tldr; achieved a 75% accuracy on CIFAR-10 with 22 epochs and 63% accuracy with 25 epochs on the CIFAR-100 data-set. Were it not for the early stop, the accuracy would have continued to improve over a longer training cycle which means it would have eventually met my target accuracy of 80% accuracy.

While researching the state of the art of the CIFAR-10 dataset, I noticed many transformers that had an accuracy between 96-99%. Given that I would be implementing a model using convolution layers I decided that 84% percent would be initially fair. However, taking into consideration that I would be training my model locally without the advantage of a GPU cluster, I adjusted my target accuracy to 80-82%.

Initially, I used a simple architecture to assess the model's ability to overfit a subset of the CIFAR-10 dataset. While the model was successful in overfitting this subset, the same version of the model did not perform well on the full dataset. I used the model's lack of a great performance to check whether the model's initial accuracy and loss were correct.

Building on this, I decided that I would try to intentionally overfit the model on the full data set so that I could experiment with the learning rate and see how it affected the validation loss. I began experimenting with a number of data augmentation techniques to see how they affect the current state of the model– these adjustments appeared to improve the model's accuracy. After tweaking these parameters I found a good balance and I decided I would work on increasing the validation loss. I observed a pattern where the validation loss would plateau, prompting me to experiment with different learning rates and weight decay. While experimenting, I realized that a constant learning rate made the model's proficiency in reducing loss stagnate. I also realized that weight decay would negatively affect the stability of the model: specifically it would make the validation loss oscillate. This ultimately led me to introduce Dropout to dynamically adjust the learning rate across epochs.

I implemented an early stopping mechanism to stop the model's training whenever the model would show signs of not improving. This became particularly important as I fine-tuned the learning rate and gauged the impact of Dropout on the models performance.

To further refine the model's performance, I added Batch Normalization and an additional activation layer. This arrangement allowed the activation function to follow the Batch Normalization layer instead of being placed after the convolutional layer. I considered using GroupNorm, but I ended up not using it and instead used a preprocessing normalization method. Moreover, I added an additional data augmentation strategy, named "cutoff", to boost the model's stability and accuracy on the CIFAR-10 dataset.

Regarding the performance on the CIFAR-10 dataset, the model consistently reduced its loss, and at the 20-epoch mark it had reached 75% accuracy. Subsequently, the pace of accuracy gain and loss reduction began to become slower which prompted the early stop. Given the extended duration of these training cycles, consistently spanning multiple hours, and the model's performance, it would be fair to assume that under better conditions (better hardware and a longer training duration– around 100 epochs) the model would have achieved mid-80's accuracy. Though the CIFAR-100 progressed at a slower rate, the same can be said about the CIFAR-100 dataset. Given an additional 5-8 more hours of training (atop of the initial 3 hours) it would have likely met the targeted value at around 300 epochs.

CIFAR-10:

```
Validation Loss: 1.0072, Validation Accuracy: 0.6757
Training: 100%|                                                    | 703/703 [00:49<00:00, 14.29it/s]
Epoch 8 Summary:
Parameter Count: 4293194
Training Loss: 0.8745, Training Accuracy: 0.7703
Validation Loss: 0.8448, Validation Accuracy: 0.7105
Training: 100%|                                                    | 703/703 [00:50<00:00, 14.04it/s]
Epoch 9 Summary:
Parameter Count: 4293194
Training Loss: 0.8365, Training Accuracy: 0.7906
Validation Loss: 0.8000, Validation Accuracy: 0.7254
Training: 100%|                                                    | 703/703 [00:49<00:00, 14.22it/s]
Epoch 10 Summary:
Parameter Count: 4293194
Training Loss: 0.8191, Training Accuracy: 0.7618
Validation Loss: 0.9272, Validation Accuracy: 0.6995
Training: 100%|                                                    | 703/703 [00:46<00:00, 15.06it/s]
Epoch 11 Summary:
Parameter Count: 4293194
Training Loss: 0.8019, Training Accuracy: 0.7455
Validation Loss: 1.0252, Validation Accuracy: 0.6833
Training: 100%|                                                    | 703/703 [00:49<00:00, 14.18it/s]
Epoch 12 Summary:
Parameter Count: 4293194
Training Loss: 0.7791, Training Accuracy: 0.8054
Validation Loss: 0.8281, Validation Accuracy: 0.7268
Training: 100%|                                                    | 703/703 [00:49<00:00, 14.22it/s]
Epoch 13 Summary:
Parameter Count: 4293194
Training Loss: 0.7527, Training Accuracy: 0.8305
Validation Loss: 0.7718, Validation Accuracy: 0.7502
Training: 100%|                                                    | 703/703 [00:48<00:00, 14.40it/s]
Epoch 14 Summary:
Parameter Count: 4293194
Training Loss: 0.7338, Training Accuracy: 0.7849
Validation Loss: 0.9429, Validation Accuracy: 0.7159
Training: 100%|                                                    | 703/703 [00:46<00:00, 14.99it/s]
Epoch 15 Summary:
Parameter Count: 4293194
Training Loss: 0.7301, Training Accuracy: 0.7738
Validation Loss: 1.0304, Validation Accuracy: 0.7073
Training: 100%|                                                    | 703/703 [00:49<00:00, 14.15it/s]
Epoch 16 Summary:
Parameter Count: 4293194
Training Loss: 0.6991, Training Accuracy: 0.7877
Validation Loss: 1.0440, Validation Accuracy: 0.7071
Training: 100%|                                                    | 703/703 [00:58<00:00, 12.02it/s]
Epoch 17 Summary:
Parameter Count: 4293194
Training Loss: 0.6921, Training Accuracy: 0.7938
Validation Loss: 0.9984, Validation Accuracy: 0.7061
Training: 100%|                                                    | 703/703 [01:00<00:00, 11.69it/s]
Epoch 18 Summary:
Parameter Count: 4293194
Training Loss: 0.6730, Training Accuracy: 0.8094
Validation Loss: 0.9334, Validation Accuracy: 0.7238
Training: 100%|                                                    | 703/703 [00:47<00:00, 14.96it/s]
Epoch 19 Summary:
Parameter Count: 4293194
Training Loss: 0.6740, Training Accuracy: 0.8636
Validation Loss: 0.7931, Validation Accuracy: 0.7572
Training: 100%|                                                    | 703/703 [00:49<00:00, 14.22it/s]
Epoch 20 Summary:
Parameter Count: 4293194
Training Loss: 0.6514, Training Accuracy: 0.8538
Validation Loss: 0.8579, Validation Accuracy: 0.7450
Training: 100%|                                                    | 703/703 [00:48<00:00, 14.51it/s]
Epoch 21 Summary:
Parameter Count: 4293194
Training Loss: 0.6474, Training Accuracy: 0.8415
Validation Loss: 0.8834, Validation Accuracy: 0.7358
Training: 100%|                                                    | 703/703 [00:50<00:00, 14.05it/s]
Epoch 22 Summary:
Parameter Count: 4293194
Training Loss: 0.6417, Training Accuracy: 0.8687
Validation Loss: 0.8516, Validation Accuracy: 0.7508
Training: 100%|                                                    | 703/703 [00:48<00:00, 14.35it/s]
Early stopping due to no improvement
Model saved successfully at /Users/Work/Desktop/fall_23/DL/ws/hw4/best_model.ckpt.
Final Evaluating Model
Final Test Accuracy: 0.7395
(venv) ~/Desktop/fall_23/DL/ws/hw4 @ diegomac $ []
```

CIFAR-100:

```
Validation Loss: 2.9339, Validation Accuracy: 0.5783
Training: 100%|                                        | 703/703 [00:50<00:00, 14.02it/s]
Model saved successfully at /Users/Work/Desktop/fall_23/DL/ws/hw4/best_model.ckpt.
Epoch 14 Summary:
Parameter Count: 4339364
Training Loss: 3.2425, Training Accuracy: 0.3540
Validation Loss: 2.8243, Validation Accuracy: 0.6040
Training: 100%|                                        | 703/703 [00:50<00:00, 13.86it/s]
Epoch 15 Summary:
Parameter Count: 4339364
Training Loss: 3.1887, Training Accuracy: 0.3523
Validation Loss: 2.8298, Validation Accuracy: 0.6082
Training: 100%|                                        | 703/703 [00:48<00:00, 14.60it/s]
Epoch 16 Summary:
Parameter Count: 4339364
Training Loss: 3.1596, Training Accuracy: 0.3504
Validation Loss: 2.8638, Validation Accuracy: 0.5861
Training: 100%|                                        | 703/703 [00:48<00:00, 14.59it/s]
Epoch 17 Summary:
Parameter Count: 4339364
Training Loss: 3.1174, Training Accuracy: 0.3434
Validation Loss: 2.8967, Validation Accuracy: 0.5843
Training: 100%|                                        | 703/703 [00:49<00:00, 14.23it/s]
Epoch 18 Summary:
Parameter Count: 4339364
Training Loss: 3.0877, Training Accuracy: 0.3580
Validation Loss: 2.8508, Validation Accuracy: 0.5921
Training: 100%|                                        | 703/703 [00:50<00:00, 13.94it/s]
Epoch 19 Summary:
Parameter Count: 4339364
Training Loss: 3.0633, Training Accuracy: 0.3638
Validation Loss: 2.8338, Validation Accuracy: 0.5948
Training: 100%|                                        | 703/703 [00:49<00:00, 14.30it/s]
Epoch 20 Summary:
Parameter Count: 4339364
Training Loss: 3.0372, Training Accuracy: 0.3738
Validation Loss: 2.8283, Validation Accuracy: 0.5933
Training: 100%|                                        | 703/703 [00:49<00:00, 14.27it/s]
Epoch 21 Summary:
Parameter Count: 4339364
Training Loss: 3.0108, Training Accuracy: 0.3976
Validation Loss: 2.8055, Validation Accuracy: 0.6006
Training: 100%|                                        | 703/703 [00:48<00:00, 14.54it/s]
Model saved successfully at /Users/Work/Desktop/fall_23/DL/ws/hw4/best_model.ckpt.
Epoch 22 Summary:
Parameter Count: 4339364
Training Loss: 2.9788, Training Accuracy: 0.3997
Validation Loss: 2.7793, Validation Accuracy: 0.6104
Training: 100%|                                        | 703/703 [00:49<00:00, 14.28it/s]
Epoch 23 Summary:
Parameter Count: 4339364
Training Loss: 2.9553, Training Accuracy: 0.3801
Validation Loss: 2.8404, Validation Accuracy: 0.5962
Training: 100%|                                        | 703/703 [00:51<00:00, 13.63it/s]
Epoch 24 Summary:
Parameter Count: 4339364
Training Loss: 2.9410, Training Accuracy: 0.3643
Validation Loss: 2.9267, Validation Accuracy: 0.5707
Training: 100%|                                        | 703/703 [00:49<00:00, 14.29it/s]
Model saved successfully at /Users/Work/Desktop/fall_23/DL/ws/hw4/best_model.ckpt.
Epoch 25 Summary:
Parameter Count: 4339364
Training Loss: 2.9295, Training Accuracy: 0.4315
Validation Loss: 2.7131, Validation Accuracy: 0.6304
Training:  58%|                        | 410/703 [00:32<00:19, 15.12it/s]
```