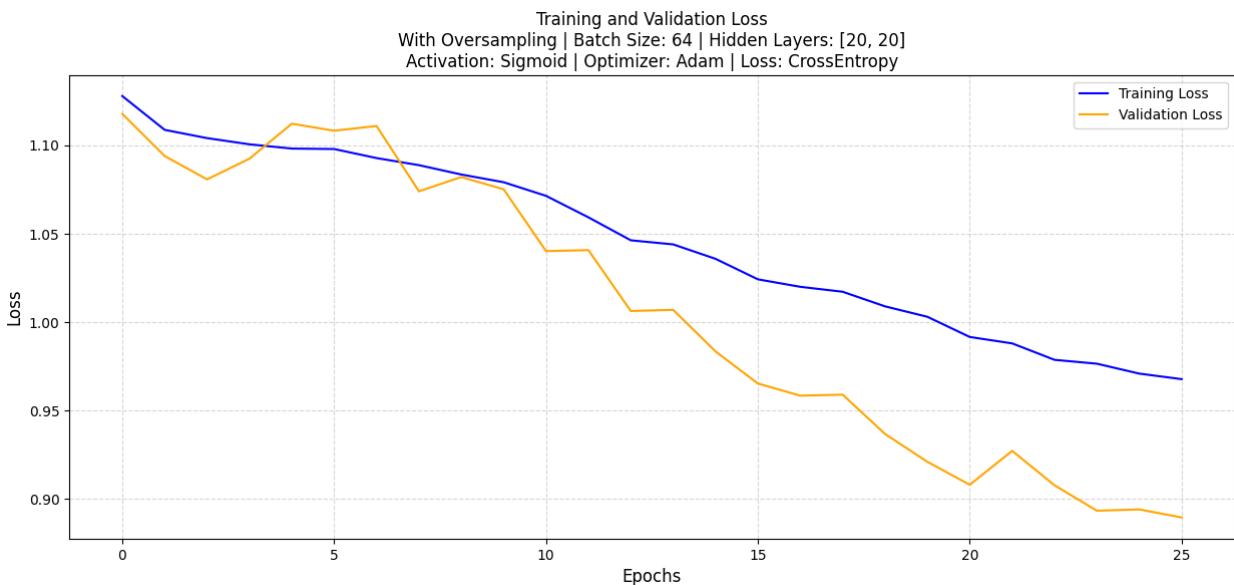
Early stopping triggered



Early stopping triggered

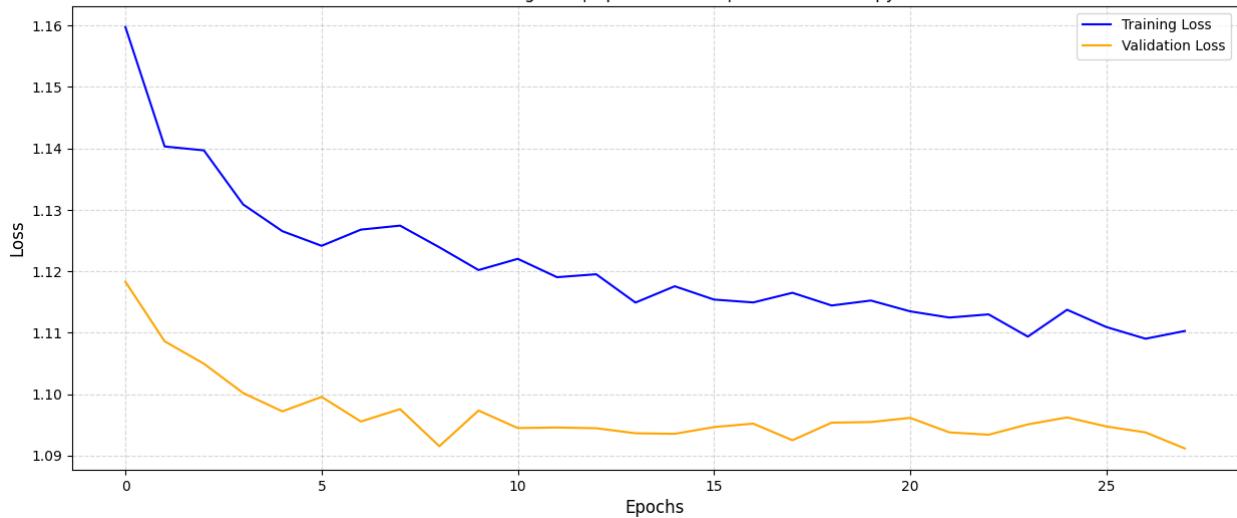


Early stopping triggered



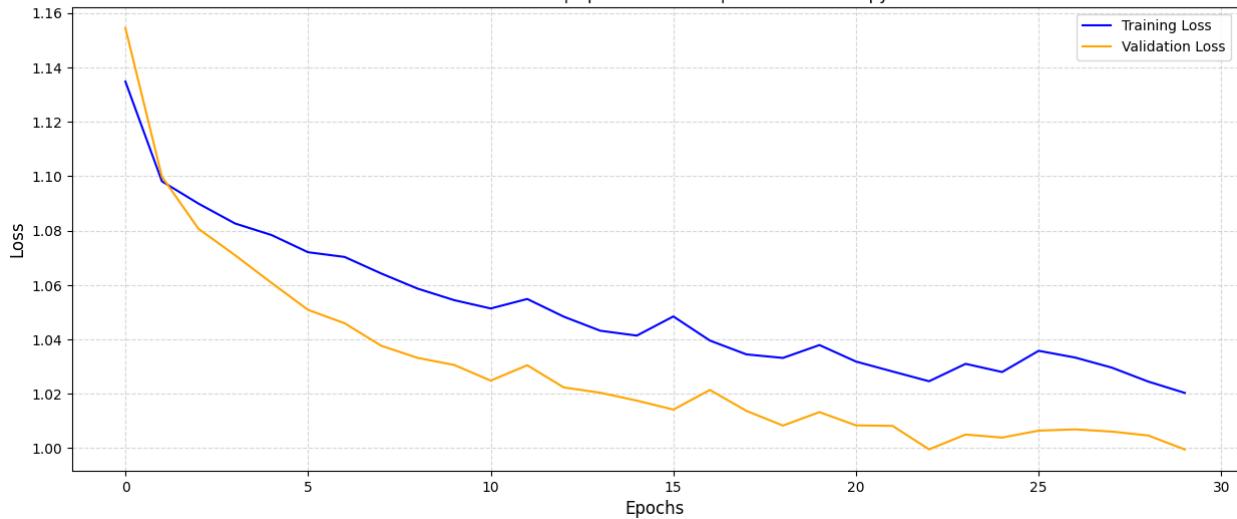
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [20, 20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

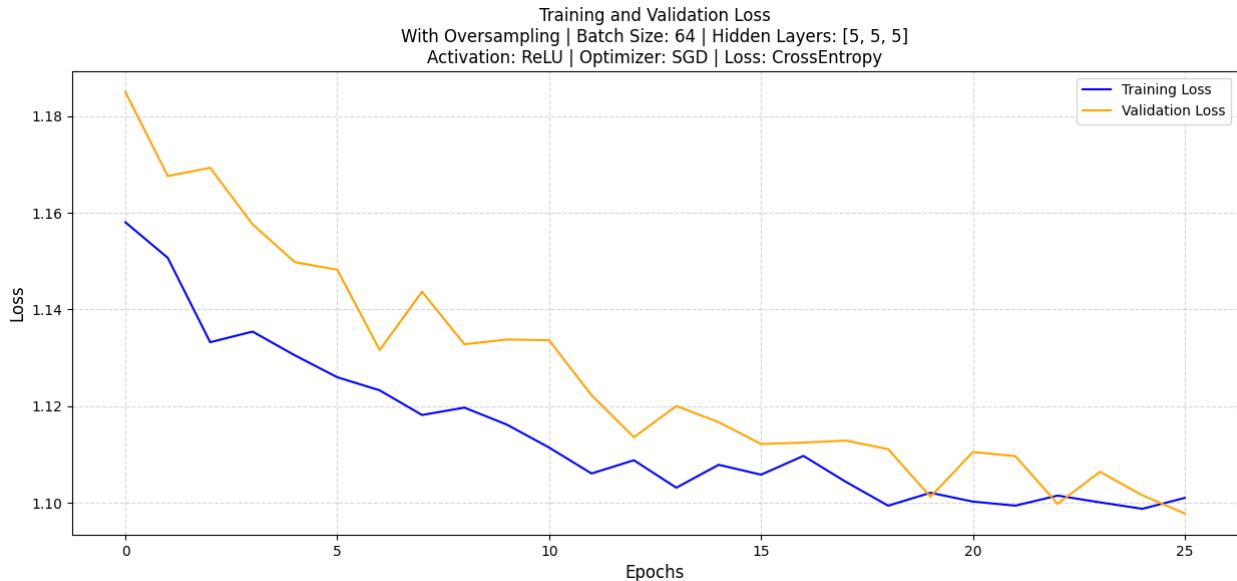


Early stopping triggered

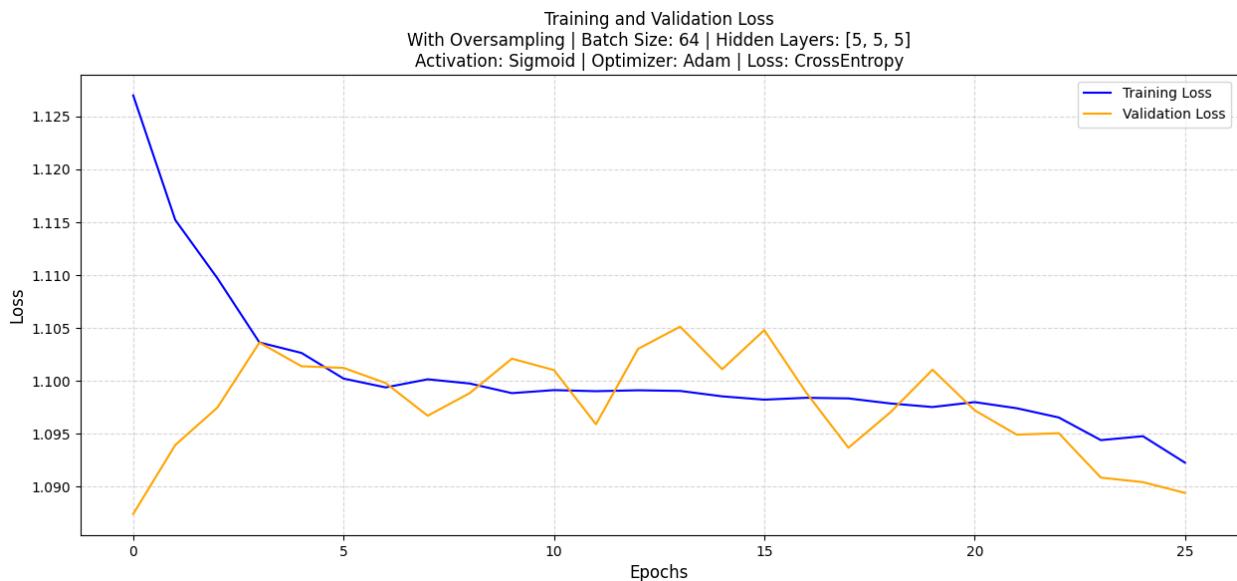
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [5, 5, 5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered

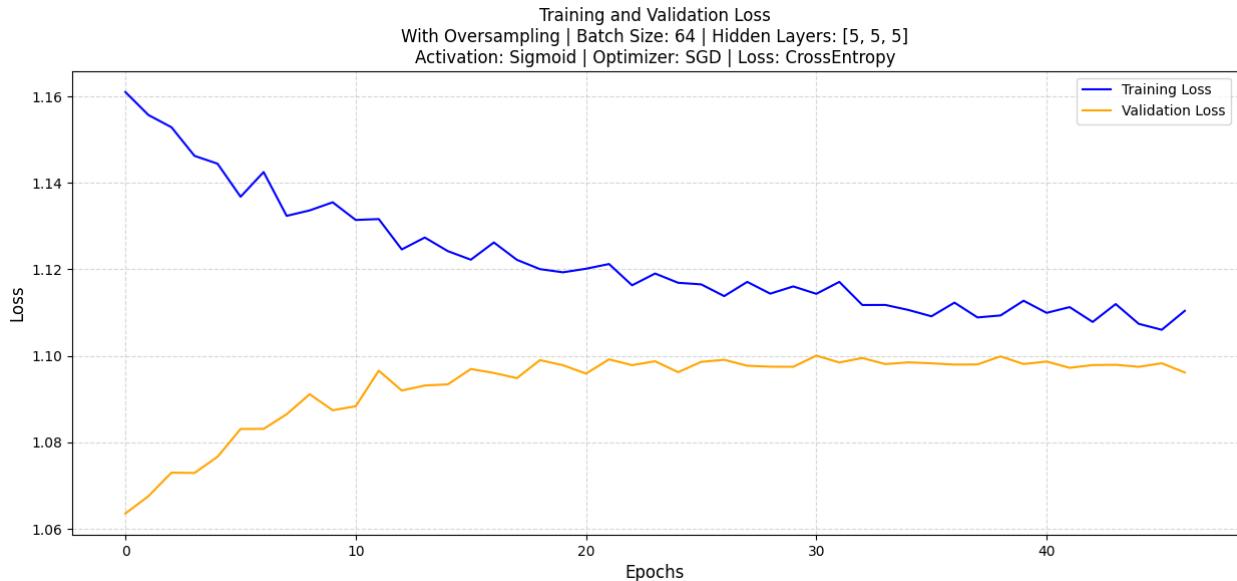


Early stopping triggered

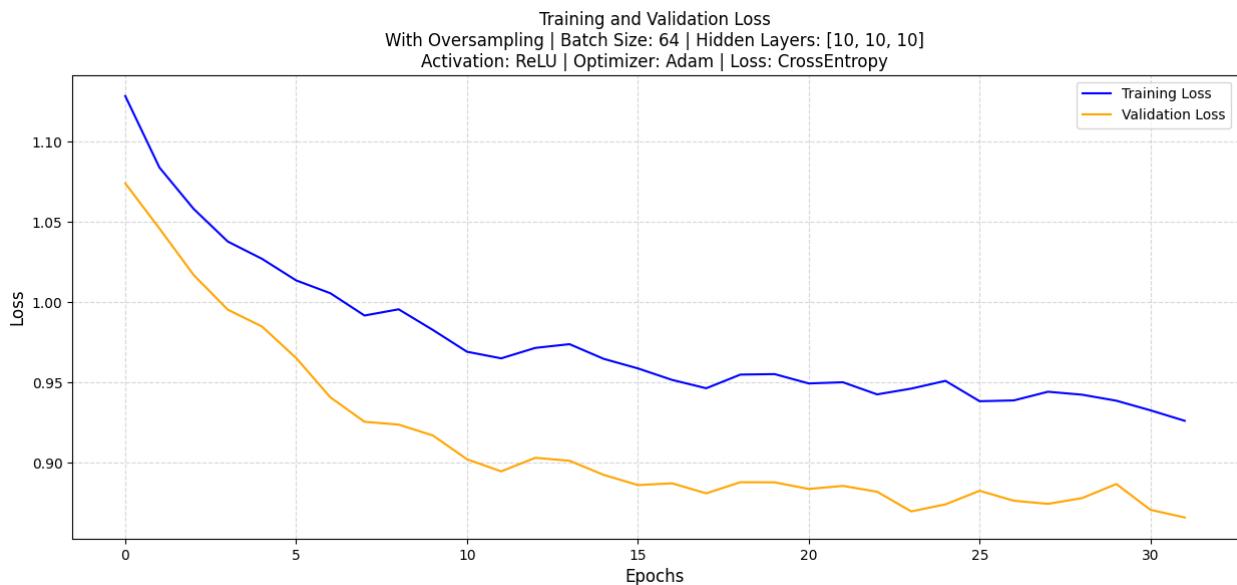


Early stopping triggered

```
c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```

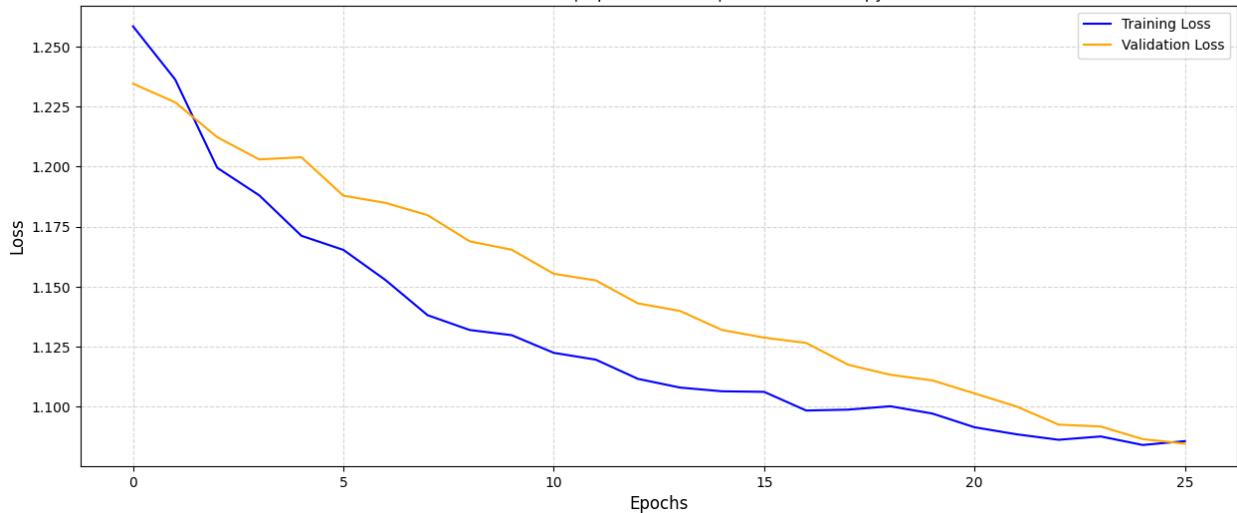


Early stopping triggered



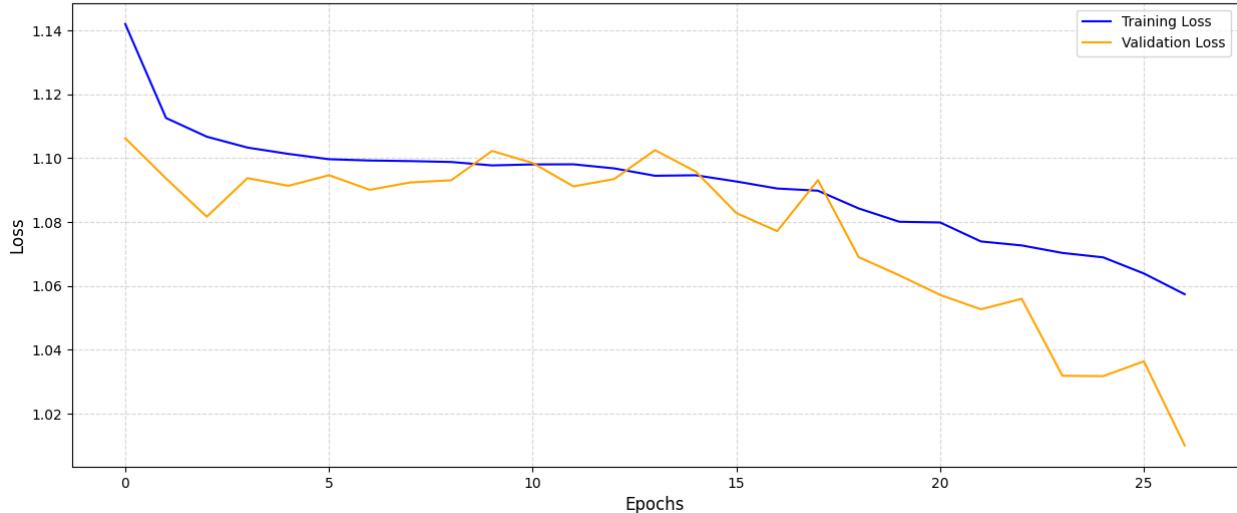
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10, 10, 10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

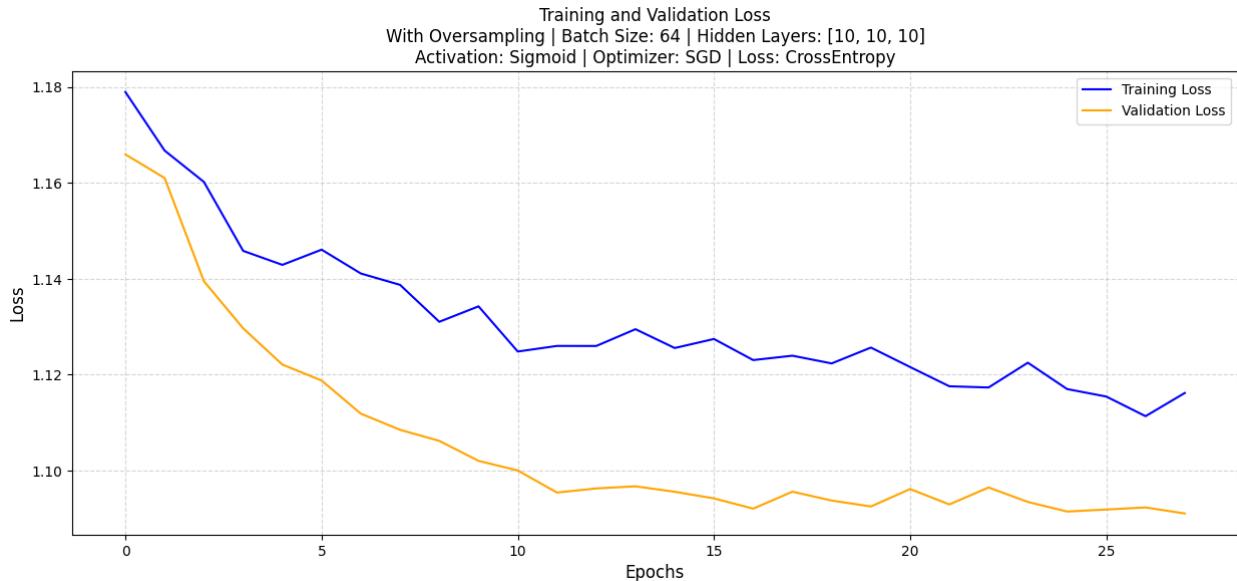


Early stopping triggered

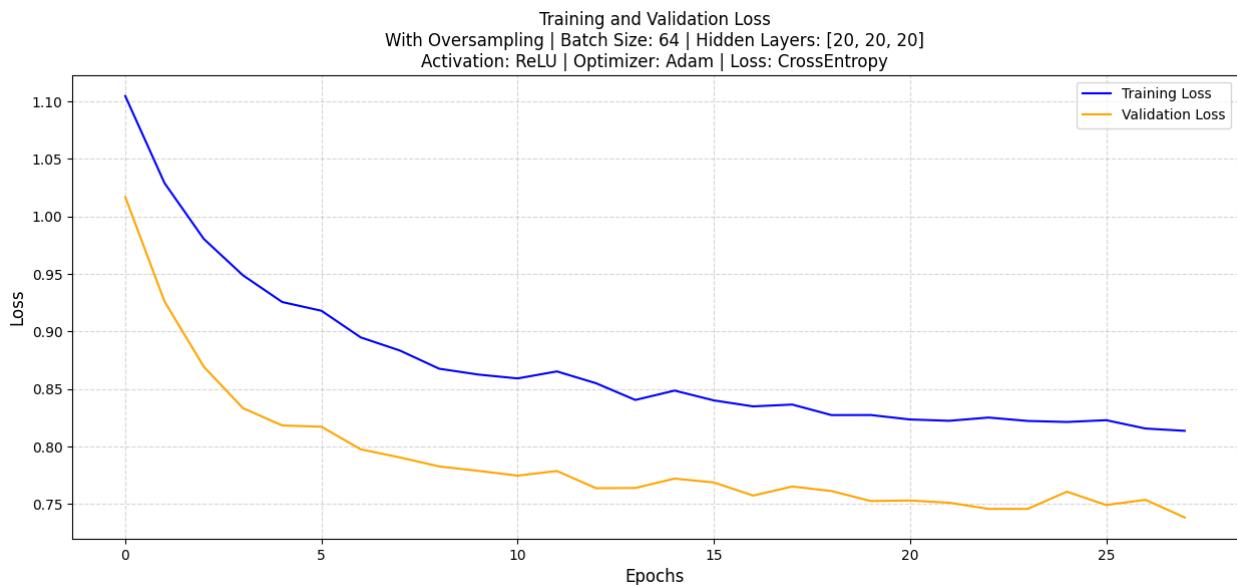
Training and Validation Loss
With Oversampling | Batch Size: 64 | Hidden Layers: [10, 10, 10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



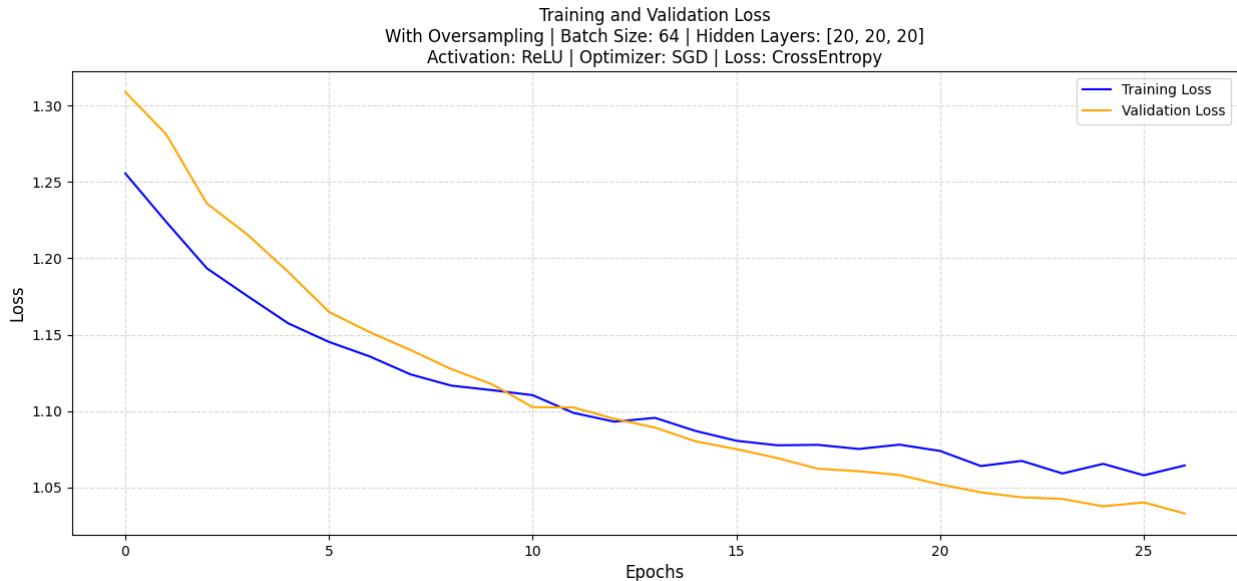
Early stopping triggered



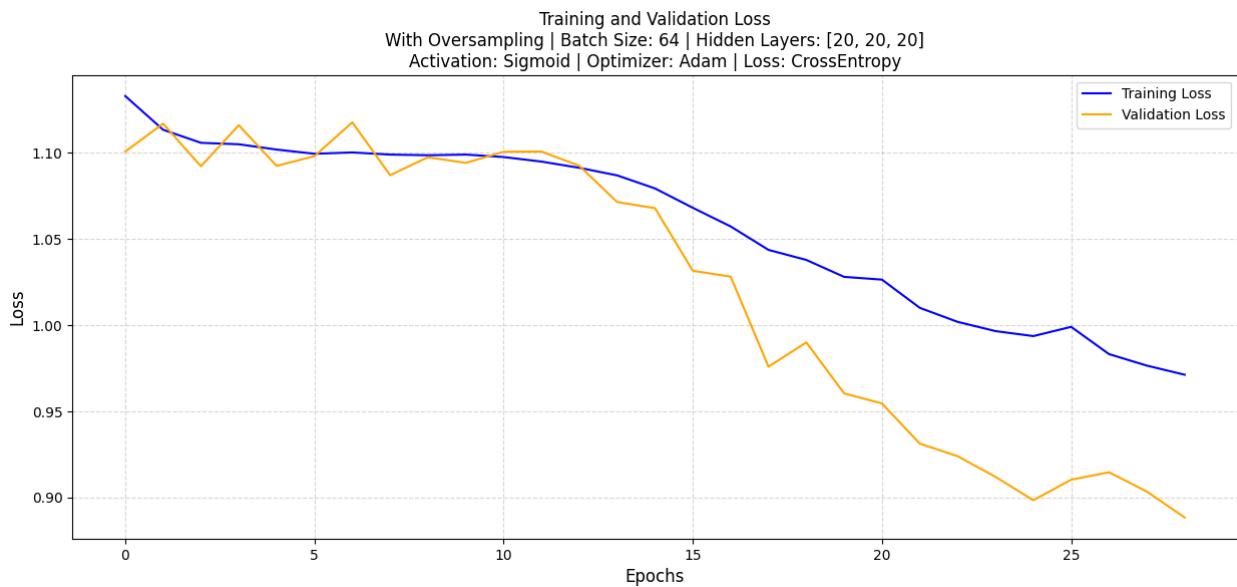
Early stopping triggered

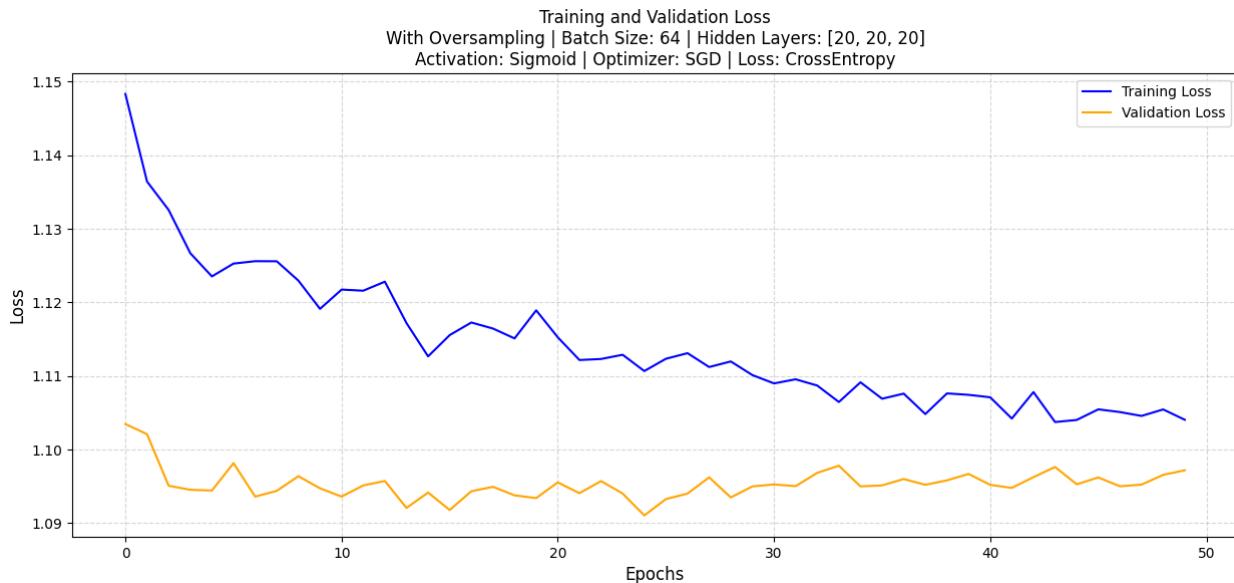


Early stopping triggered

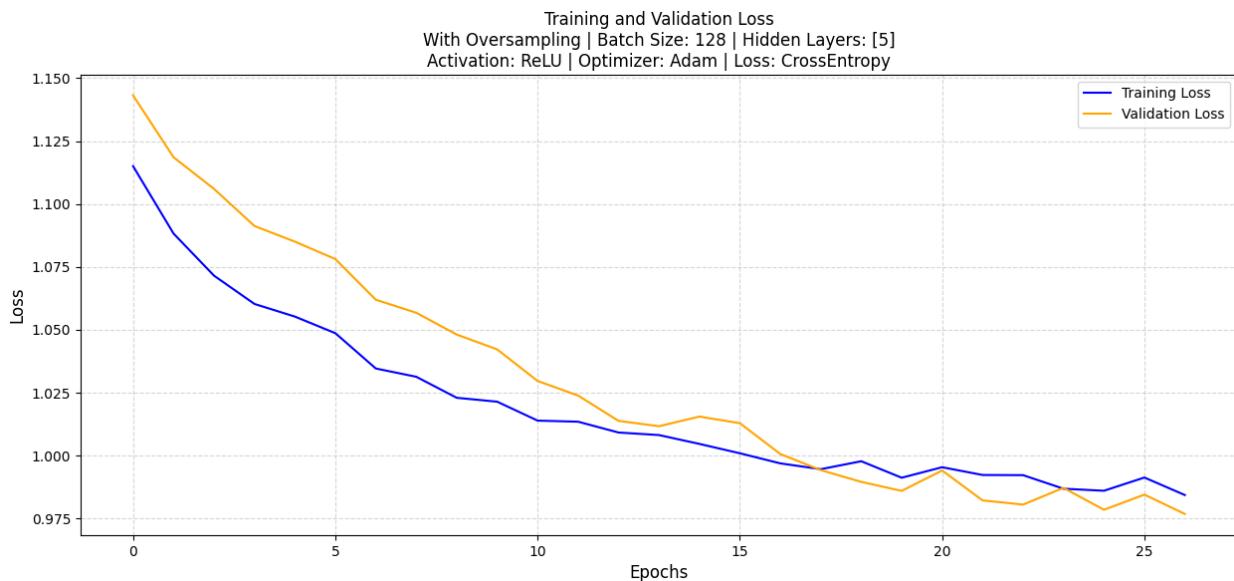


Early stopping triggered

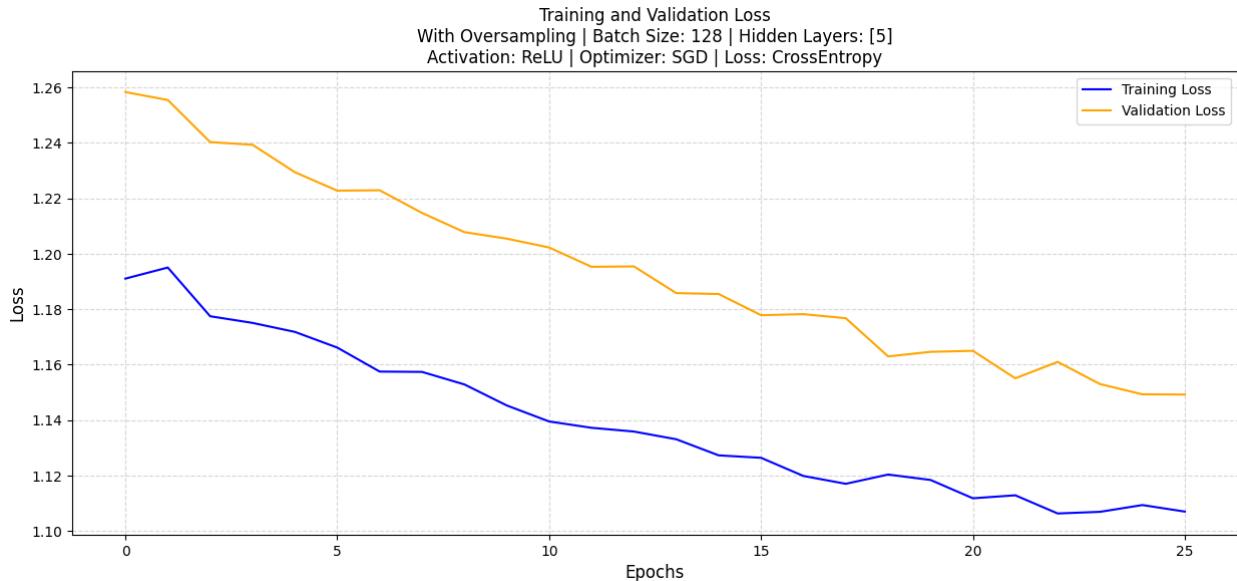




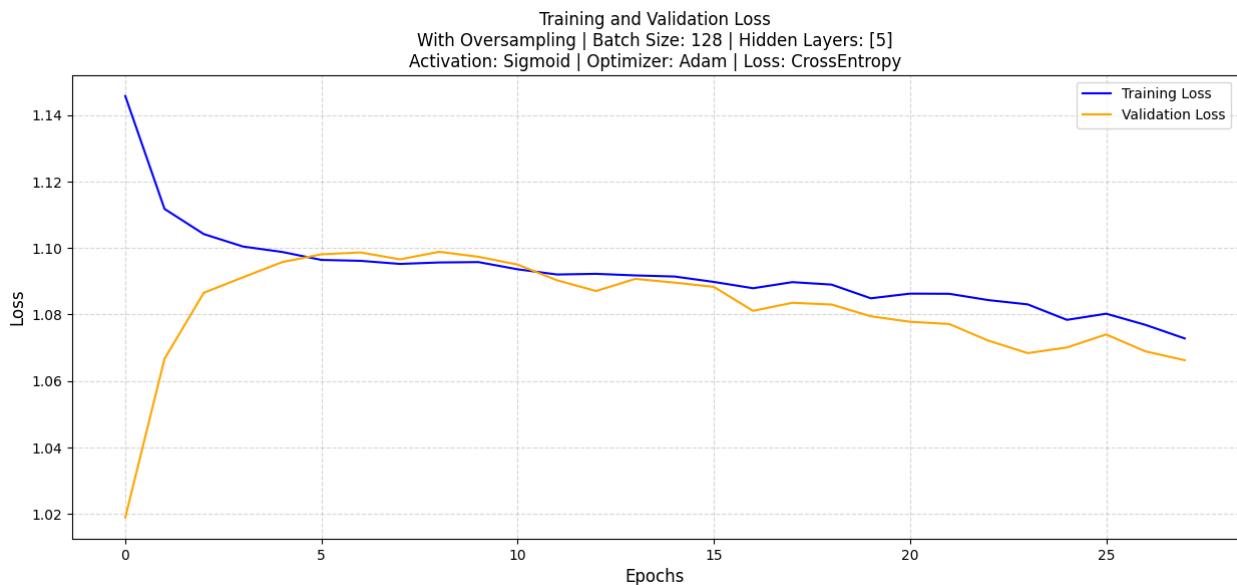
Early stopping triggered



Early stopping triggered

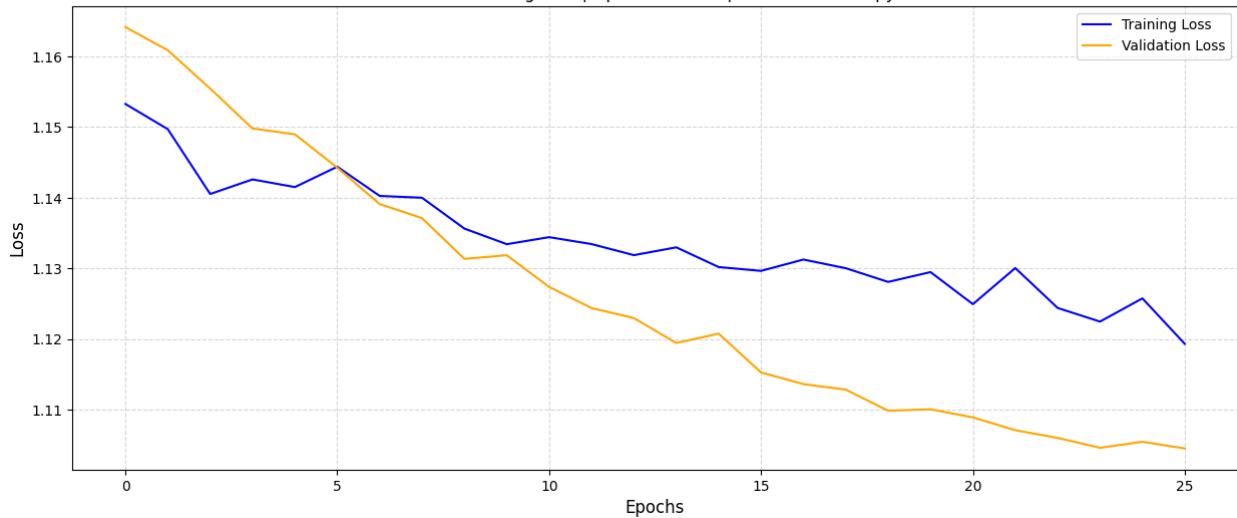


Early stopping triggered



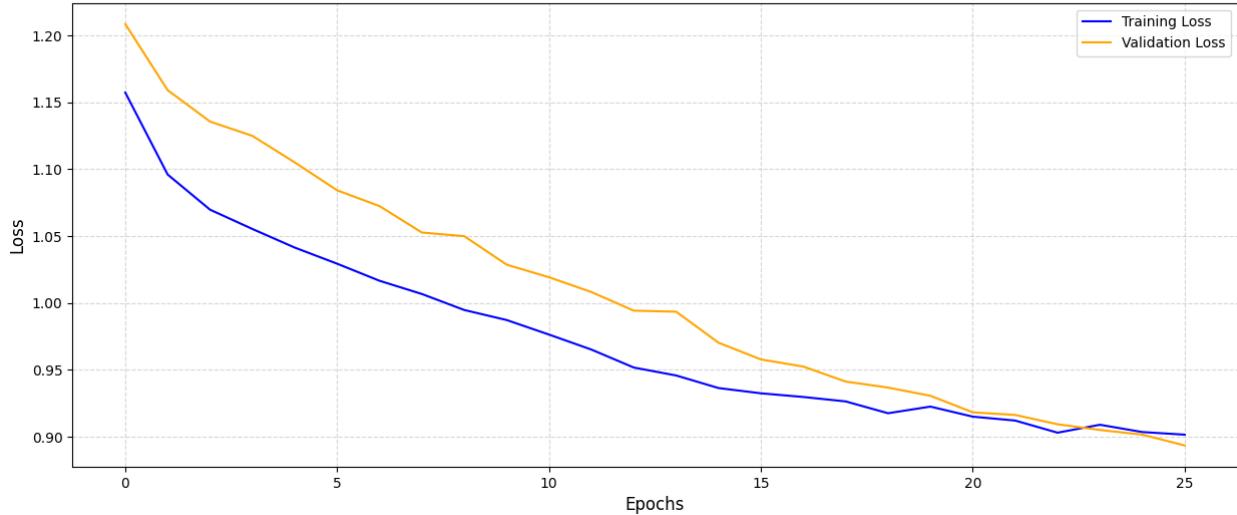
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



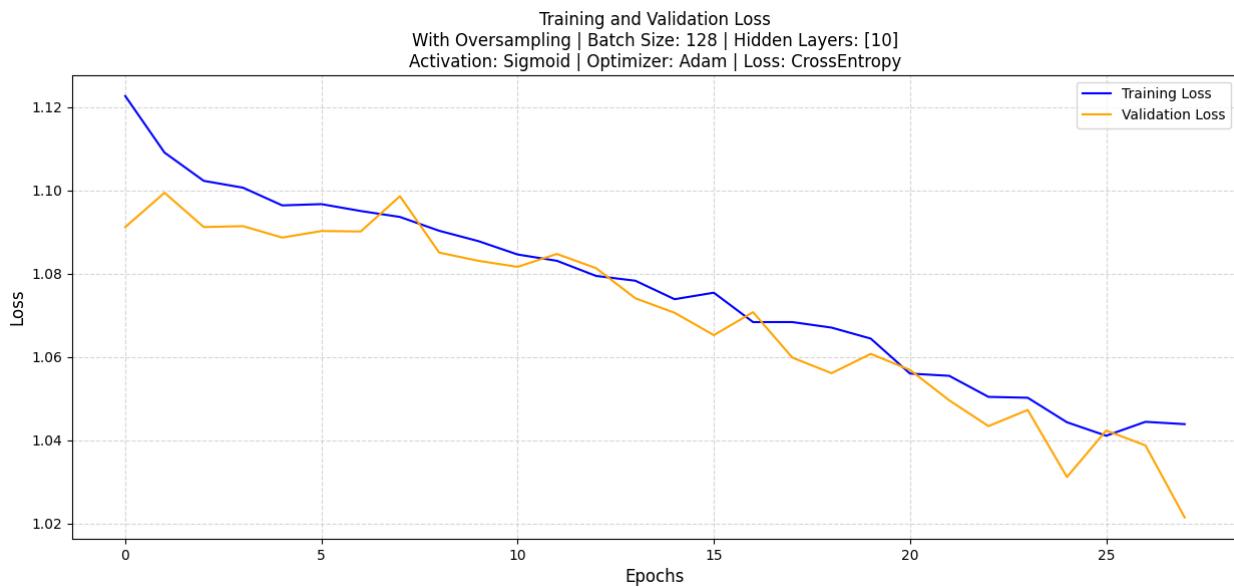
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy

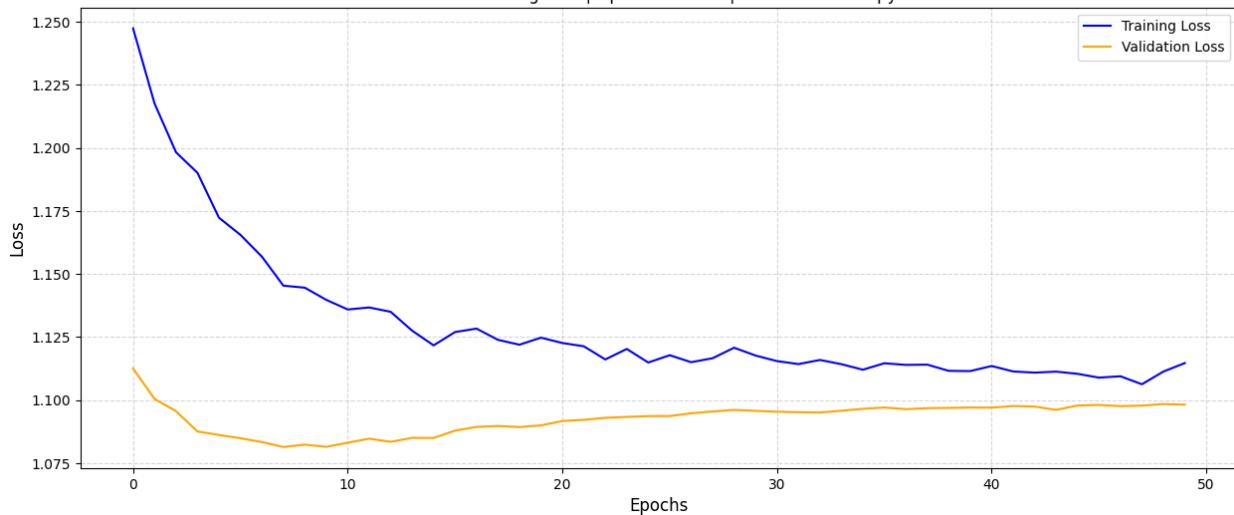




Early stopping triggered

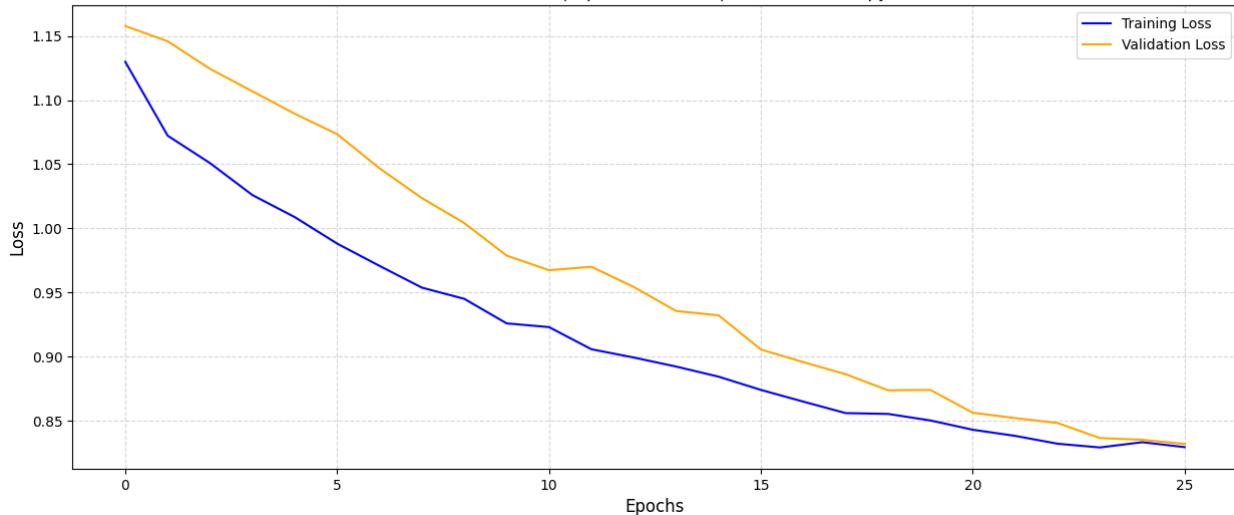


Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

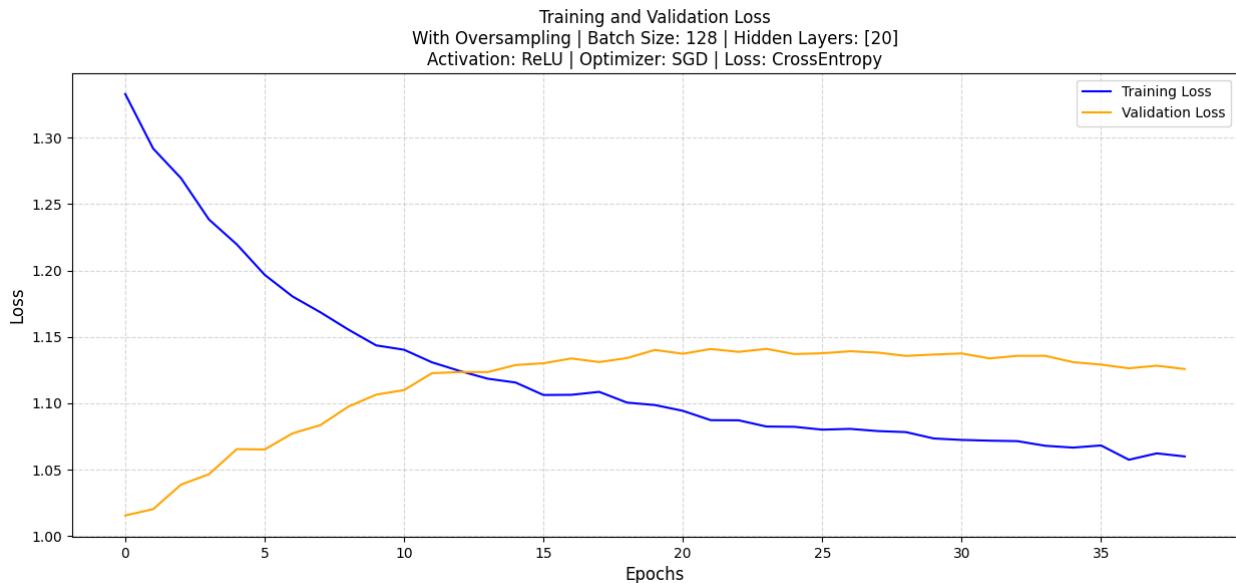


Early stopping triggered

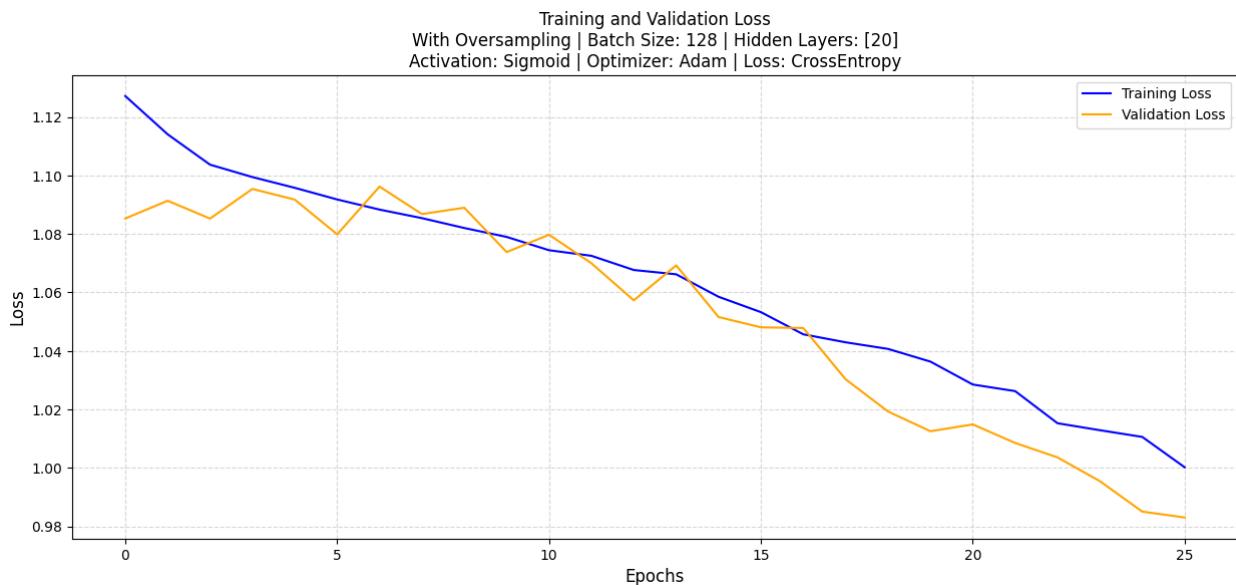
Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



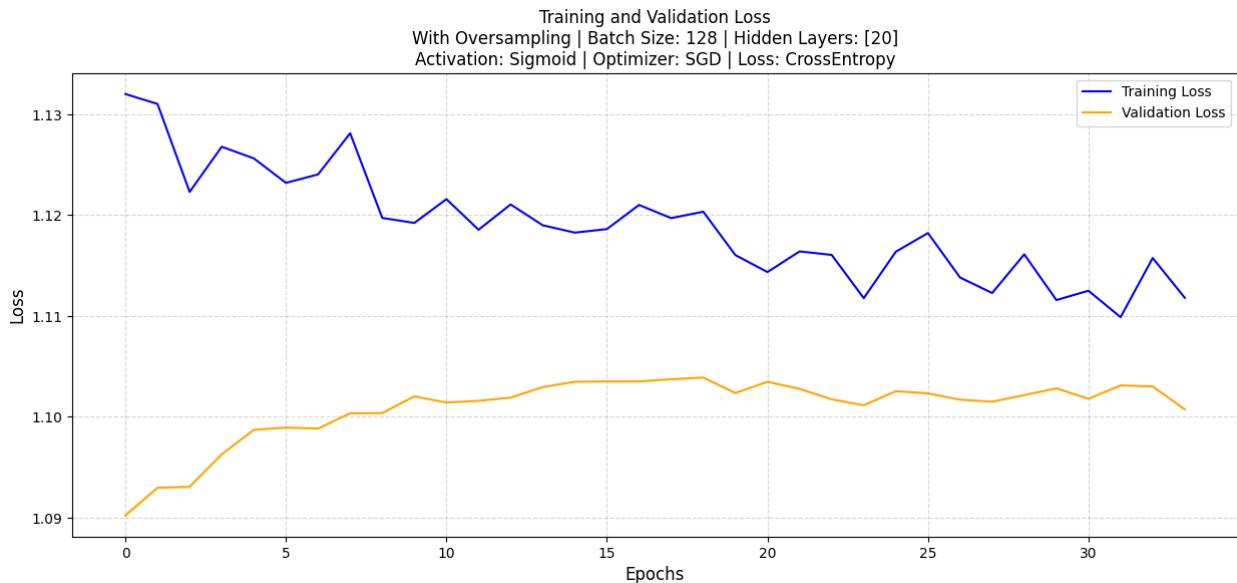
Early stopping triggered



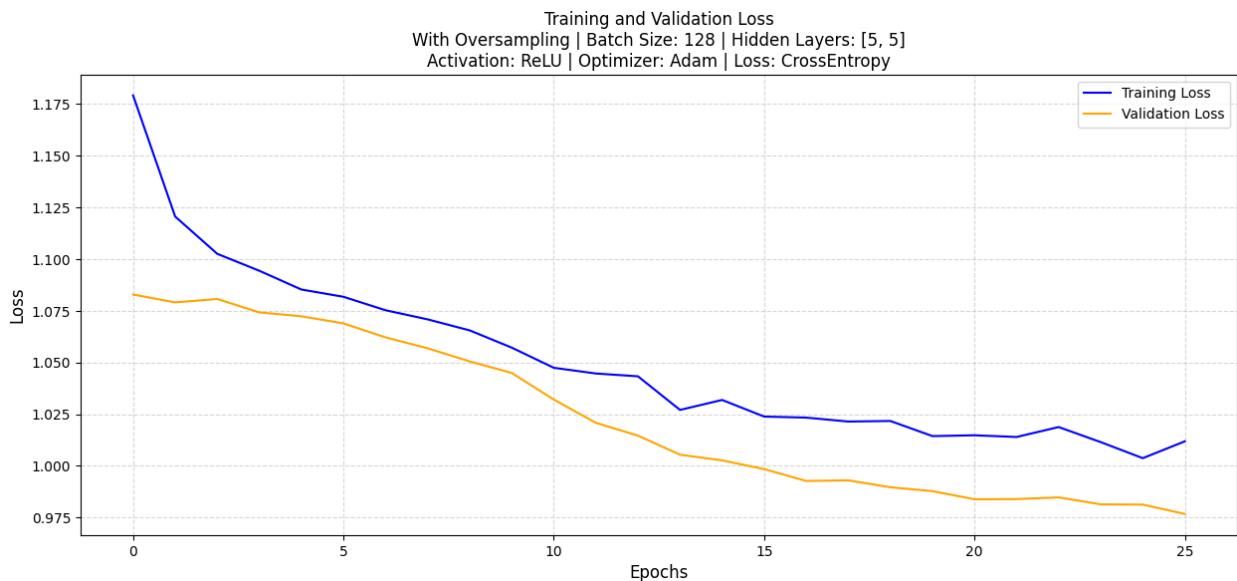
Early stopping triggered



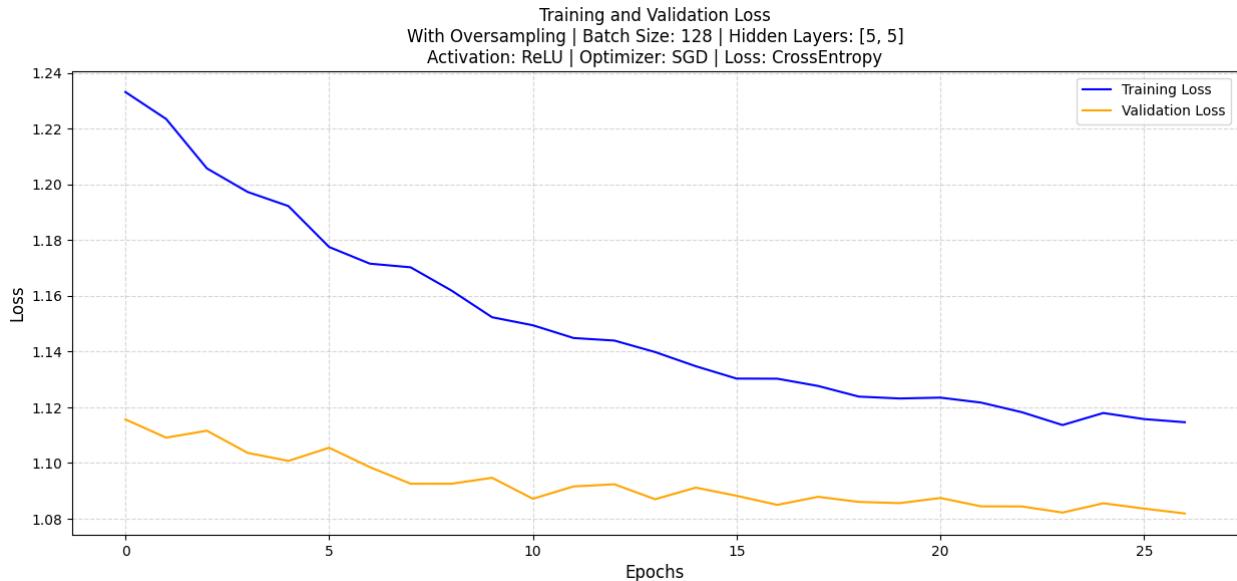
Early stopping triggered



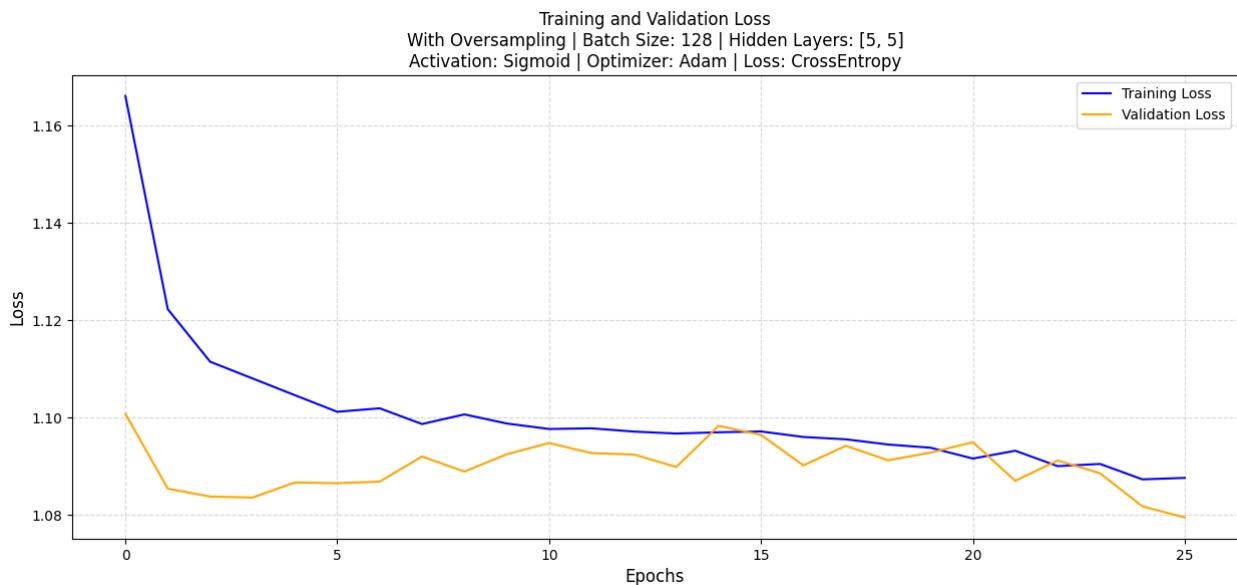
Early stopping triggered



Early stopping triggered

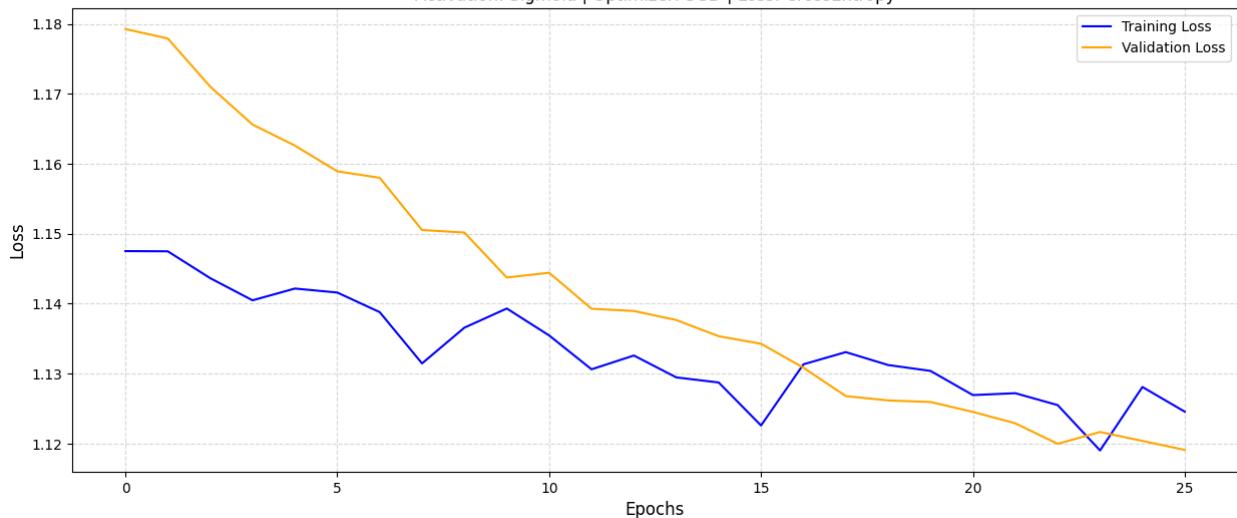


Early stopping triggered



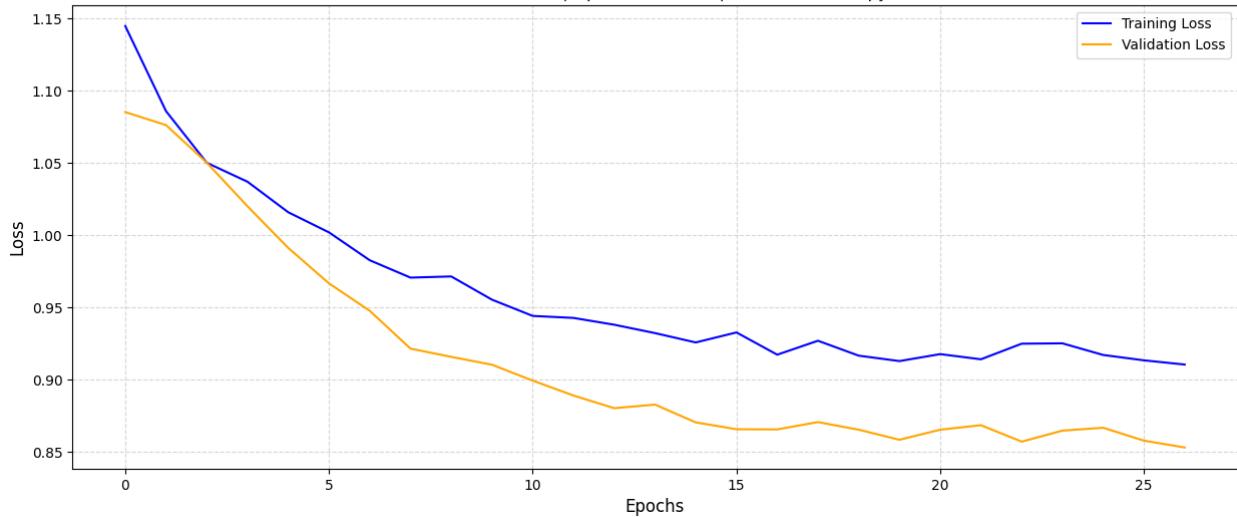
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [5, 5]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



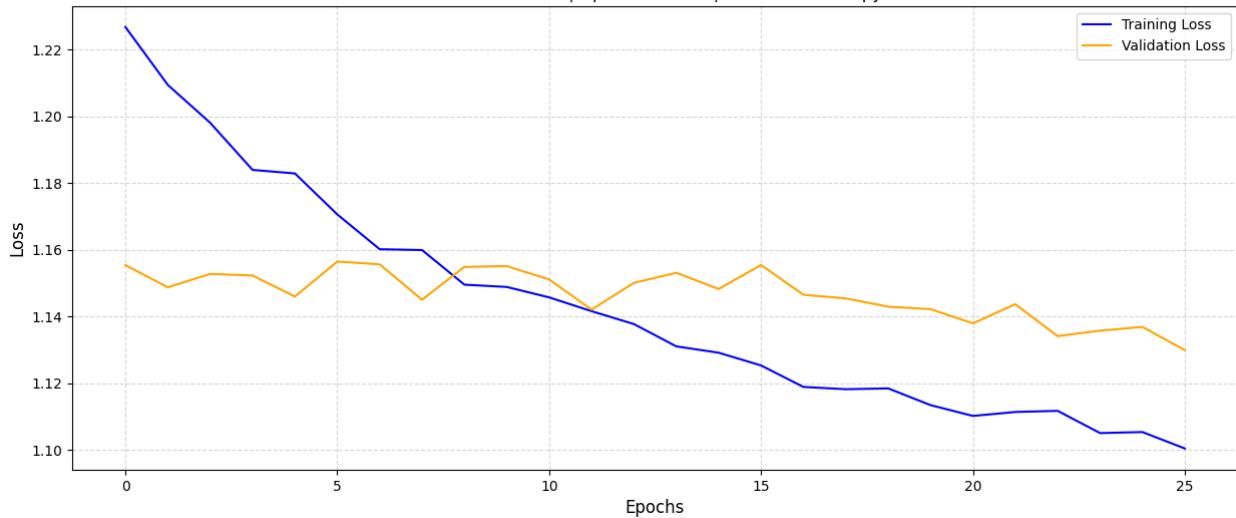
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



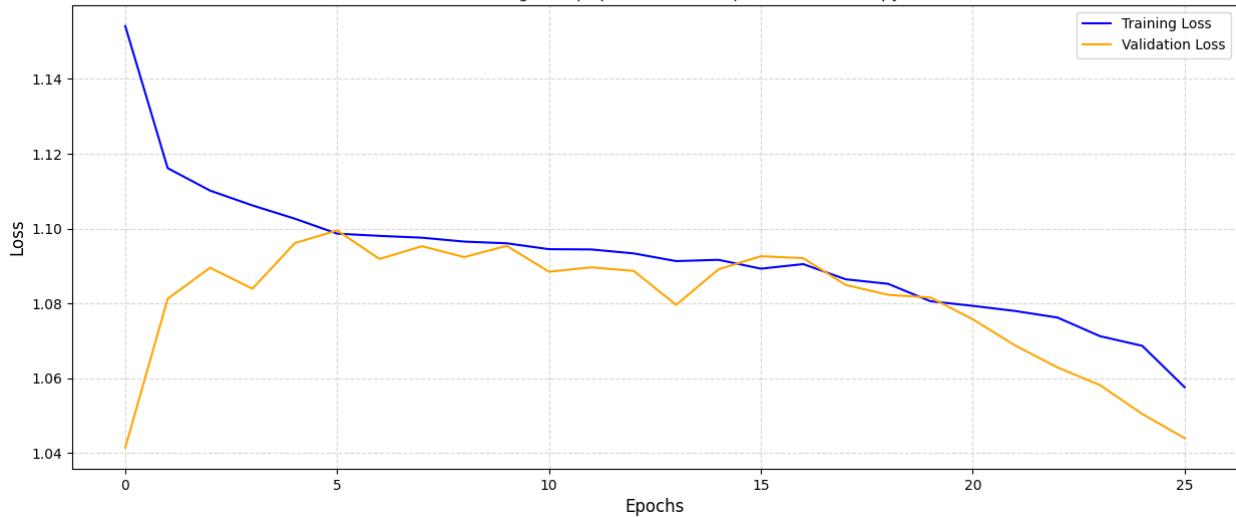
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



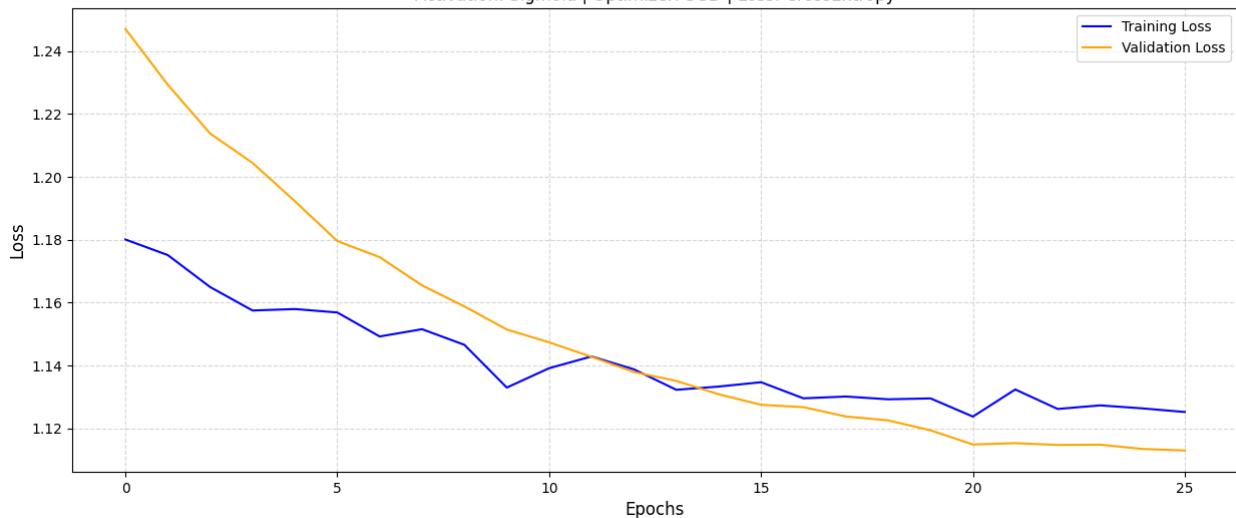
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



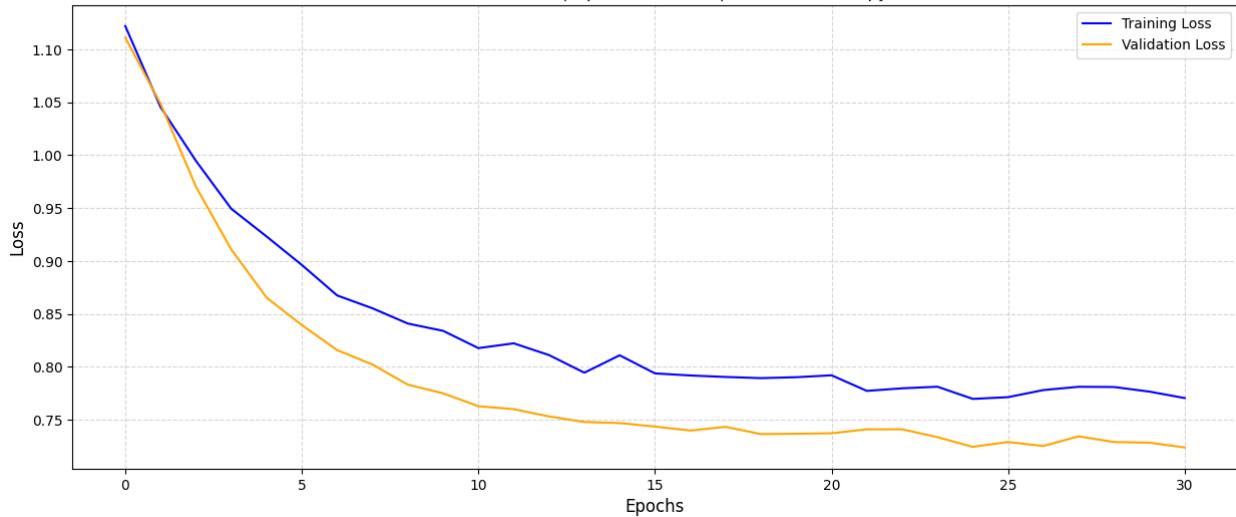
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



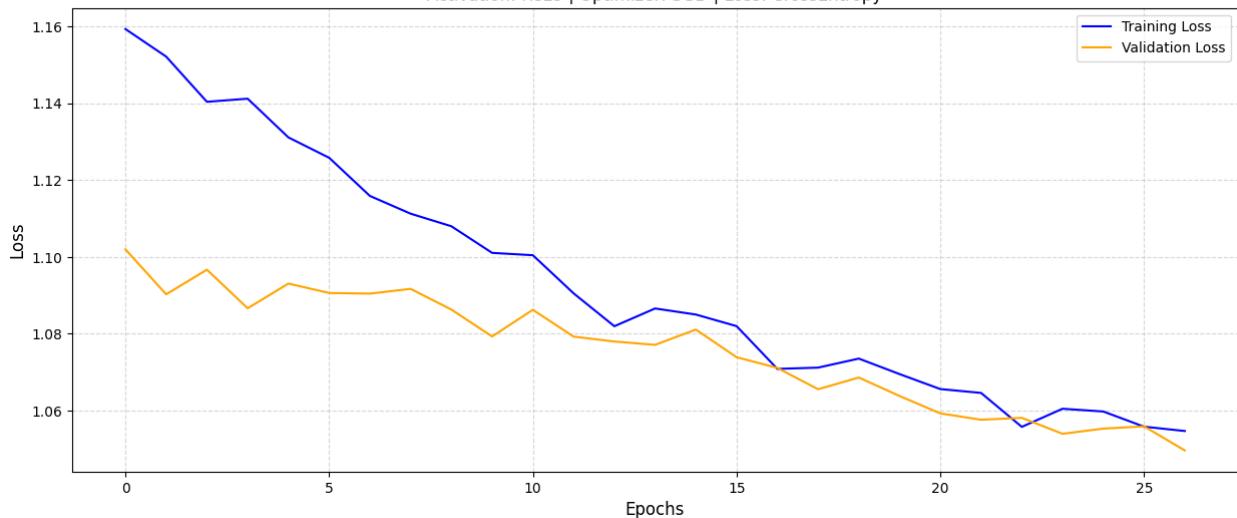
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



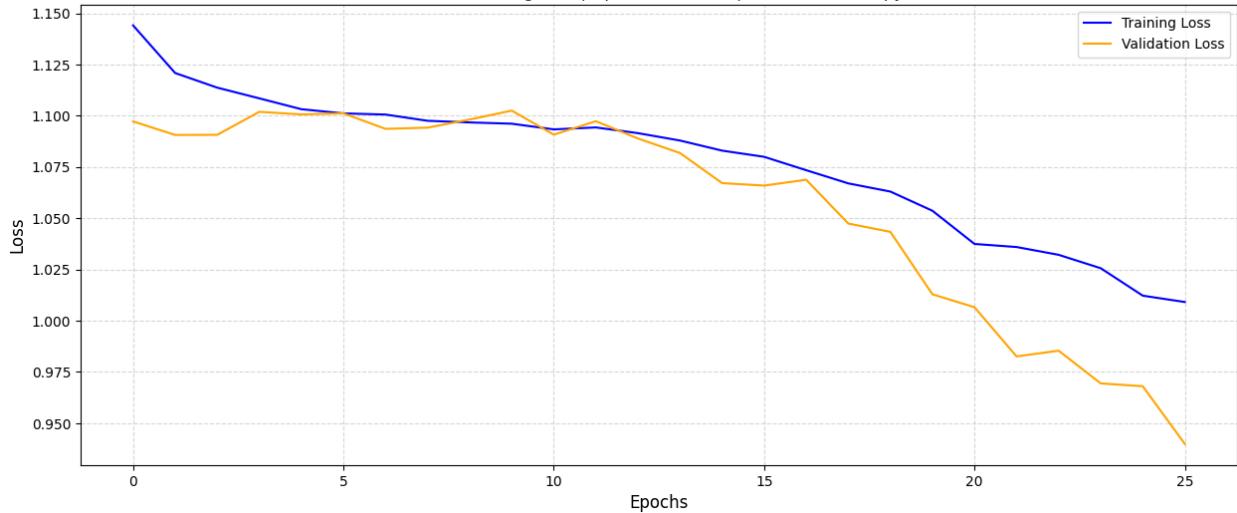
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy



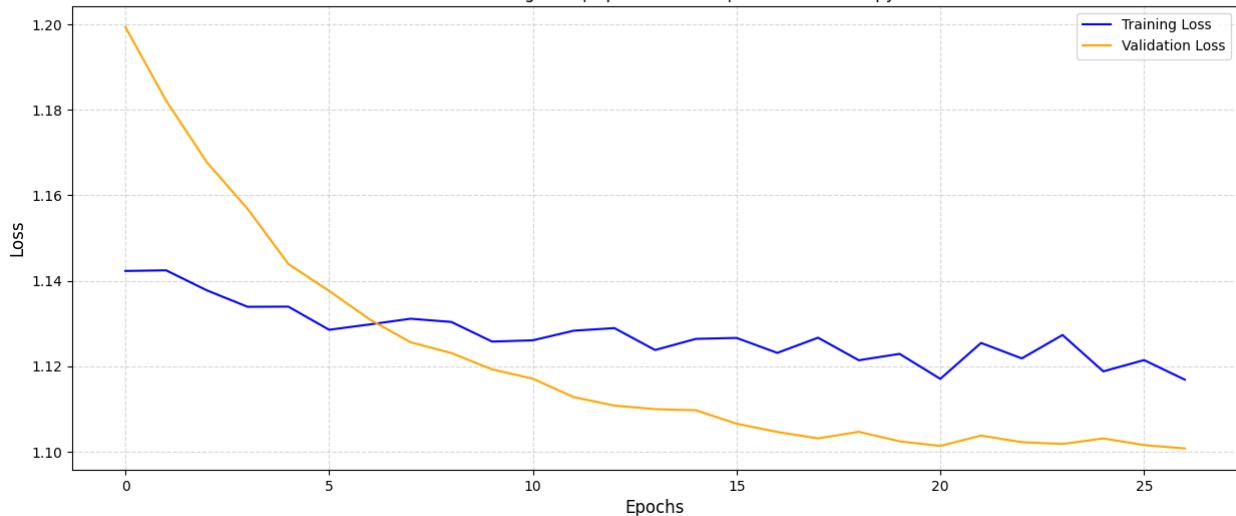
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



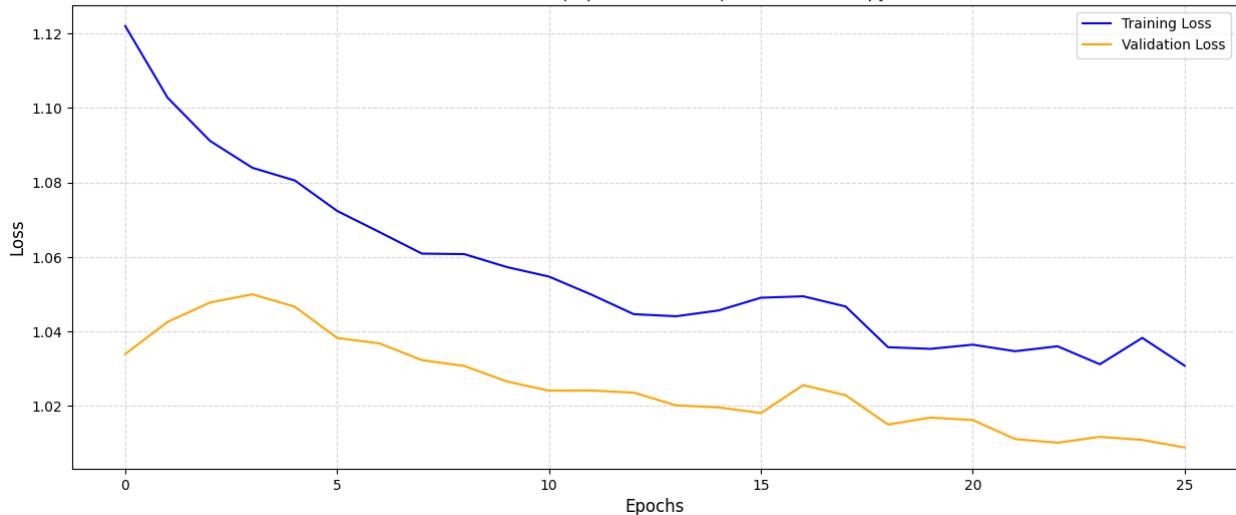
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy

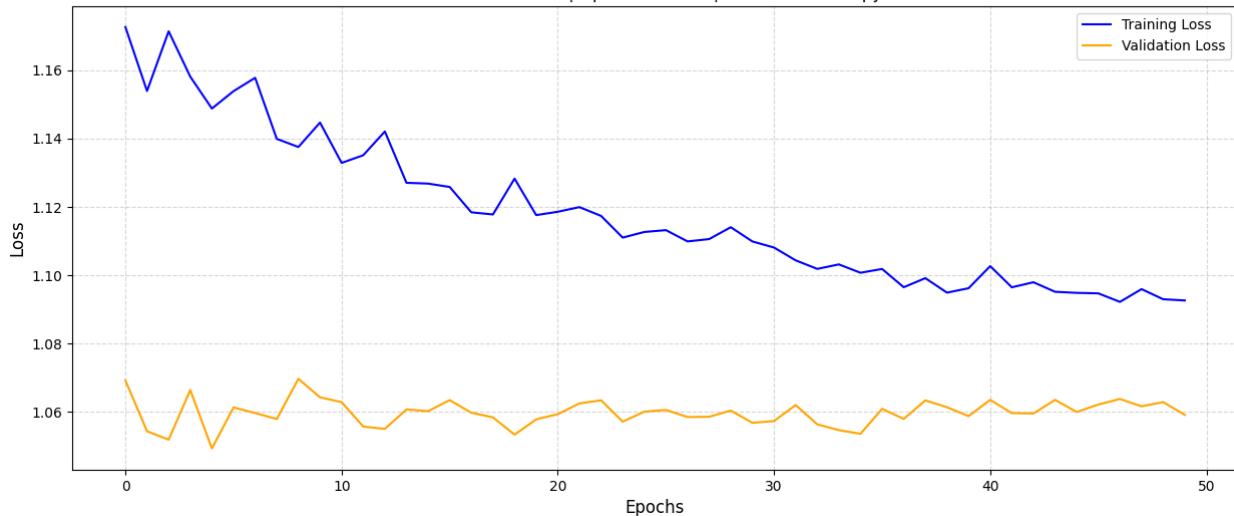


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [5, 5, 5]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy

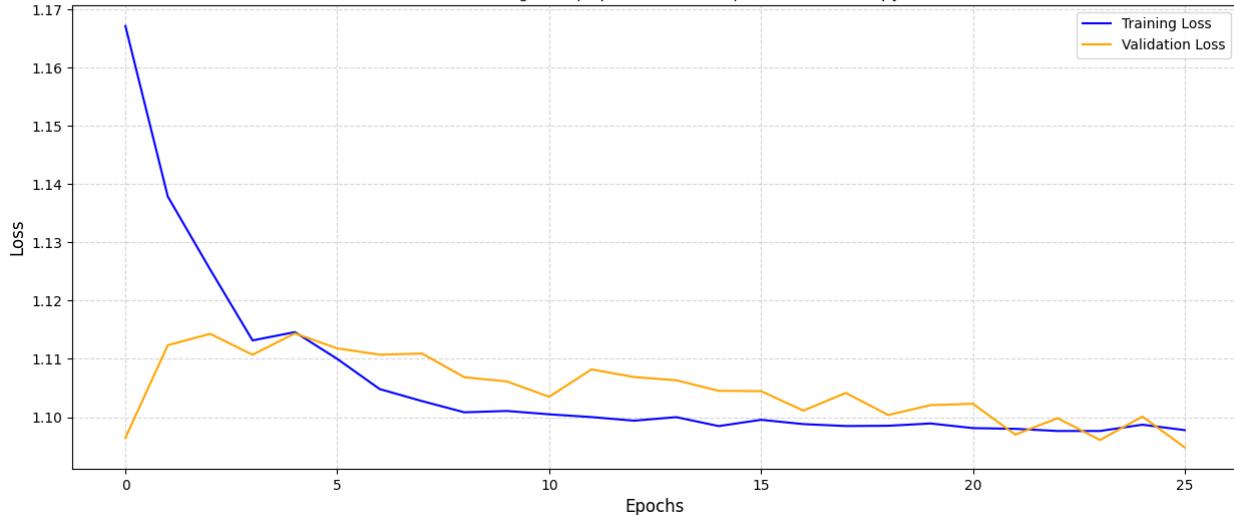


Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [5, 5, 5]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

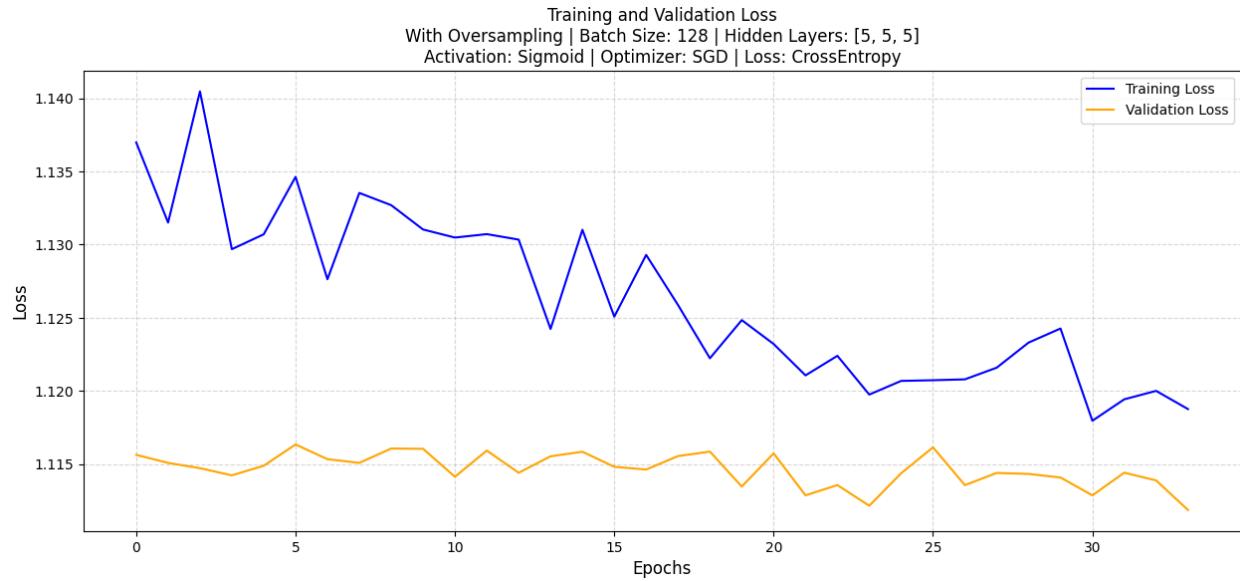


Early stopping triggered

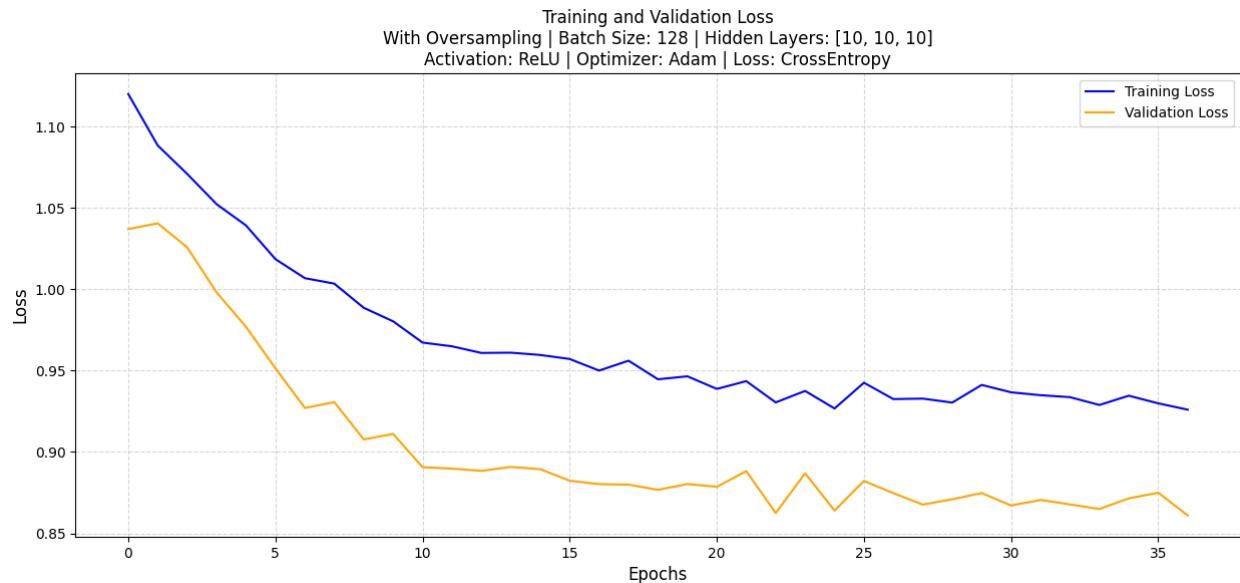
Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [5, 5, 5]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered

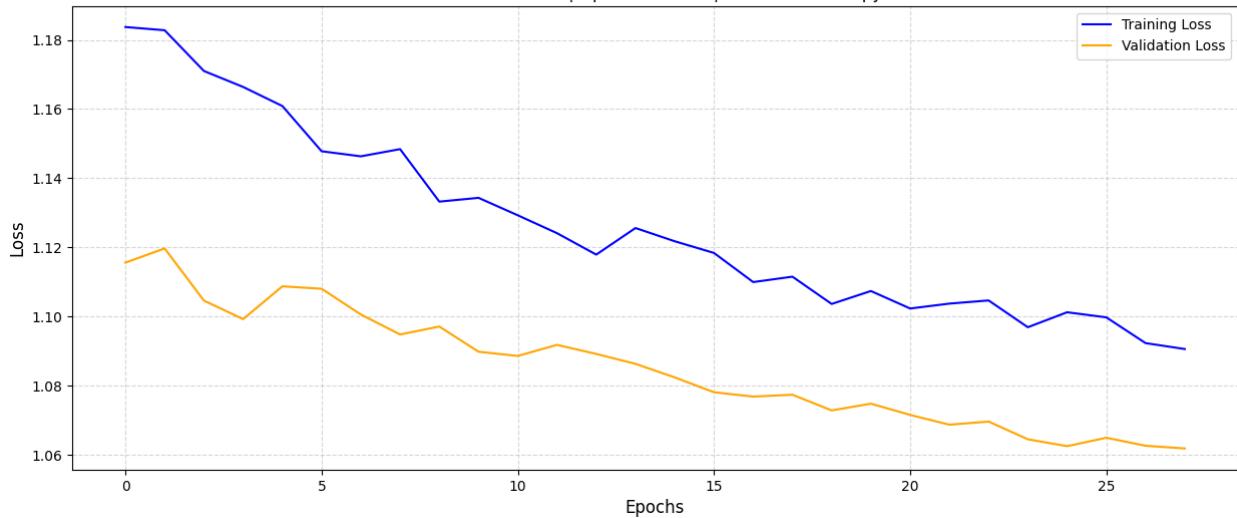


Early stopping triggered



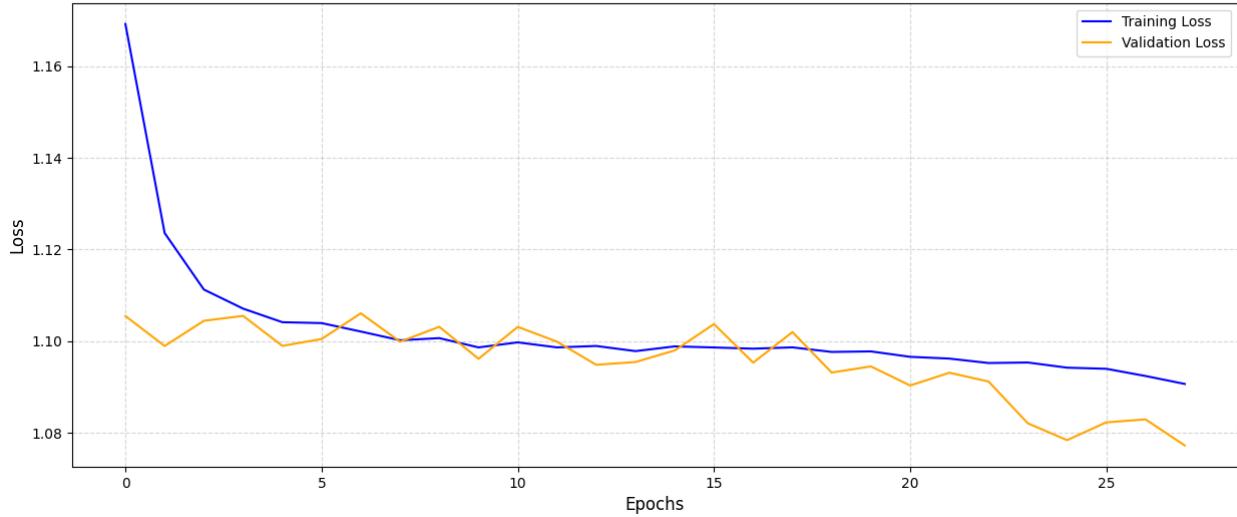
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10, 10]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

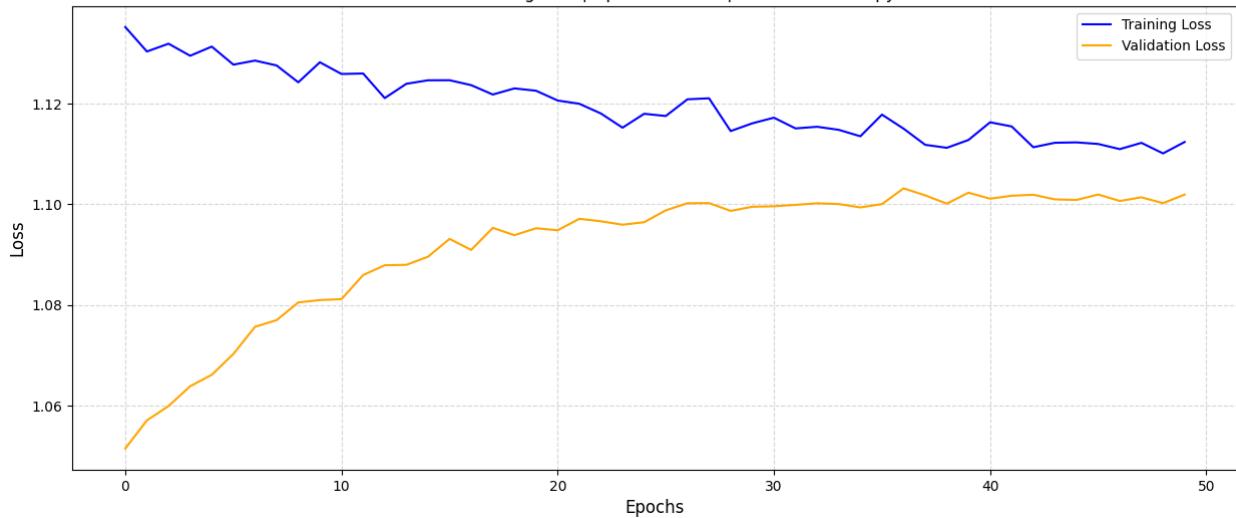


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10, 10]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy

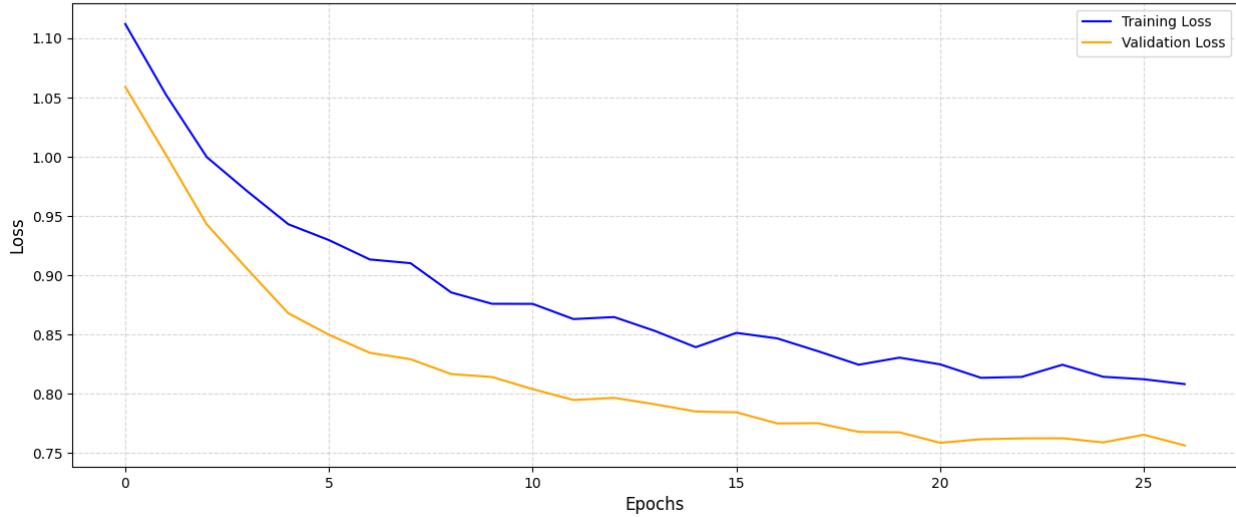


Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [10, 10, 10]
Activation: Sigmoid | Optimizer: SGD | Loss: CrossEntropy



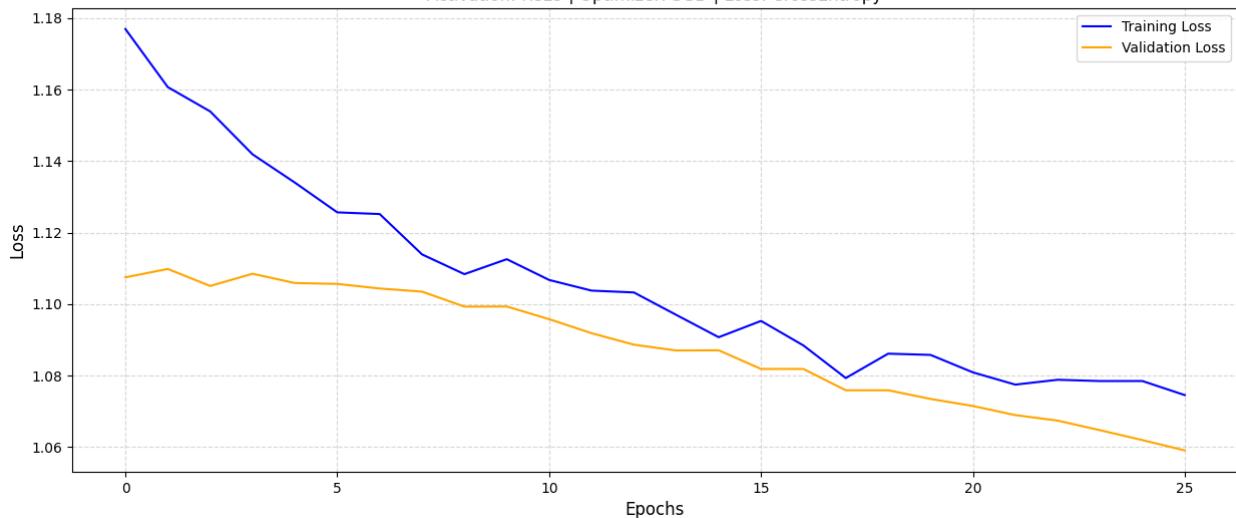
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20, 20]
Activation: ReLU | Optimizer: Adam | Loss: CrossEntropy



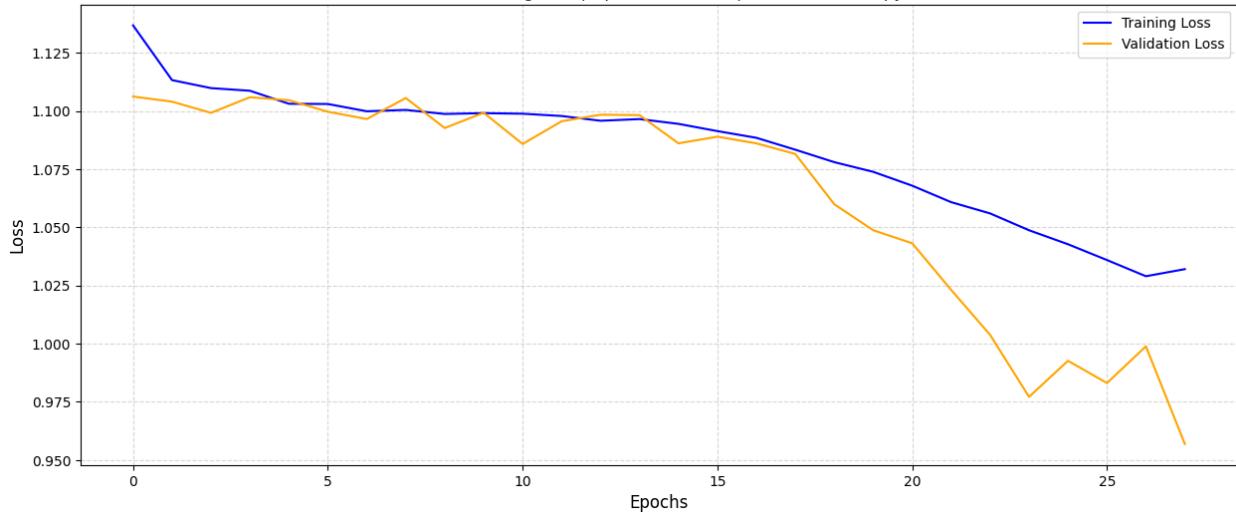
Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20, 20]
Activation: ReLU | Optimizer: SGD | Loss: CrossEntropy

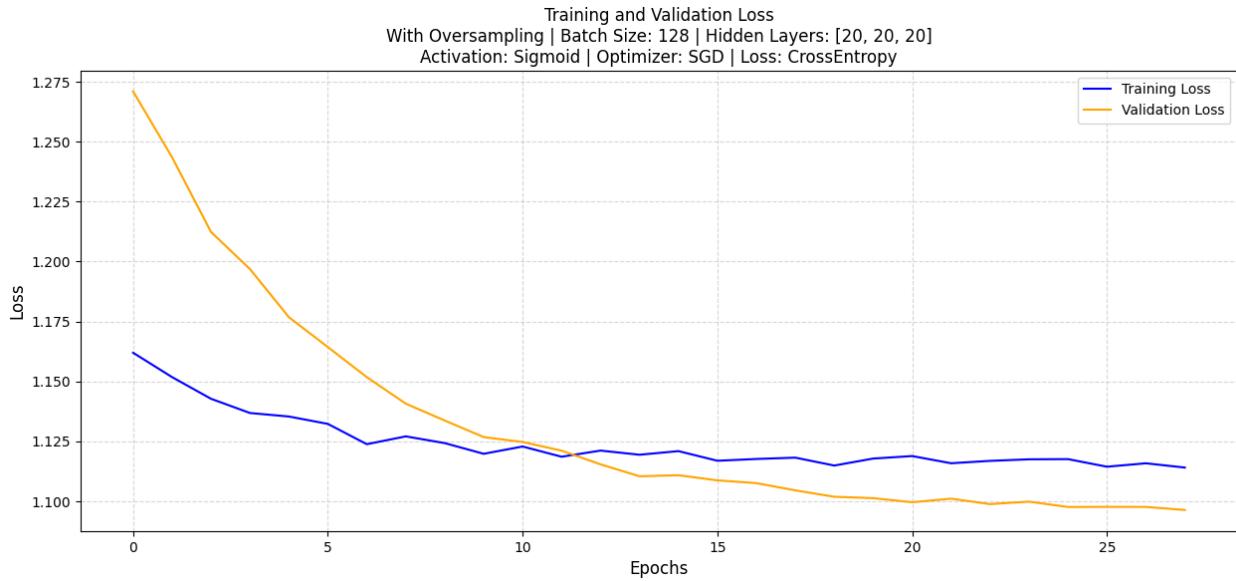


Early stopping triggered

Training and Validation Loss
With Oversampling | Batch Size: 128 | Hidden Layers: [20, 20, 20]
Activation: Sigmoid | Optimizer: Adam | Loss: CrossEntropy



Early stopping triggered



```
Global best model is saved at: best_model_With
Oversampling_32_[20]_scaled.pth with validation accuracy:
0.7400560224089636
```

```
df_results_scaled = pd.DataFrame(results_scaled)
top_10_results_scaled =
df_results_scaled.sort_values(by='val_accuracy',
ascending=False).head(10)
print("Top 10 Results scaled based on Validation Accuracy:")
display(top_10_results_scaled)
```

```
Top 10 Results scaled based on Validation Accuracy:
```

	oversample	batch_size	hidden_layers	activation_fn
optimizer \				
116 With Oversampling		32	[20]	ReLU
Adam				
20 No Oversampling		32	[20, 20]	ReLU
Adam				
8 No Oversampling		32	[20]	ReLU
Adam				
152 With Oversampling		64	[20]	ReLU
Adam				
188 With Oversampling		128	[20]	ReLU
Adam				
56 No Oversampling		64	[20, 20]	ReLU
Adam				
128 With Oversampling		32	[20, 20]	ReLU
Adam				
16 No Oversampling		32	[10, 10]	ReLU
Adam				
44 No Oversampling		64	[20]	ReLU

```

Adam
112 With Oversampling           32      [10]      ReLU
Adam

    loss_function  val_accuracy  test_accuracy  precision  recall
f1_score \
116  CrossEntropy      0.740056      0.714426  0.736503  0.714426
0.711331
20   CrossEntropy      0.739496      0.713446  0.690231  0.713446
0.696814
8    CrossEntropy      0.717647      0.713936  0.689370  0.713936
0.701437
152  CrossEntropy      0.710924      0.689920  0.713869  0.689920
0.688916
188  CrossEntropy      0.709804      0.682241  0.711577  0.682241
0.688286
56   CrossEntropy      0.696359      0.678484  0.665731  0.678484
0.653432
128  CrossEntropy      0.692437      0.607580  0.684826  0.607580
0.549218
16   CrossEntropy      0.688515      0.680281  0.658227  0.680281
0.662624
44   CrossEntropy      0.685714      0.689757  0.665273  0.689757
0.675538
112  CrossEntropy      0.665546      0.653815  0.674888  0.653815
0.655811

                                         confusion_matrix      time
116  [[210, 1, 0], [287, 1597, 966], [23, 471, 2566]]  30.592003
20   [[0, 211, 0], [0, 1772, 1078], [0, 465, 2595]]  28.032449
8    [[0, 211, 0], [0, 2028, 822], [0, 718, 2342]]  22.347897
152  [[211, 0, 0], [344, 1549, 957], [34, 563, 2463]]  16.487619
188  [[208, 3, 0], [409, 1664, 777], [54, 702, 2304]]  10.447798
56   [[0, 211, 0], [0, 1422, 1428], [0, 329, 2731]]  16.221898
128  [[208, 3, 0], [318, 643, 1889], [30, 162, 2868]]  26.359205
16   [[0, 211, 0], [0, 1625, 1225], [0, 521, 2539]]  29.908552
44   [[0, 203, 8], [0, 1800, 1050], [0, 638, 2422]]  15.704833
112  [[193, 18, 0], [369, 1529, 952], [39, 741, 2280]]  31.724901

if global_best_path:
    print(f"Loading global best model from: {global_best_path}")

    global_best_model_info = max(results_scaled, key=lambda x:
x['val_accuracy'])

        print("Global Best Model Information:")
        print(f"Validation Accuracy:
{global_best_model_info['val_accuracy']:.4f}")
        print(f"Test Accuracy:
{global_best_model_info['test_accuracy']:.4f}")

```

```

print(f"Precision: {global_best_model_info['precision']:.4f}")
print(f"Recall: {global_best_model_info['recall']:.4f}")
print(f"F1 Score: {global_best_model_info['f1_score']:.4f}")
print(f"Hidden Layers: {global_best_model_info['hidden_layers']}")
print(f"Activation Function:
{global_best_model_info['activation_fn']}")
print(f"Optimizer: {global_best_model_info['optimizer']}")
print(f"Loss Function: {global_best_model_info['loss_function']}")
print(f"Oversampling: {global_best_model_info['oversample']}")
print(f"Batch Size: {global_best_model_info['batch_size']}")

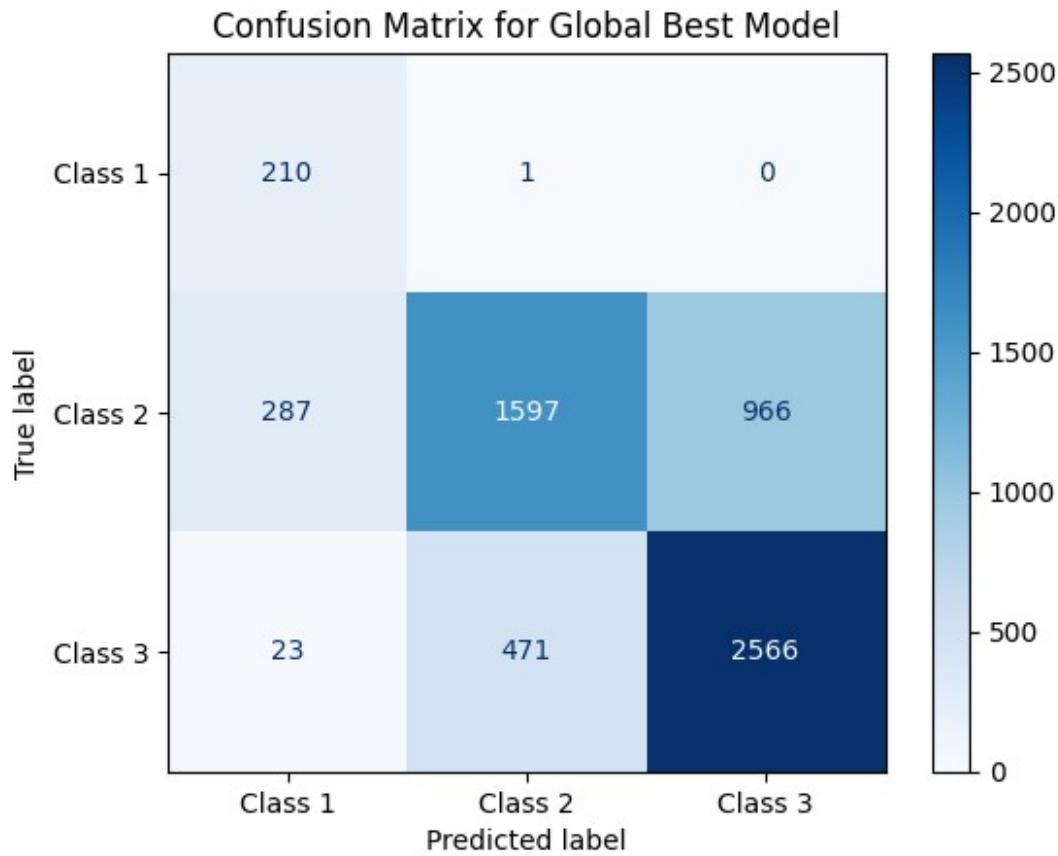
best_conf_matrix = global_best_model_info['confusion_matrix']
print("Confusion Matrix for Best Model:")
print(best_conf_matrix)

disp = ConfusionMatrixDisplay(confusion_matrix=best_conf_matrix,
display_labels=['Class 1', 'Class 2', 'Class 3'])
disp.plot(cmap=plt.cm.Blues)
plt.title("Confusion Matrix for Global Best Model")
plt.show()

hidden_layers = global_best_model_info['hidden_layers']
activation_fn =
activation_functions[global_best_model_info['activation_fn']]
global_best_model = MLP(input_size=10,
hidden_layers=hidden_layers, activation_fn=activation_fn)
global_best_model.load_state_dict(torch.load(global_best_path))
global_best_model.eval()
print("Global best model loaded successfully!")
else:
    print("No global best model found.")

Loading global best model from: best_model_With
Oversampling_32_[20]_scaled.pth
Global Best Model Information:
Validation Accuracy: 0.7401
Test Accuracy: 0.7144
Precision: 0.7365
Recall: 0.7144
F1 Score: 0.7113
Hidden Layers: [20]
Activation Function: ReLU
Optimizer: Adam
Loss Function: CrossEntropy
Oversampling: With Oversampling
Batch Size: 32
Confusion Matrix for Best Model:
[[ 210     1     0]
 [ 287 1597  966]
 [   23   471 2566]]

```



Global best model loaded successfully!

Learning rate

```

column_names = [f"col_{i}" for i in range(16)]
train_data = pd.read_csv('train_1_to_3iz.dat', sep='\t', header=None,
names=column_names)
test_data = pd.read_csv('test_1_to_3iz.dat', sep='\t', header=None,
names=column_names)

X = train_data.iloc[:, [1, 2, 3, 4, 5, 7, 8, 9, 10, 11]].values
y = train_data.iloc[:, 15].values
X_test = test_data.iloc[:, [1, 2, 3, 4, 5, 7, 8, 9, 10, 11]].values
y_test = test_data.iloc[:, 15].values

X_train, X_val, y_train, y_val = train_test_split(X, y, test_size=0.2,
random_state=42)

X_train_os, y_train_os = oversample_data(X_train, y_train)
scaler = StandardScaler()

X_train_scaled = scaler.fit_transform(X_train)
X_train_os_scaled = scaler.transform(X_train_os)

```

```

X_val_scaled = scaler.transform(X_val)
X_test_scaled = scaler.transform(X_test)

X_train = torch.tensor(X_train_scaled, dtype=torch.float32)
y_train = torch.tensor(y_train, dtype=torch.long)
X_train_os = torch.tensor(X_train_os_scaled, dtype=torch.float32)
y_train_os = torch.tensor(y_train_os, dtype=torch.long)
X_val = torch.tensor(X_val_scaled, dtype=torch.float32)
y_val = torch.tensor(y_val, dtype=torch.long)
X_test = torch.tensor(X_test_scaled, dtype=torch.float32)
y_test = torch.tensor(y_test, dtype=torch.long)

train_dataset_no_oversample = TensorDataset(X_train, y_train)
train_dataset_with_oversample = TensorDataset(X_train_os, y_train_os)
val_dataset = TensorDataset(X_val, y_val)
test_dataset = TensorDataset(X_test, y_test)

num_epochs = 50

results_scaled = []
global_best_model = None
global_best_path = None
global_best_val_accuracy = 0

criterion = nn.CrossEntropyLoss()

learning_rates = [0.0001, 0.001, 0.01, 0.1]

batch_size = 32
hidden_layers = [20]
activation_fn = nn.ReLU
optimizer_fn = optim.Adam
oversample_flag = 'With Oversampling'
train_dataset = train_dataset_with_oversample

train_loader = DataLoader(train_dataset, batch_size=batch_size,
shuffle=True)
val_loader = DataLoader(val_dataset, batch_size=batch_size,
shuffle=False)
test_loader = DataLoader(test_dataset, batch_size=batch_size,
shuffle=False)

for lr in learning_rates:
    print(f"Testing Learning Rate: {lr}")

    model = MLP(input_size=10, hidden_layers=hidden_layers,
activation_fn=activation_fn)
    optimizer = optimizer_fn(model.parameters(), lr=lr)

    start_time = time.time()
    best_val_accuracy = 0

```

```

best_val_loss = float('inf')
history = {'loss': [], 'val_loss': []}

for epoch in range(num_epochs):
    model.train()
    epoch_loss = 0
    for X_batch, y_batch in train_loader:
        optimizer.zero_grad()
        outputs = model(X_batch)
        y_batch = y_batch - 1
        loss = criterion(outputs, y_batch)
        loss.backward()
        optimizer.step()
        epoch_loss += loss.item()
    history['loss'].append(epoch_loss / len(train_loader))

    model.eval()
    val_loss = 0
    val_preds = []
    val_targets = []
    with torch.no_grad():
        for X_batch, y_batch in val_loader:
            outputs = model(X_batch)
            y_batch = y_batch - 1
            loss = criterion(outputs, y_batch)
            val_loss += loss.item()
            preds = torch.argmax(outputs, dim=1)
            val_preds.extend(preds.tolist())
            val_targets.extend(y_batch.tolist())
    history['val_loss'].append(val_loss / len(val_loader))

    val_accuracy = accuracy_score(val_targets, val_preds)
    if val_accuracy > best_val_accuracy:
        best_val_accuracy = val_accuracy

    if val_loss < best_val_loss:
        best_val_loss = val_loss
        model_path = f'best_model_lr{lr}_scaled_lr.pth'
        torch.save(model.state_dict(), model_path)

        if val_accuracy > global_best_val_accuracy:
            global_best_val_accuracy = val_accuracy
            global_best_path = model_path

    if len(history['val_loss']) > 25 and all(l >
history['val_loss'][-1] for l in history['val_loss'][-25:]):
        print("Early stopping triggered")
        break

end_time = time.time()

```

```

model.eval()
test_preds = []
test_targets = []
with torch.no_grad():
    for X_batch, y_batch in test_loader:
        outputs = model(X_batch)
        y_batch = y_batch - 1
        preds = torch.argmax(outputs, dim=1)
        test_preds.extend(preds.tolist())
        test_targets.extend(y_batch.tolist())

    test_accuracy = accuracy_score(test_targets, test_preds)
    precision, recall, f1, _ =
precision_recall_fscore_support(test_targets, test_preds,
average='weighted')
    conf_matrix = confusion_matrix(test_targets, test_preds)

results_scaled.append({
    'learning_rate': lr,
    'oversample': oversample_flag,
    'batch_size': batch_size,
    'hidden_layers': hidden_layers,
    'activation_fn': activation_fn.__name__,
    'optimizer': optimizer_fn.__name__,
    'val_accuracy': best_val_accuracy,
    'test_accuracy': test_accuracy,
    'precision': precision,
    'recall': recall,
    'f1_score': f1,
    'confusion_matrix': conf_matrix,
    'time': end_time - start_time
})

print(f"Global best model is saved at: {global_best_path} with
validation accuracy: {global_best_val_accuracy}")

Testing Learning Rate: 0.0001
Early stopping triggered
Testing Learning Rate: 0.001
Early stopping triggered
Testing Learning Rate: 0.01
Early stopping triggered
Testing Learning Rate: 0.1
Global best model is saved at: best_model_lr0.001_scaled_lr.pth with
validation accuracy: 0.7372549019607844

c:\Users\User\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\metrics\_classification.py:1509:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0

```

```
in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
    _warn_prf(average, modifier, f"{metric.capitalize()} is",
len(result))
```