

Cifar 10 Dataset classification Using CNN Based Architecture

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Initial Set Up

Initial Set Up

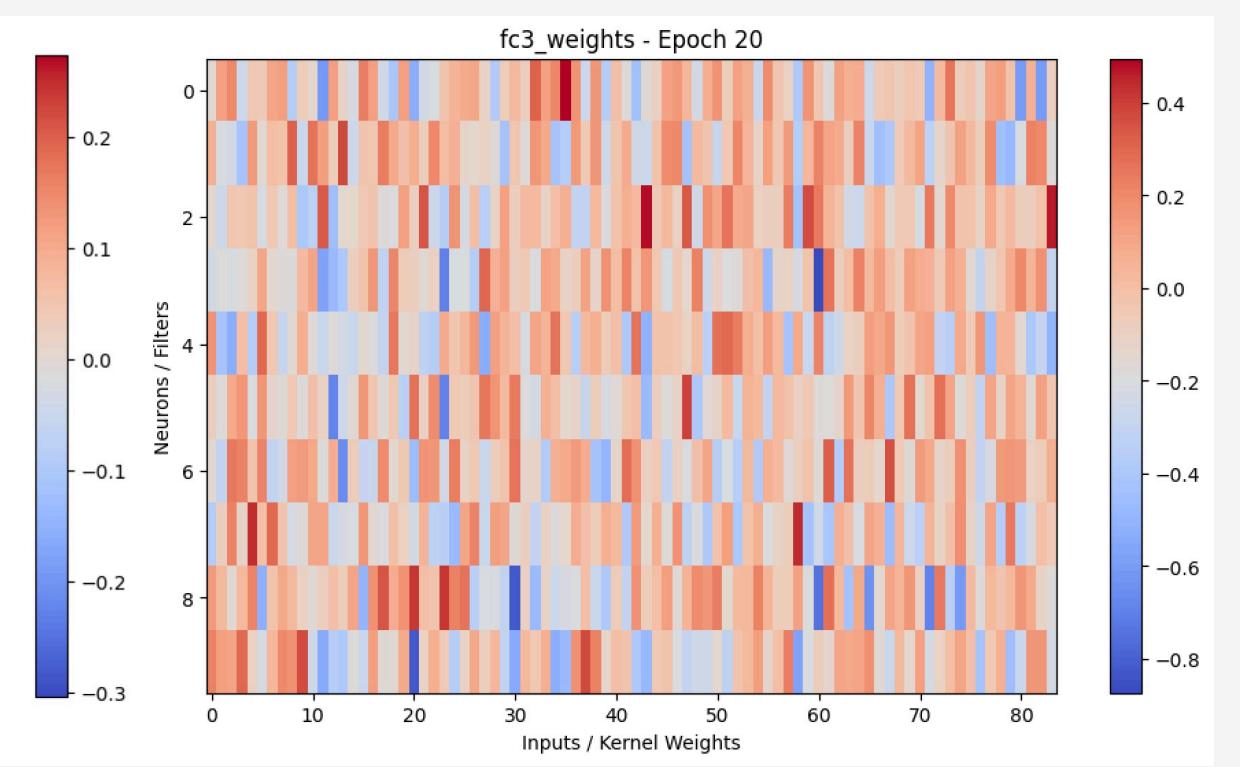
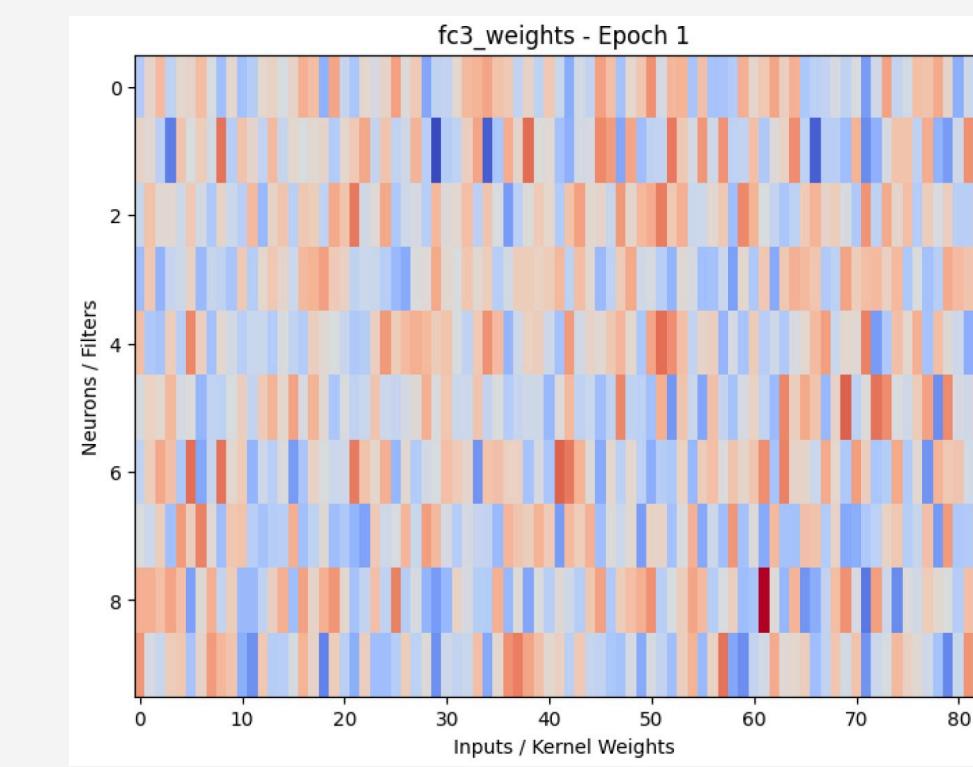
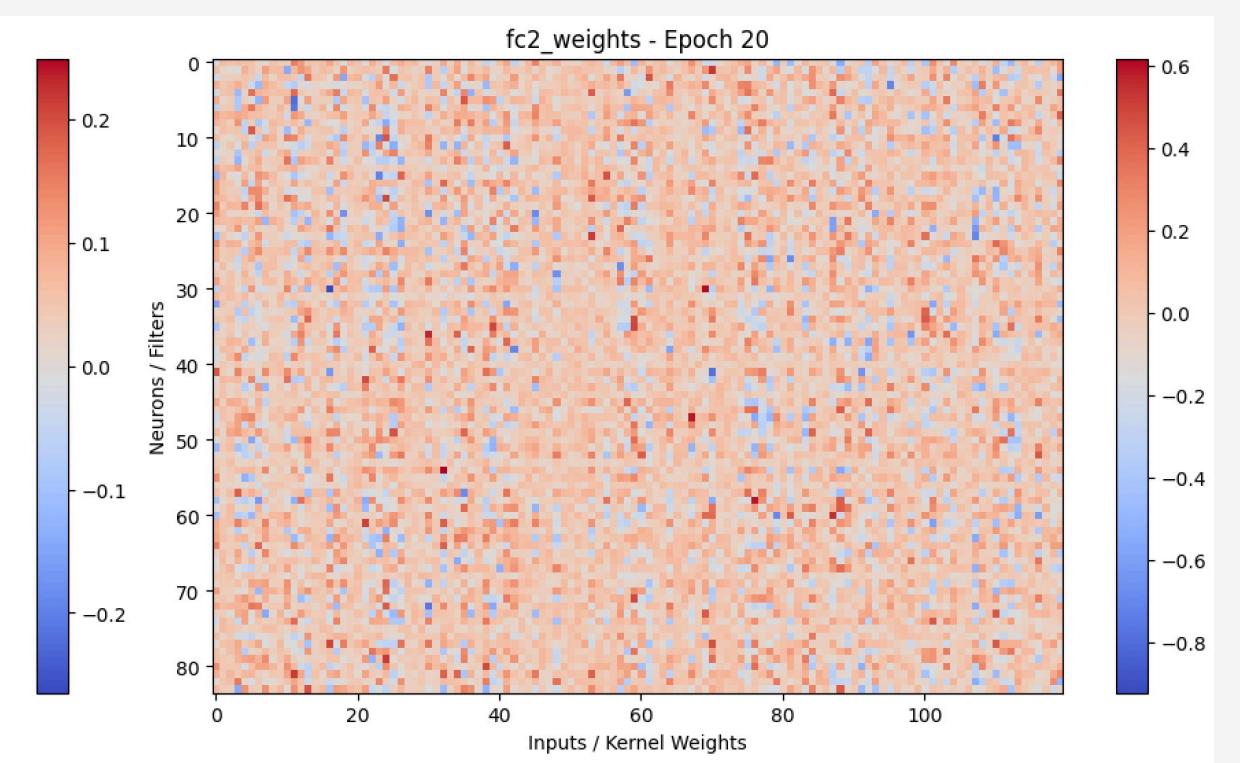
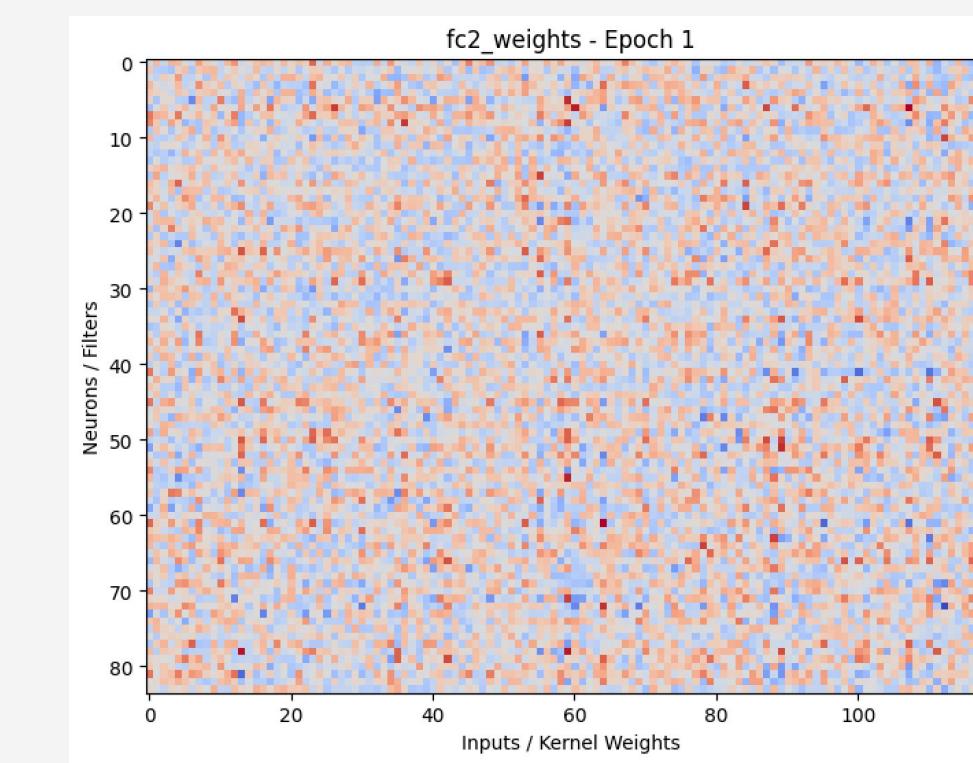
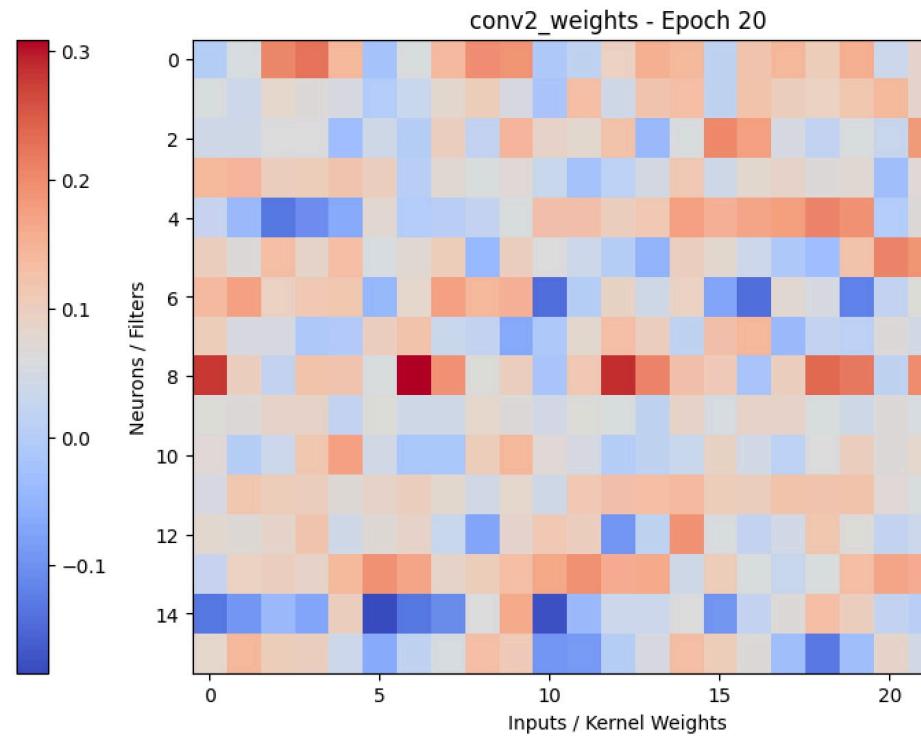
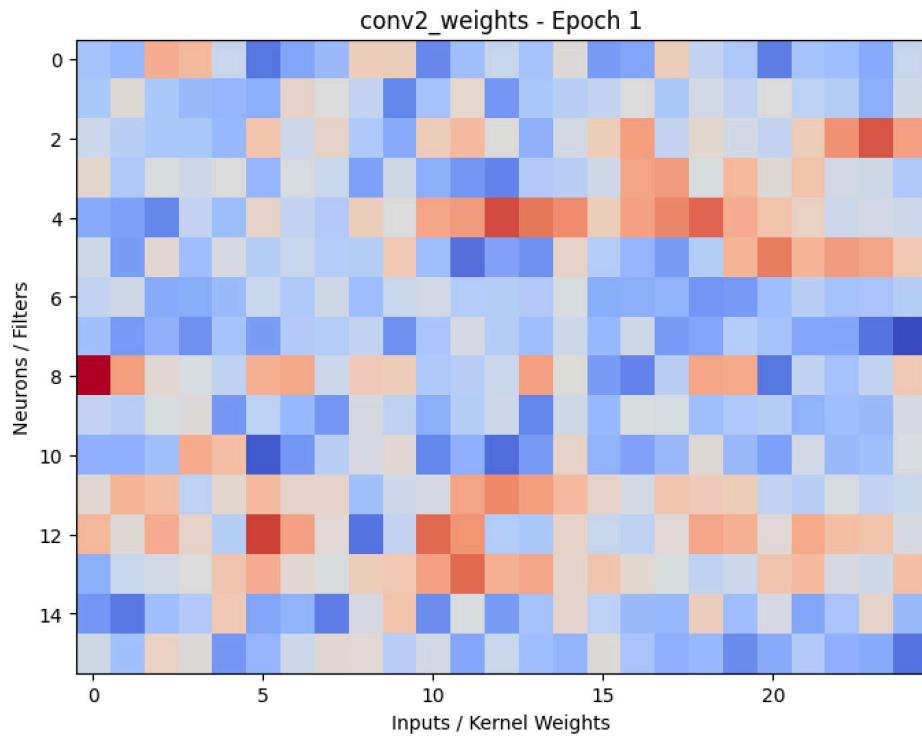
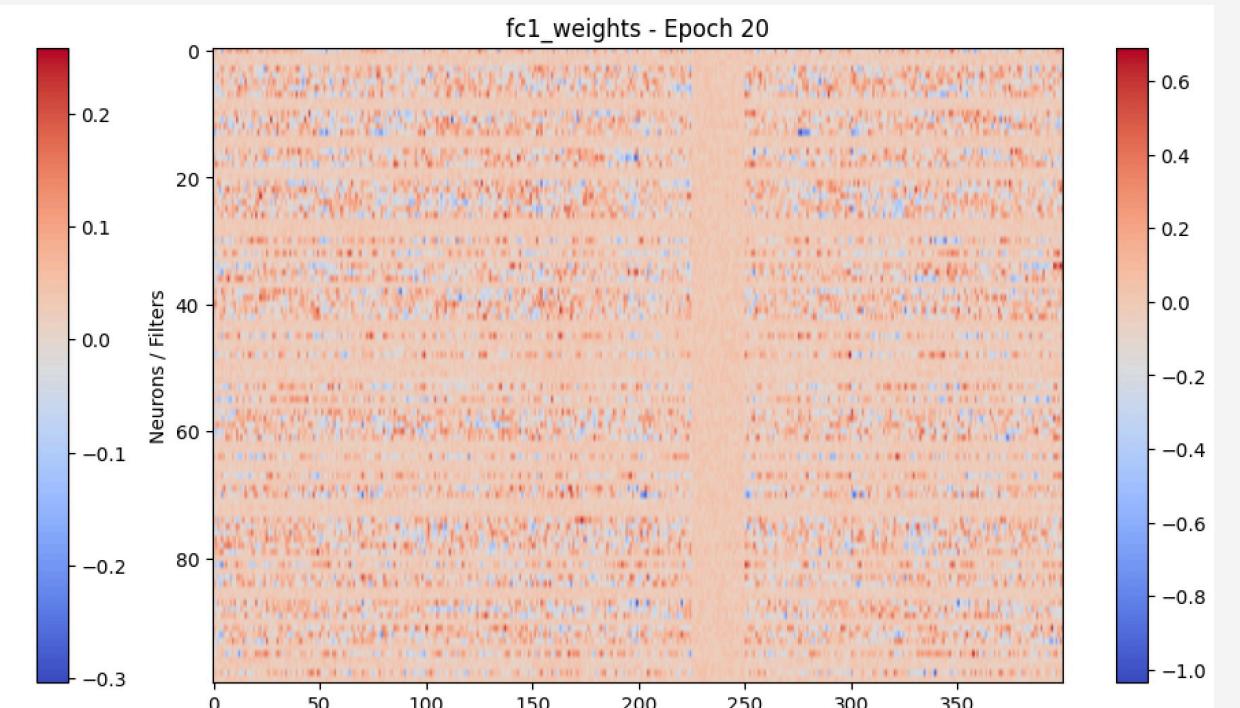
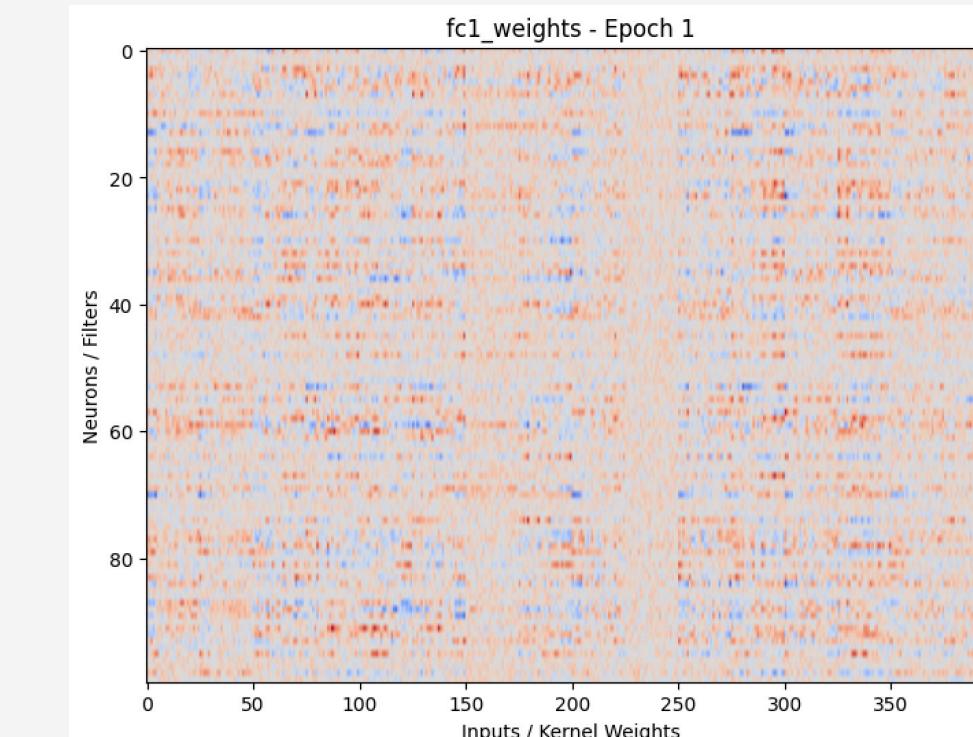
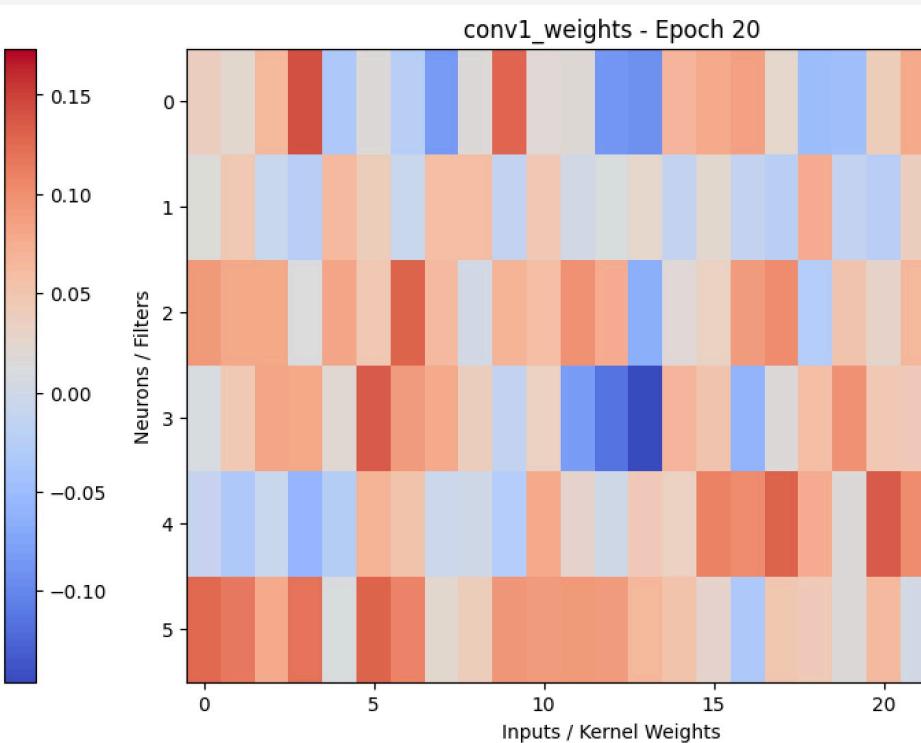
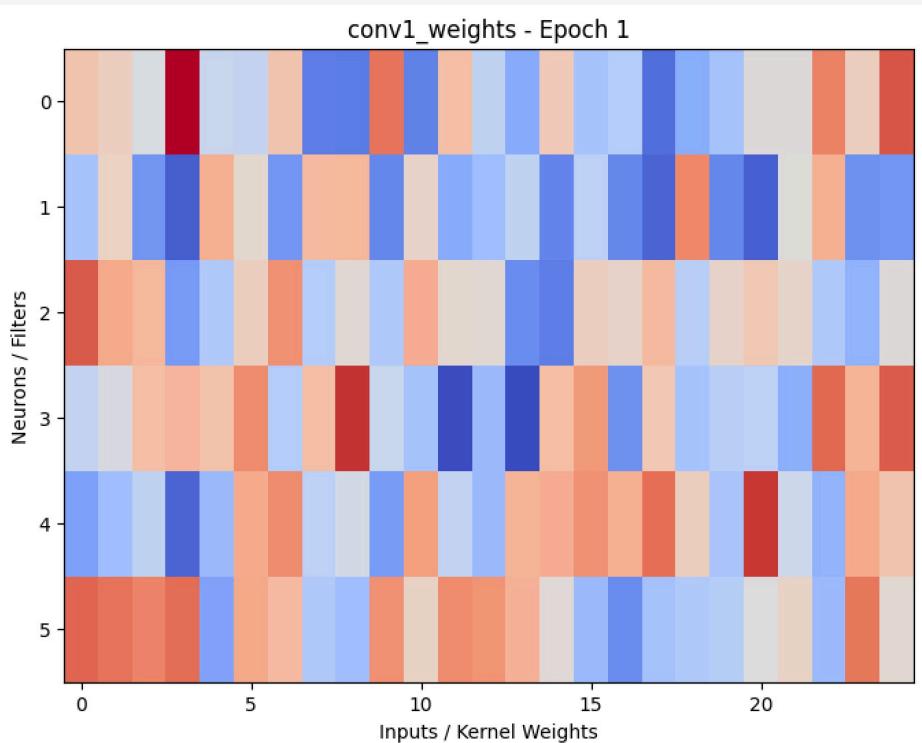
Layer Type	Name	Input Shape	Output Shape	Kernel/Units	Activation	Additional Info
Conv2D	conv1	(3, 32, 32)	(6, 28, 28)	(5×5)	ReLU	6 filters
MaxPool2D	pool1	(6, 28, 28)	(6, 14, 14)	(2×2)	-	Stride 2
Conv2D	conv2	(6, 14, 14)	(16, 10, 10)	(5×5)	ReLU	16 filters
MaxPool2D	pool2	(16, 10, 10)	(16, 5, 5)	(2×2)	-	Stride 2
Flatten	-	(16, 5, 5)	(400)	-	-	-
Dense (FC)	fc1	(400)	(120)	120	ReLU	-
Dense (FC)	fc2	(120)	(84)	84	ReLU	-
Dense (FC)	fc3	(84)	(10)	10	Softmax (implied)	Output layer

Initial Set Up - Results

Test Accuracy: 0.6301									
Confusion Matrix:									
[[737 19 37 15 33 9 12 10 80 48]									
[33 745 9 9 15 5 17 1 32 134]									
[75 14 430 88 124 78 99 56 18 18]									
[37 20 58 419 108 169 88 38 19 44]									
[35 9 55 63 643 34 73 66 11 11]									
[23 7 56 195 85 479 50 71 13 21]									
[10 17 38 79 60 21 746 8 3 18]									
[18 9 27 71 89 85 10 657 10 24]									
[91 72 13 22 13 4 5 4 731 45]									
[55 112 7 24 15 5 16 21 31 714]]									
	precision	recall	f1-score	support					
0	0.66	0.74	0.70	1000					
1	0.73	0.74	0.74	1000					
2	0.59	0.43	0.50	1000					
3	0.43	0.42	0.42	1000					
4	0.54	0.64	0.59	1000					
5	0.54	0.48	0.51	1000					
6	0.67	0.75	0.71	1000					
7	0.70	0.66	0.68	1000					
8	0.77	0.73	0.75	1000					
9	0.66	0.71	0.69	1000					
accuracy			0.63	10000					
macro avg	0.63	0.63	0.63	10000					
weighted avg	0.63	0.63	0.63	10000					

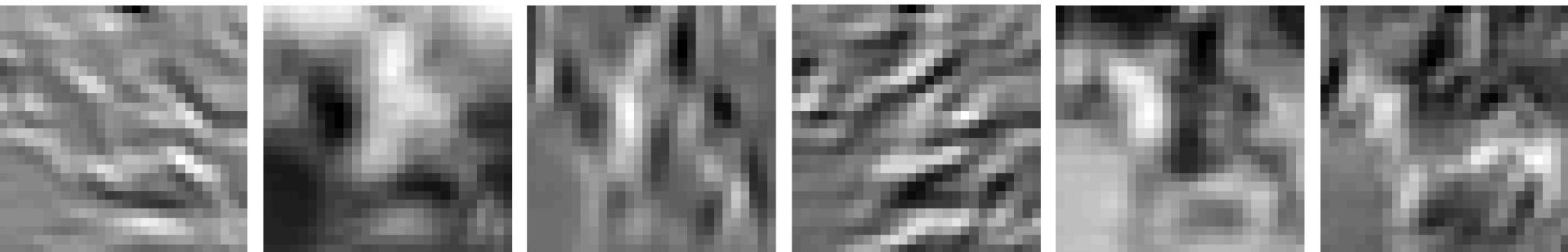
Epoch [1/20], Loss: 1.699694
Epoch [2/20], Loss: 1.428943
Epoch [3/20], Loss: 1.313796
Epoch [4/20], Loss: 1.228308
Epoch [5/20], Loss: 1.157734
Epoch [6/20], Loss: 1.110951
Epoch [7/20], Loss: 1.068465
Epoch [8/20], Loss: 1.031655
Epoch [9/20], Loss: 0.992683
Epoch [10/20], Loss: 0.963897
Epoch [11/20], Loss: 0.941074
Epoch [12/20], Loss: 0.912179
Epoch [13/20], Loss: 0.888991
Epoch [14/20], Loss: 0.871666
Epoch [15/20], Loss: 0.854179
Epoch [16/20], Loss: 0.829949
Epoch [17/20], Loss: 0.811289
Epoch [18/20], Loss: 0.798257
Epoch [19/20], Loss: 0.783154
Epoch [20/20], Loss: 0.762043

Initial Plots - Weights

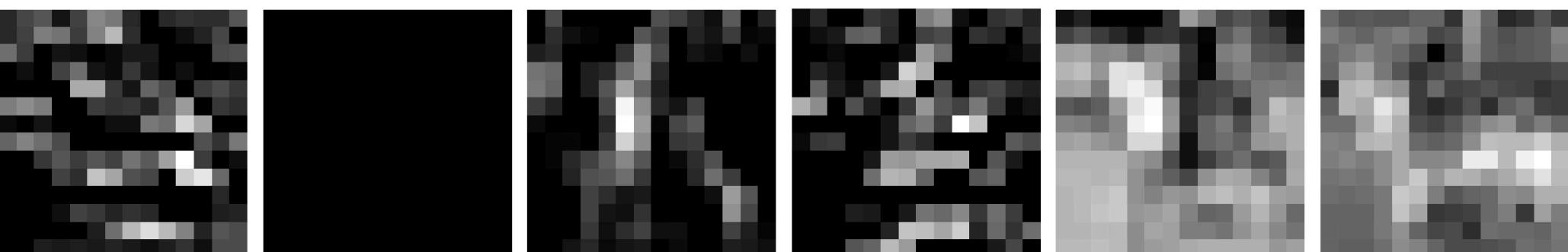


Visualizing Feature Maps

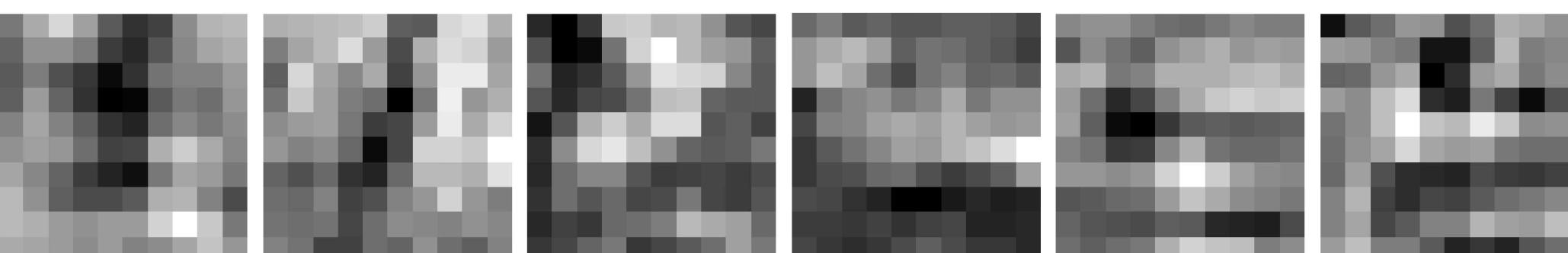
Feature Maps after Conv1



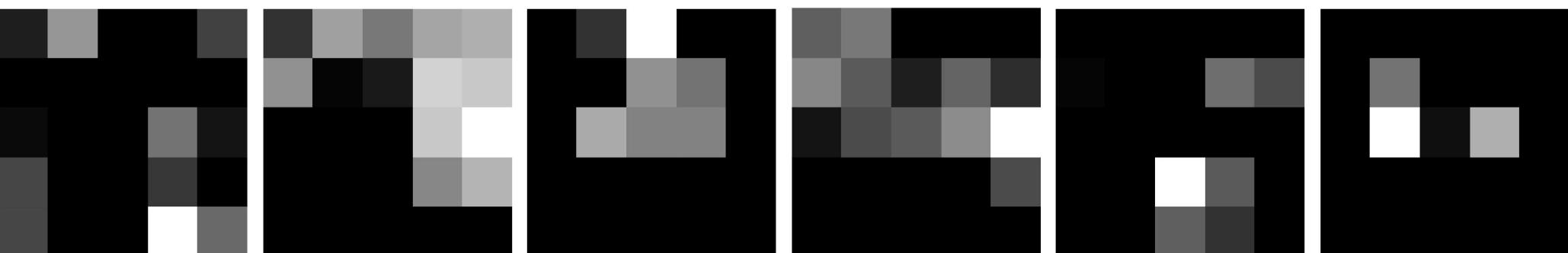
Feature Maps after Pool1



Feature Maps after Conv2



Feature Maps after Pool2



Adding New Layers, Modifying Filters

Set Up - 1

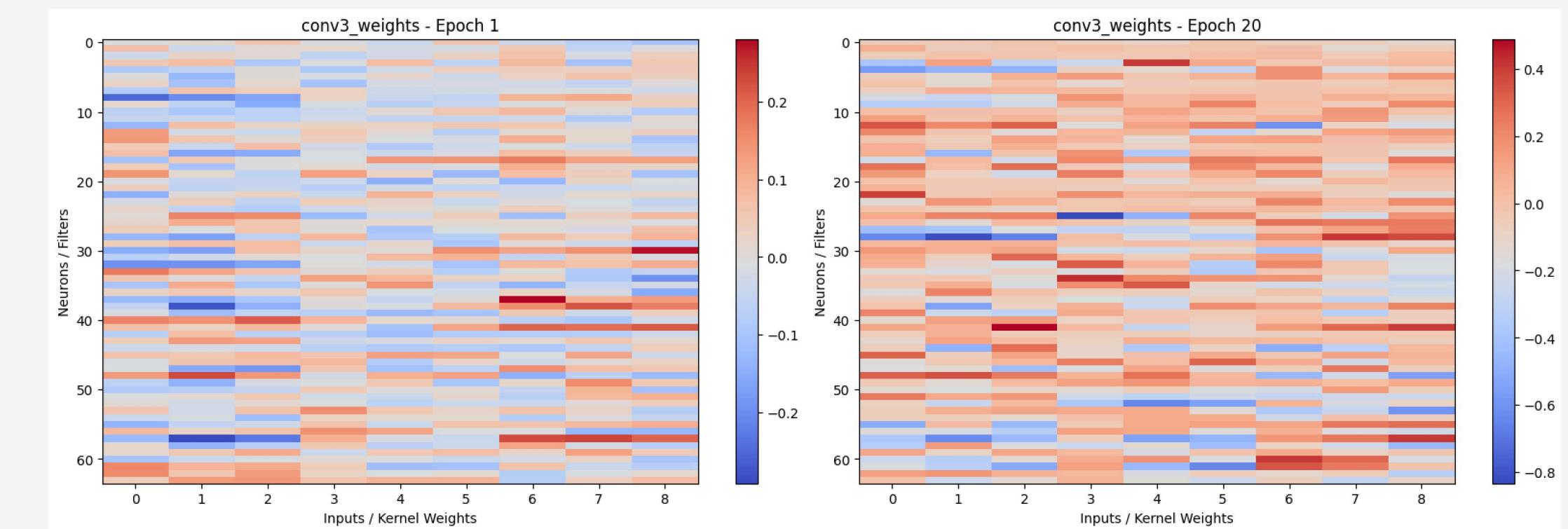
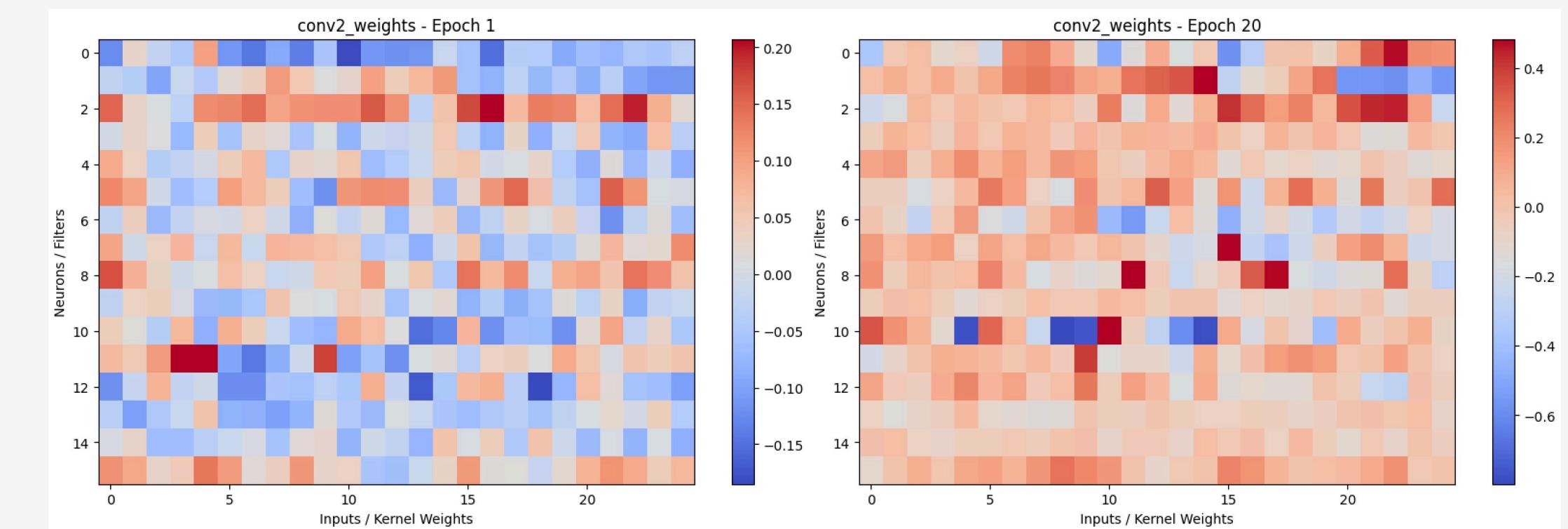
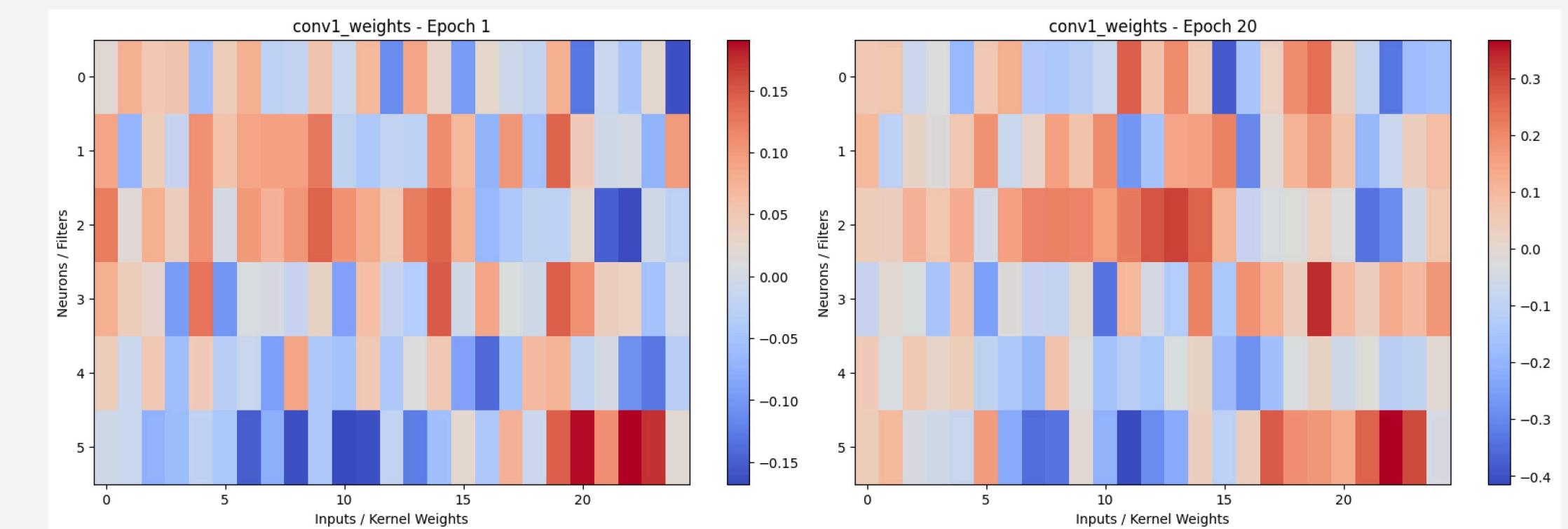
Layer Type	Name	Input Shape	Output Shape	Kernel/Units	Activation	Additional Info
Conv2D	conv1	(3, 32, 32)	(32, 28, 28)	(5×5)	ReLU	Increased filters from 6 → 32
MaxPool2D	pool1	(32, 28, 28)	(32, 14, 14)	(2×2)	-	Stride 2
Conv2D	conv2	(32, 14, 14)	(64, 10, 10)	(5×5)	ReLU	Increased filters from 16 → 64
MaxPool2D	pool2	(64, 10, 10)	(64, 5, 5)	(2×2)	-	Stride 2
Conv2D	conv3	(64, 5, 5)	(128, 3, 3)	(3×3)	ReLU	Increased filters from 64 → 128
GlobalAvgPool2D	gap	(128, 3, 3)	(128)	-	-	Reduces dimensions
Flatten	-	(64, 5, 5)	(1600)	-	-	Adjusted for increased filters
Dense (FC)	fc1	(1600)	(512)	120	ReLU	Increased neurons from 120 → 512
Dense (FC)	fc2	(512)	(256)	84	ReLU	Increased neurons from 84 → 256
Dense (FC)	fc3	(256)	(10)	10	Softmax (implied)	Output layer

Results

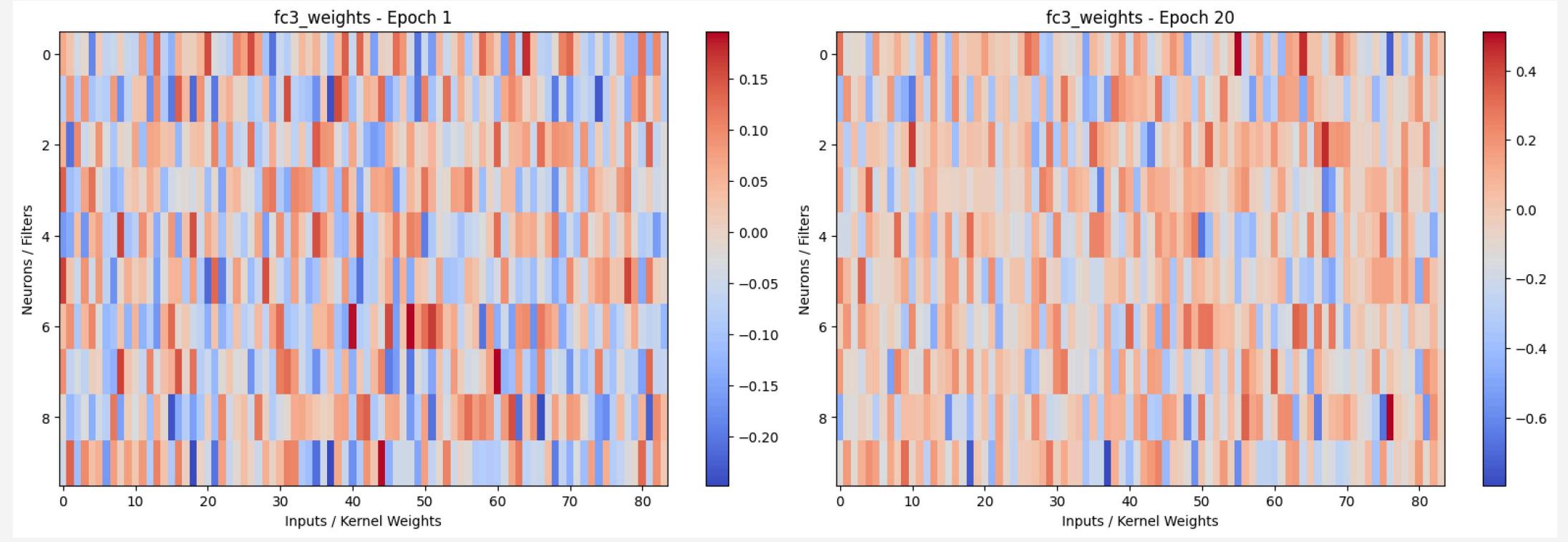
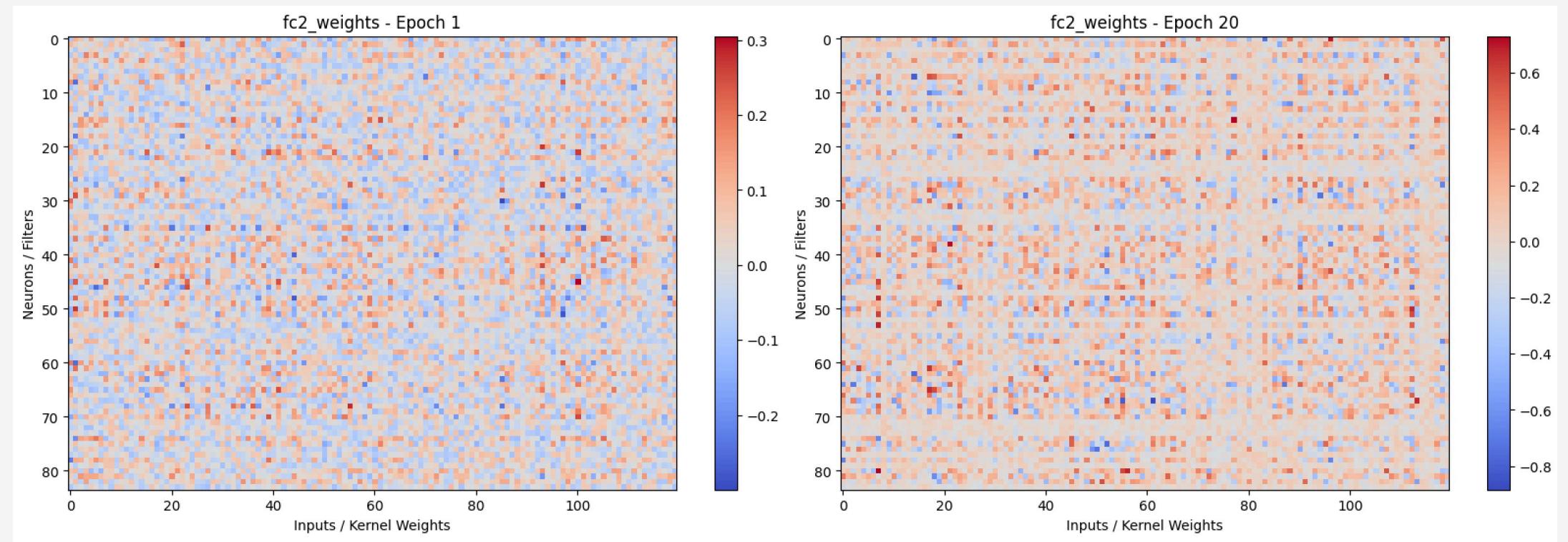
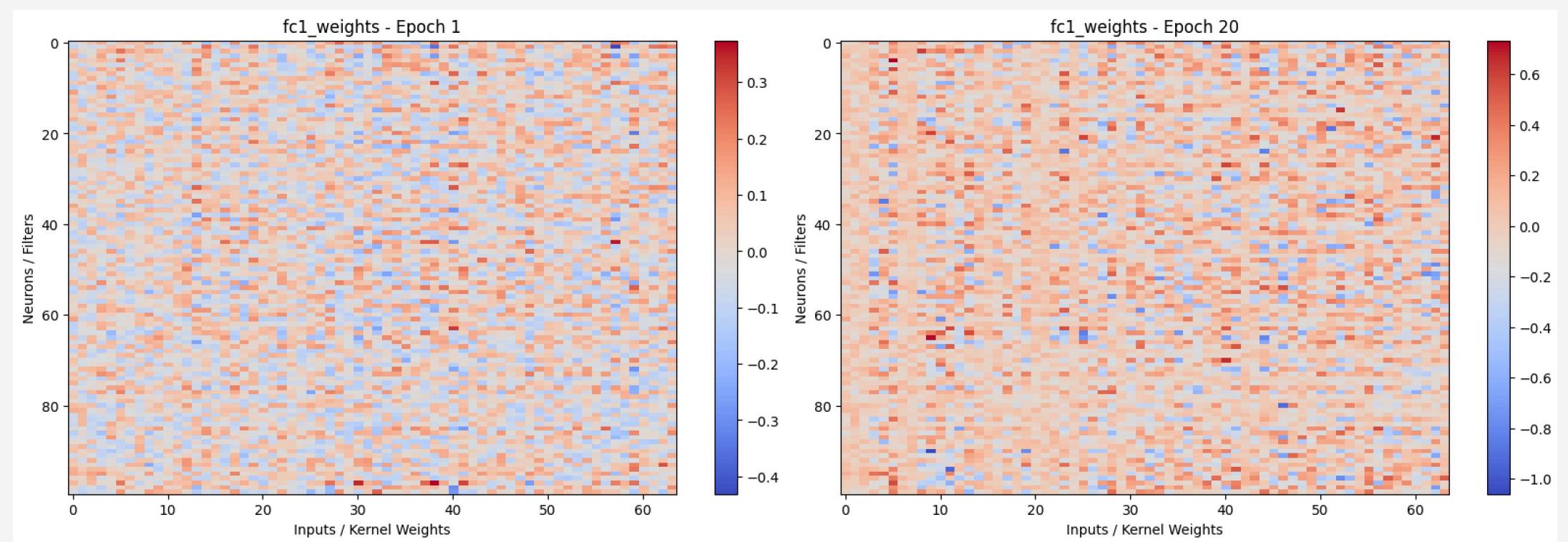
Test Accuracy: 0.7187									
Confusion Matrix:									
[[744 11 46 28 23 12 14 16 62 44]									
[20 772 4 14 4 4 16 4 30 132]									
[57 6 592 81 73 66 72 30 11 12]									
[13 7 44 533 54 217 68 34 8 22]									
[20 2 64 66 655 49 51 72 15 6]									
[7 5 40 145 35 695 23 46 1 3]									
[3 3 27 84 34 20 811 6 3 9]									
[14 2 17 58 70 75 10 734 2 18]									
[73 26 14 18 11 4 12 8 801 33]									
[29 25 12 16 6 9 13 14 26 850]]									
	precision	recall	f1-score	support					
0	0.76	0.74	0.75	1000					
1	0.90	0.77	0.83	1000					
2	0.69	0.59	0.64	1000					
3	0.51	0.53	0.52	1000					
4	0.68	0.66	0.67	1000					
5	0.60	0.69	0.65	1000					
6	0.74	0.81	0.78	1000					
7	0.76	0.73	0.75	1000					
8	0.84	0.80	0.82	1000					
9	0.75	0.85	0.80	1000					
accuracy			0.72	10000					
macro avg	0.72	0.72	0.72	10000					
weighted avg	0.72	0.72	0.72	10000					

Epoch [1/20], Loss: 1.674477
Epoch [2/20], Loss: 1.292165
Epoch [3/20], Loss: 1.126243
Epoch [4/20], Loss: 1.014138
Epoch [5/20], Loss: 0.921575
Epoch [6/20], Loss: 0.848513
Epoch [7/20], Loss: 0.789142
Epoch [8/20], Loss: 0.738794
Epoch [9/20], Loss: 0.698406
Epoch [10/20], Loss: 0.655262
Epoch [11/20], Loss: 0.619182
Epoch [12/20], Loss: 0.583807
Epoch [13/20], Loss: 0.548404
Epoch [14/20], Loss: 0.519887
Epoch [15/20], Loss: 0.491176
Epoch [16/20], Loss: 0.459597
Epoch [17/20], Loss: 0.432931
Epoch [18/20], Loss: 0.410020
Epoch [19/20], Loss: 0.380788
Epoch [20/20], Loss: 0.354959

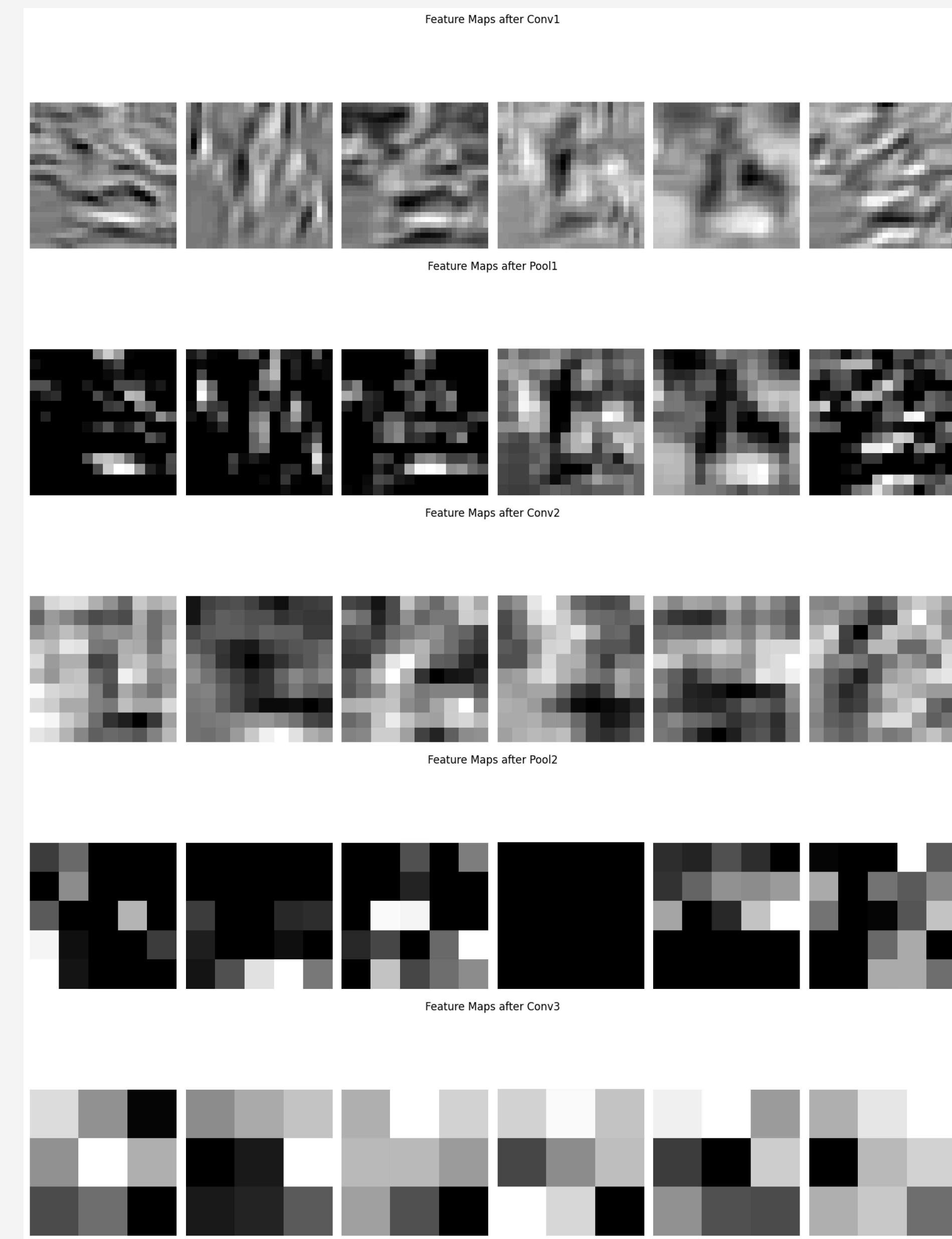
Weights Plots



Weights Plots



Visualizing Feature Maps



Modifying Kernel Size

Set Up - 2

Layer Type	Name	Input Shape	Output Shape	Kernel/Units	Activation	Additional Info
Conv2D	conv1	(3, 32, 32)	(32, 30, 30)	(3×3)	ReLU	Reduced kernel from 5×5 → 3×3
MaxPool2D	pool1	(32, 30, 30)	(32, 15, 15)	(2×2)	-	Stride 2
Conv2D	conv2	(32, 15, 15)	(64, 13, 13)	(3×3)	ReLU	Reduced kernel from 5×5 → 3×3
MaxPool2D	pool2	(64, 13, 13)	(64, 6, 6)	(2×2)	-	Stride 2
Conv2D	conv3	(64, 6, 6)	(128, 4, 4)	(3×3)	ReLU	Same kernel size, but adjusted shape
GlobalAvgPool2D	gap	(128, 4, 4)	(128)	-	-	Reduces dimensions
Flatten	-	(64, 6, 6)	(2304)	-	-	Adjusted for modified feature map sizes
Dense (FC)	fc1	(2304)	(512)	120	ReLU	Increased neurons from 120 → 512
Dense (FC)	fc2	(512)	(256)	84	ReLU	Increased neurons from 84 → 256
Dense (FC)	fc3	(256)	(10)	10	Softmax (implied)	Output layer

Results

Test Accuracy: 0.7258

Confusion Matrix:

```
[[811 16 52 21 7 5 10 12 42 24]
 [ 23 857 12 8 1 6 12 1 32 48]
 [ 75 3 637 52 49 69 81 17 10 7]
 [ 20 5 103 518 42 171 99 19 18 5]
 [ 26 3 106 61 592 47 95 62 7 11]
 [ 10 6 47 167 31 666 31 33 5 4]
 [ 4 5 44 41 9 10 869 8 7 3]
 [ 23 3 41 56 46 89 15 710 4 13]
 [ 70 22 15 19 3 3 9 3 845 11]
 [ 44 101 14 12 4 6 20 12 34 753]]
```

	precision	recall	f1-score	support
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0	0.73	0.81	0.77	1000
1	0.84	0.86	0.85	1000
2	0.59	0.64	0.62	1000
3	0.54	0.52	0.53	1000
4	0.76	0.59	0.66	1000
5	0.62	0.67	0.64	1000
6	0.70	0.87	0.78	1000
7	0.81	0.71	0.76	1000
8	0.84	0.84	0.84	1000
9	0.87	0.75	0.81	1000

accuracy			0.73	10000
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macro avg	0.73	0.73	0.73	10000
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weighted avg	0.73	0.73	0.73	10000
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Epoch [1/20], Loss: 1.743678

Epoch [2/20], Loss: 1.356872

Epoch [3/20], Loss: 1.170729

Epoch [4/20], Loss: 1.049881

Epoch [5/20], Loss: 0.967754

Epoch [6/20], Loss: 0.895674

Epoch [7/20], Loss: 0.842022

Epoch [8/20], Loss: 0.801260

Epoch [9/20], Loss: 0.761648

Epoch [10/20], Loss: 0.729621

Epoch [11/20], Loss: 0.697111

Epoch [12/20], Loss: 0.668363

Epoch [13/20], Loss: 0.637082

Epoch [14/20], Loss: 0.616867

Epoch [15/20], Loss: 0.592638

Epoch [16/20], Loss: 0.570367

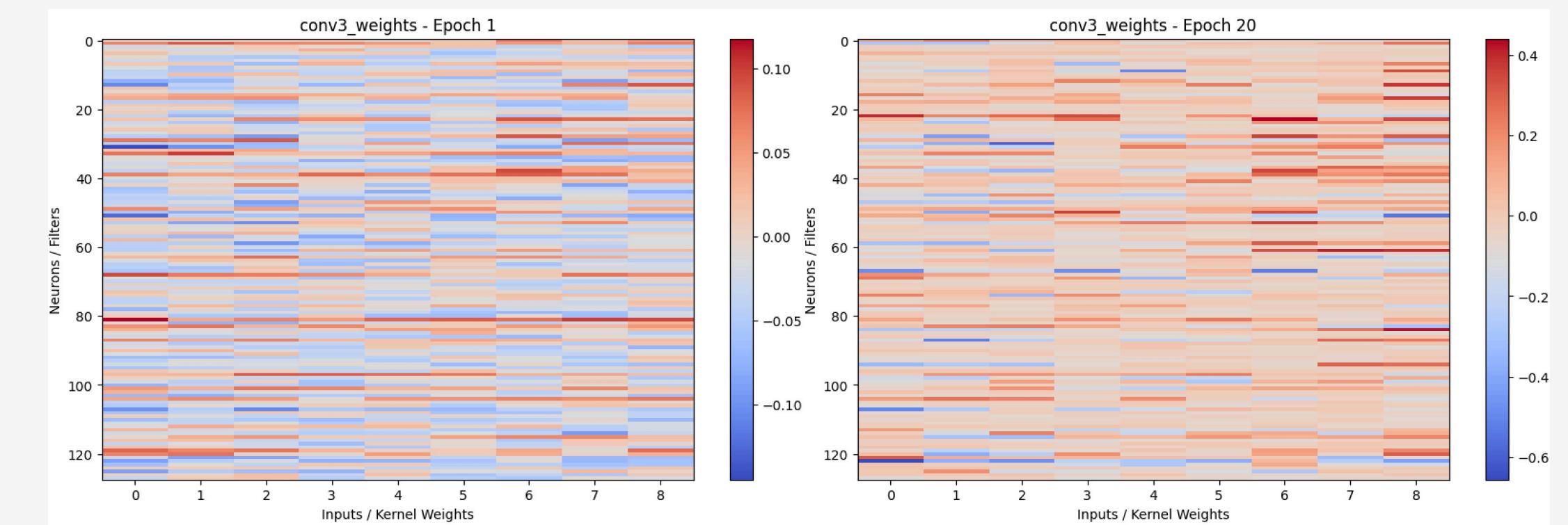
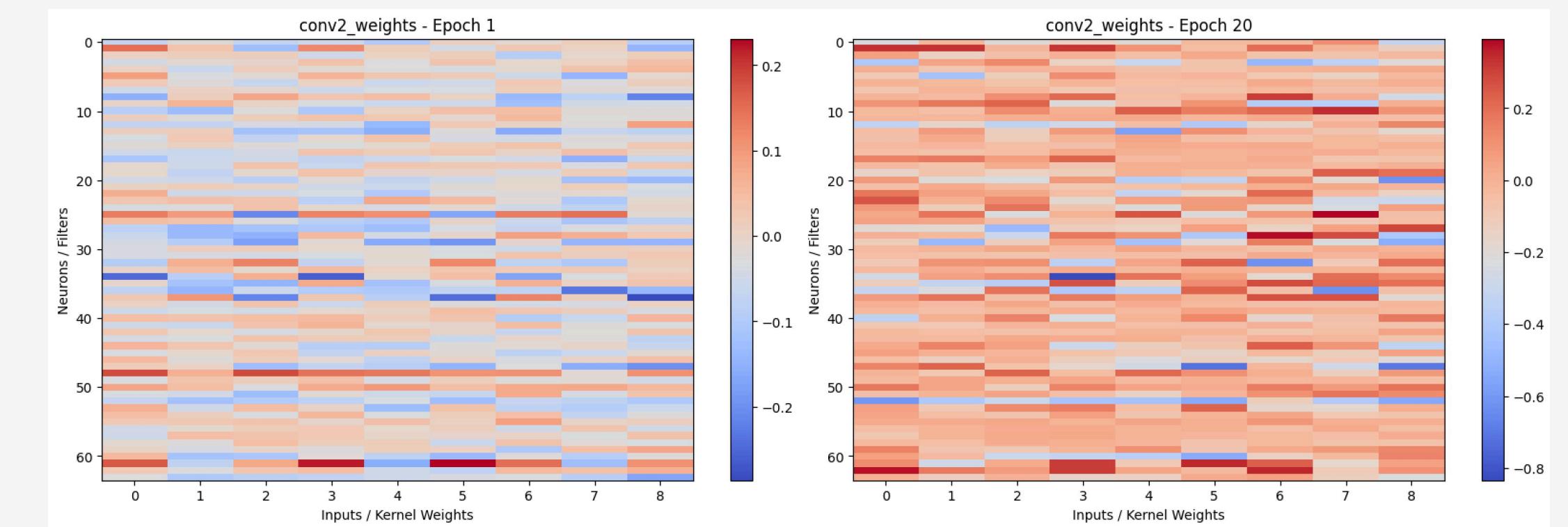
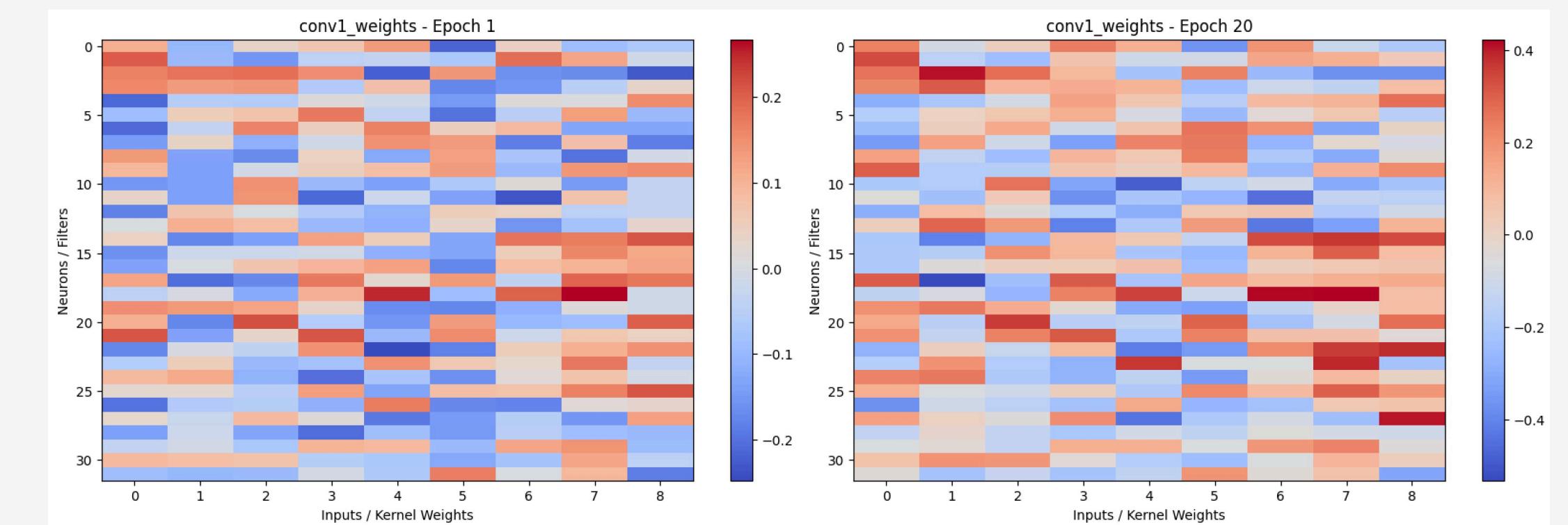
Epoch [17/20], Loss: 0.546347

Epoch [18/20], Loss: 0.522440

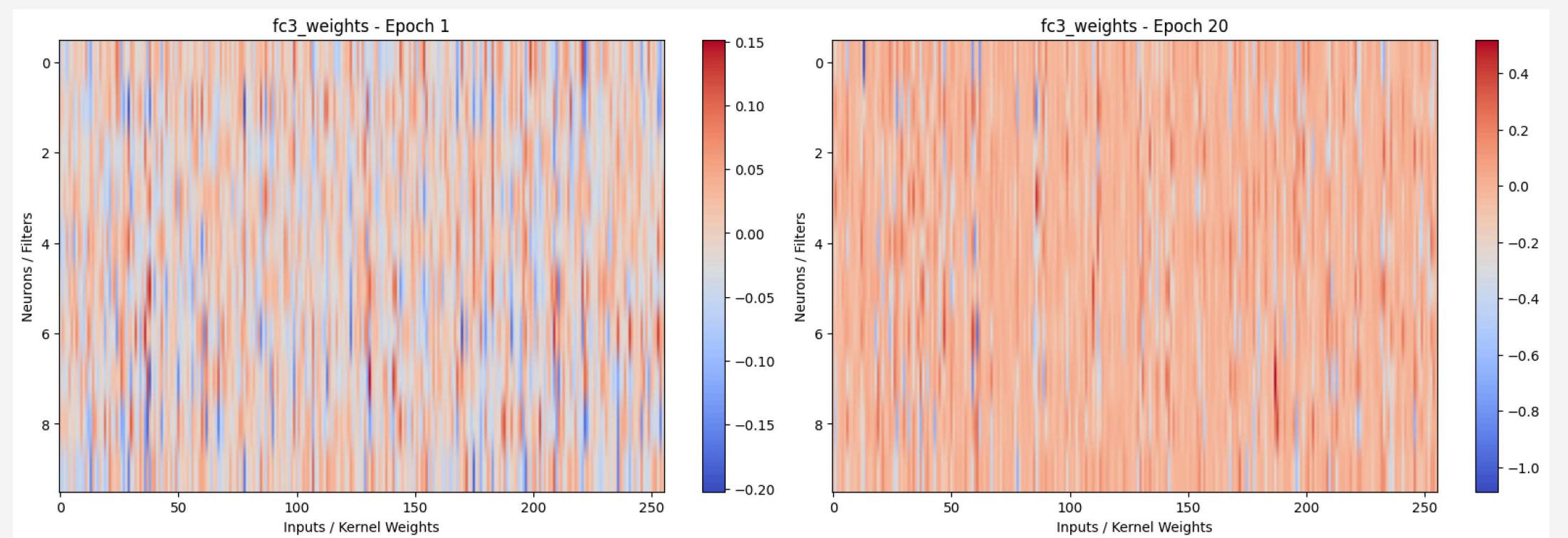
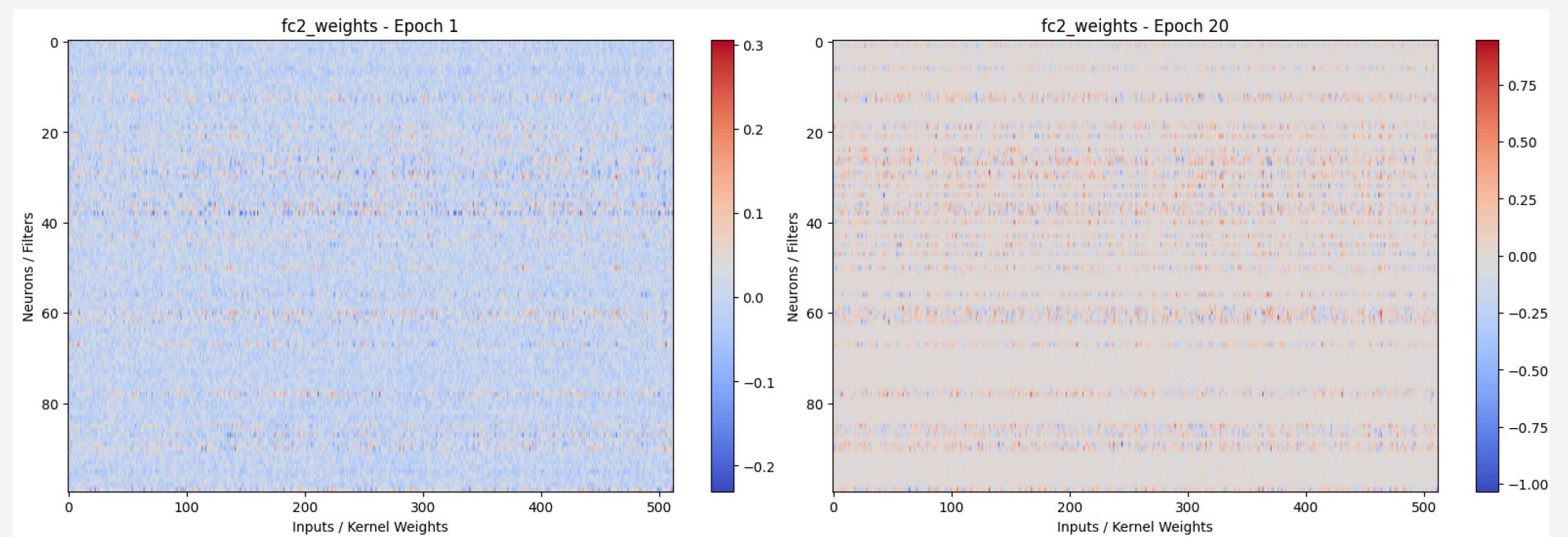
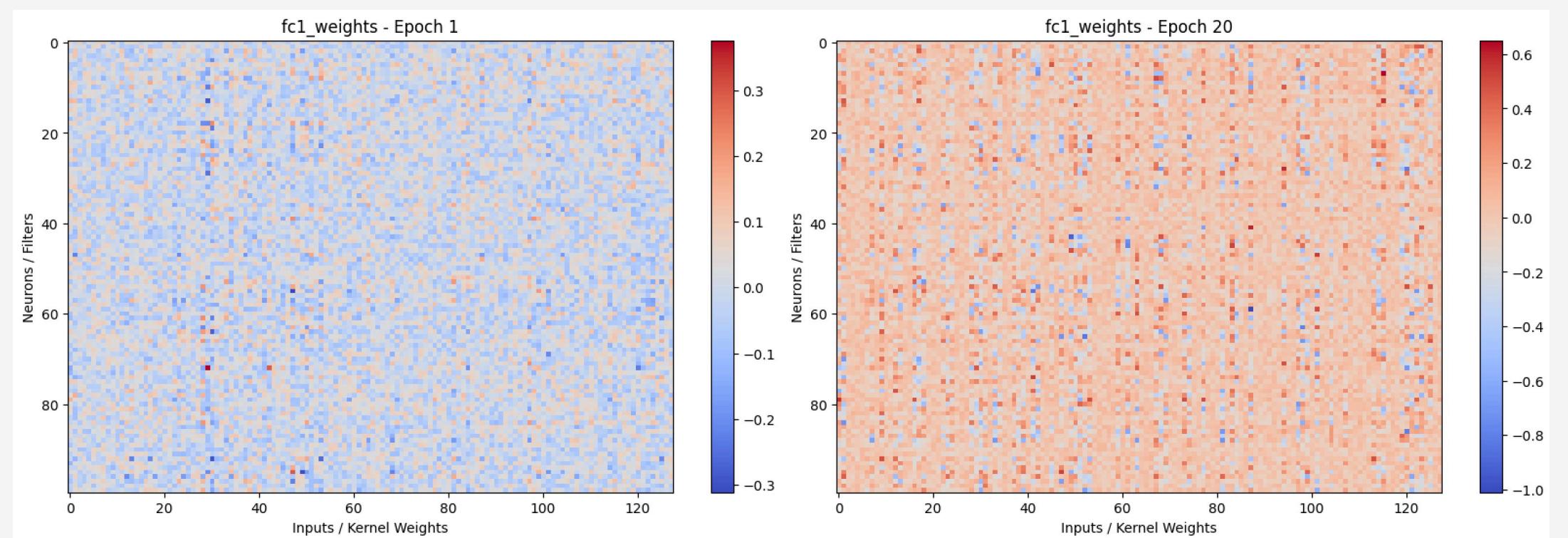
Epoch [19/20], Loss: 0.506280

Epoch [20/20], Loss: 0.484608

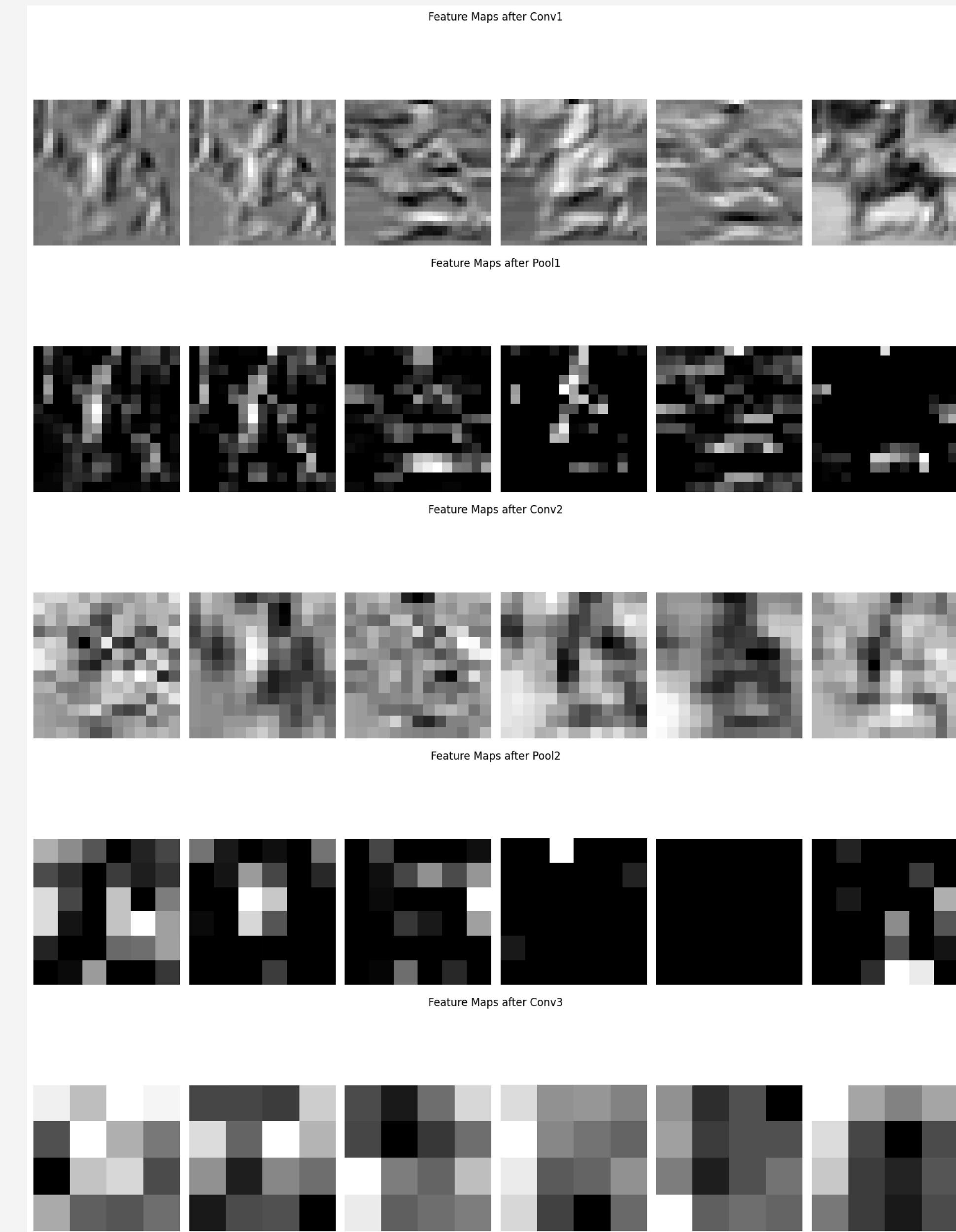
Weights Plots



Weights Plots



Visualizing Feature Maps



Batch Norm + Dropout

Set Up - 3

Layer Type	Name	Input Shape	Output Shape	Kernel/Units	Activation	Additional Info
Conv2D	conv1	(3, 32, 32)	(32, 28, 28)	(5×5)	ReLU	32 filters
BatchNorm2D	bn1	(32, 28, 28)	(32, 28, 28)	-	-	-
MaxPool2D	pool1	(32, 28, 28)	(32, 14, 14)	(2×2)	-	Stride 2
Conv2D	conv2	(32, 14, 14)	(64, 10, 10)	(5×5)	ReLU	Increased filters from 16 → 64
BatchNorm2D	bn2	(64, 10, 10)	(64, 10, 10)	-	-	-
MaxPool2D	pool2	(64, 10, 10)	(64, 5, 5)	(2×2)	-	Stride 2
Flatten	-	(64, 5, 5)	(1600)	-	-	Adjusted for increased filters
Dense (FC)	fc1	(1600)	(512)	120	ReLU	Increased neurons from 120 → 512
Dropout	drop1	(256)	(256)	-	-	Dropout 0.5
Dense (FC)	fc2	(512)	(256)	84	ReLU	Increased neurons from 84 → 256
Dropout	drop2	(128)	(128)	-	-	Dropout 0.5
Dense (FC)	fc3	(256)	(10)	10	Softmax (implied)	Output layer

Changes:

- Added BatchNorm layers after each convolutional layer for better training stability.
- Increased the number of filters to extract more features.
- Added Dropout in fully connected layers to reduce overfitting.

Results

Test Accuracy: 0.7597

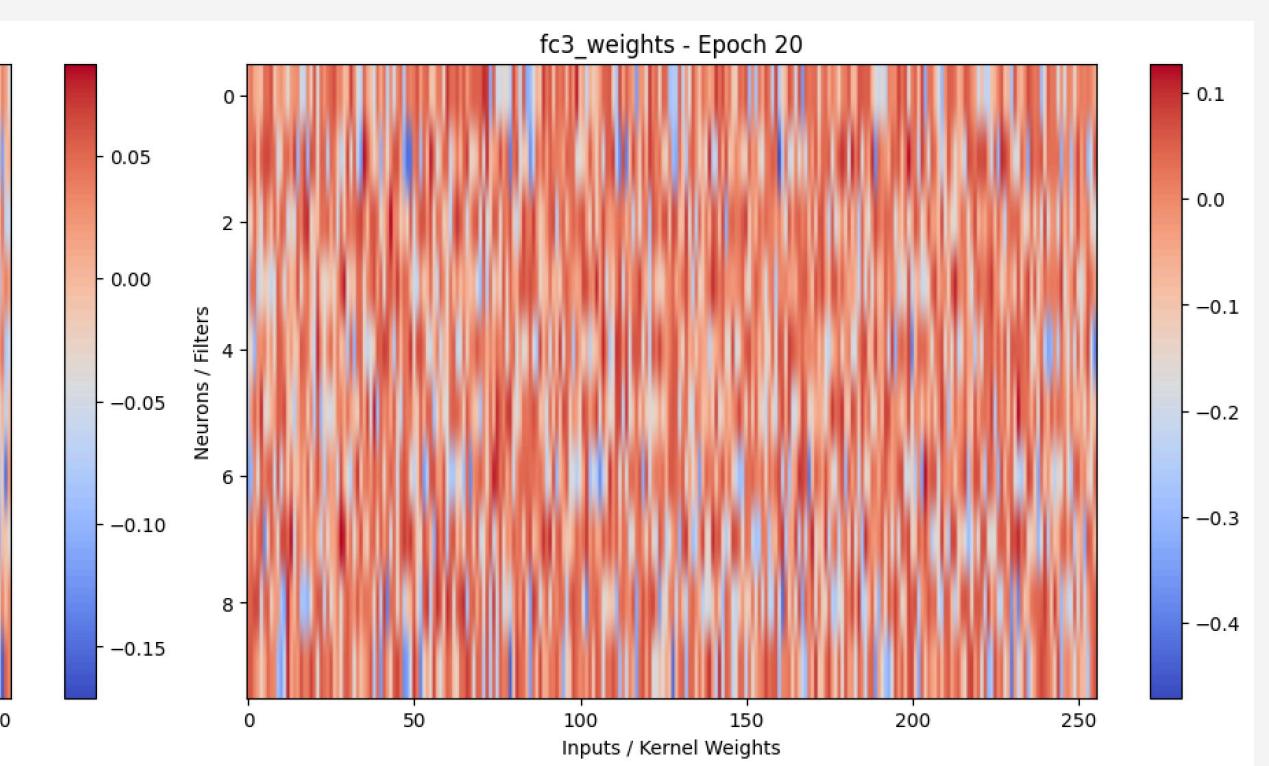
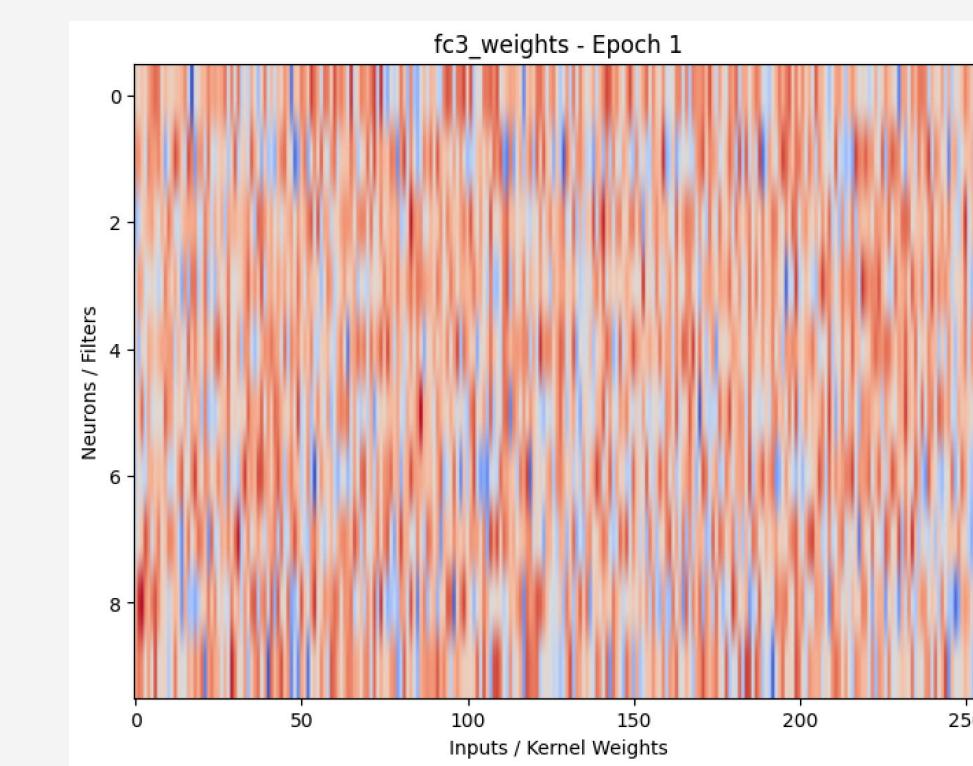
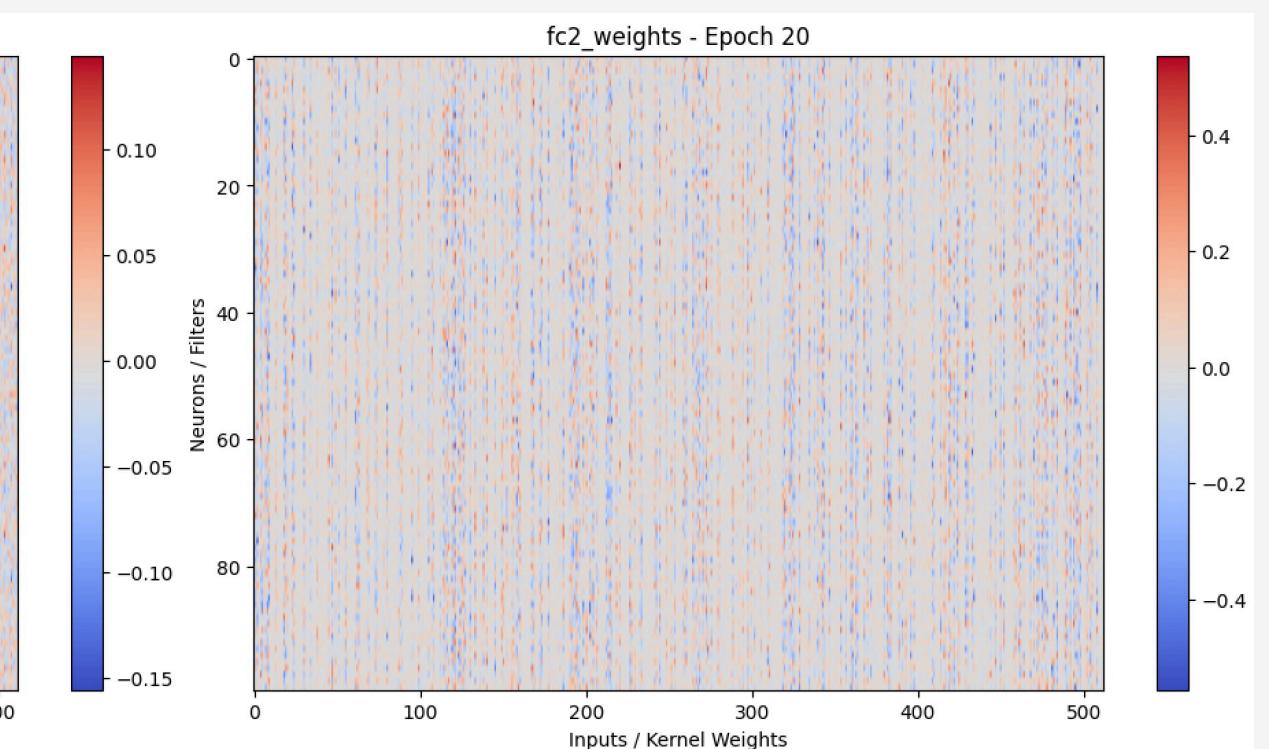
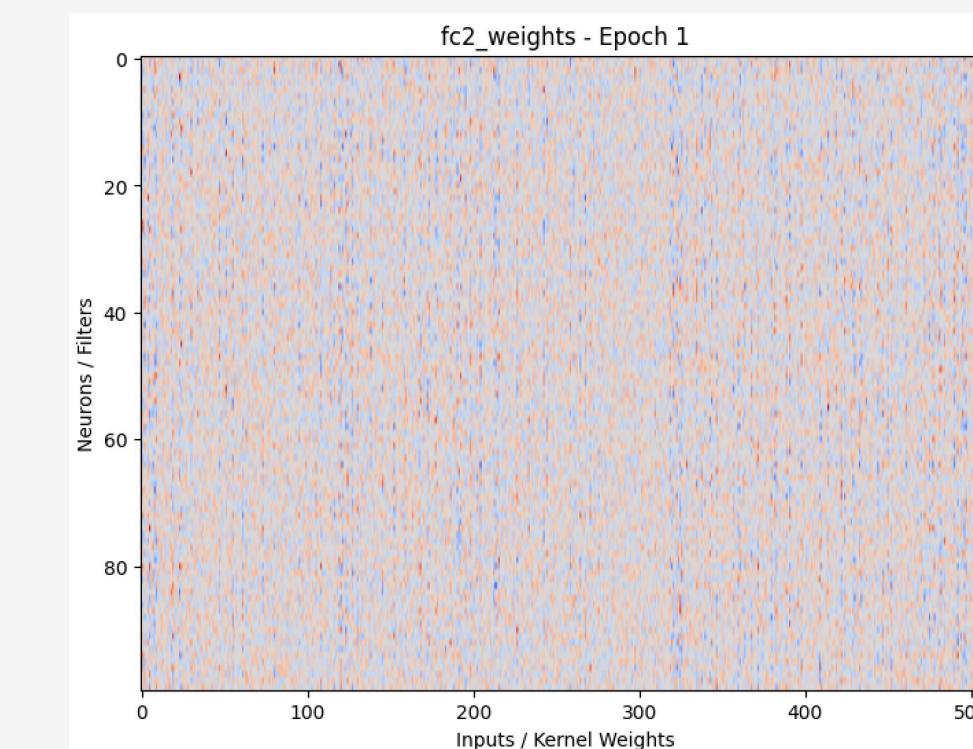
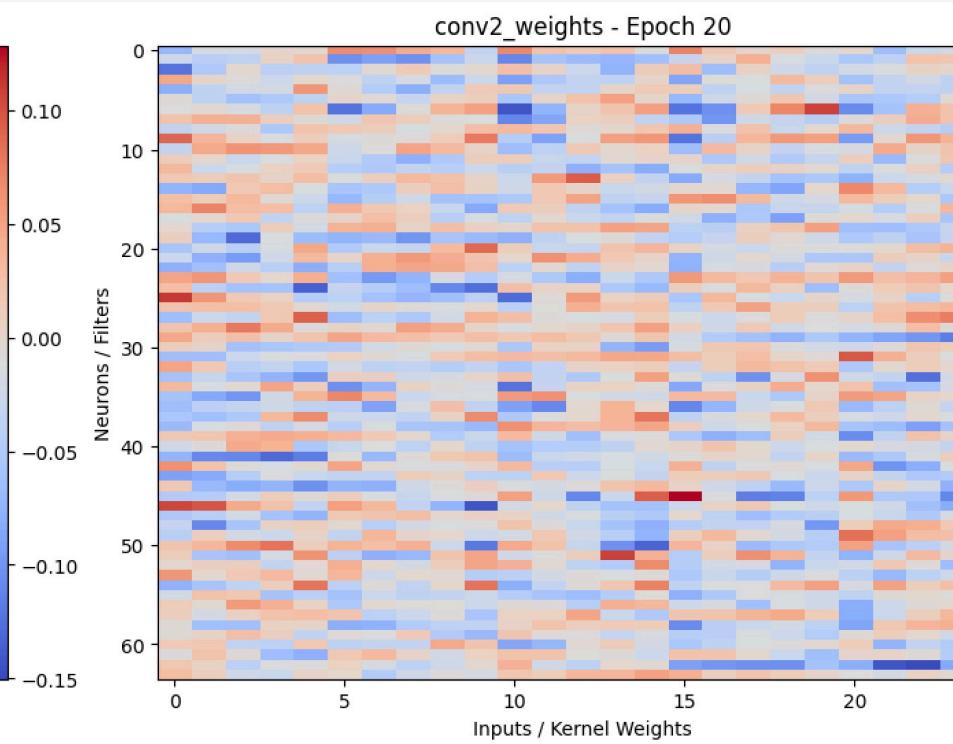
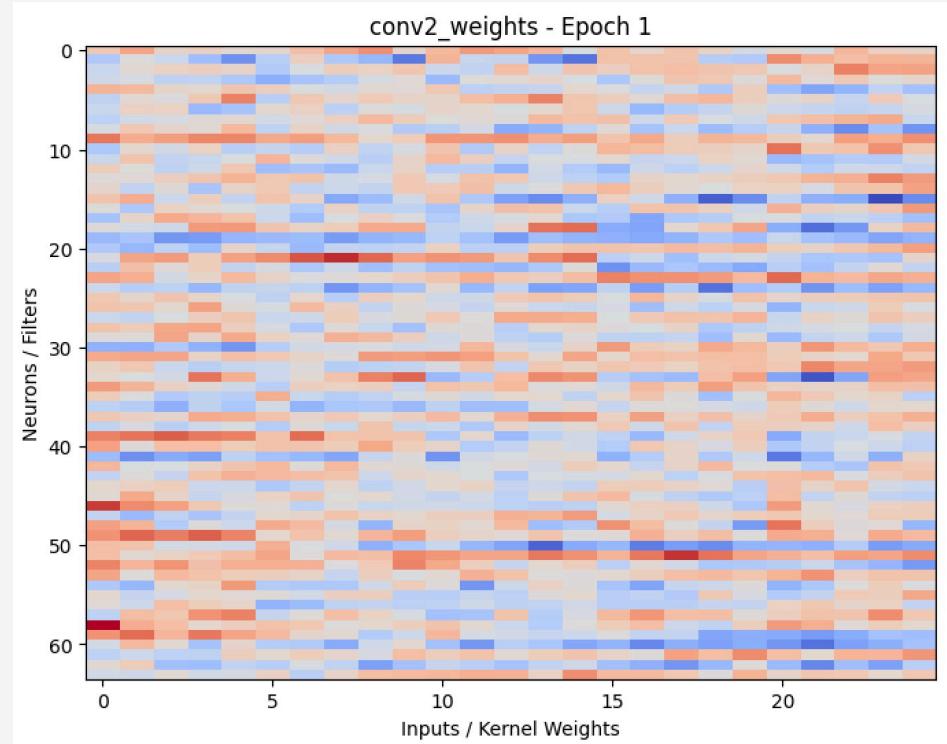
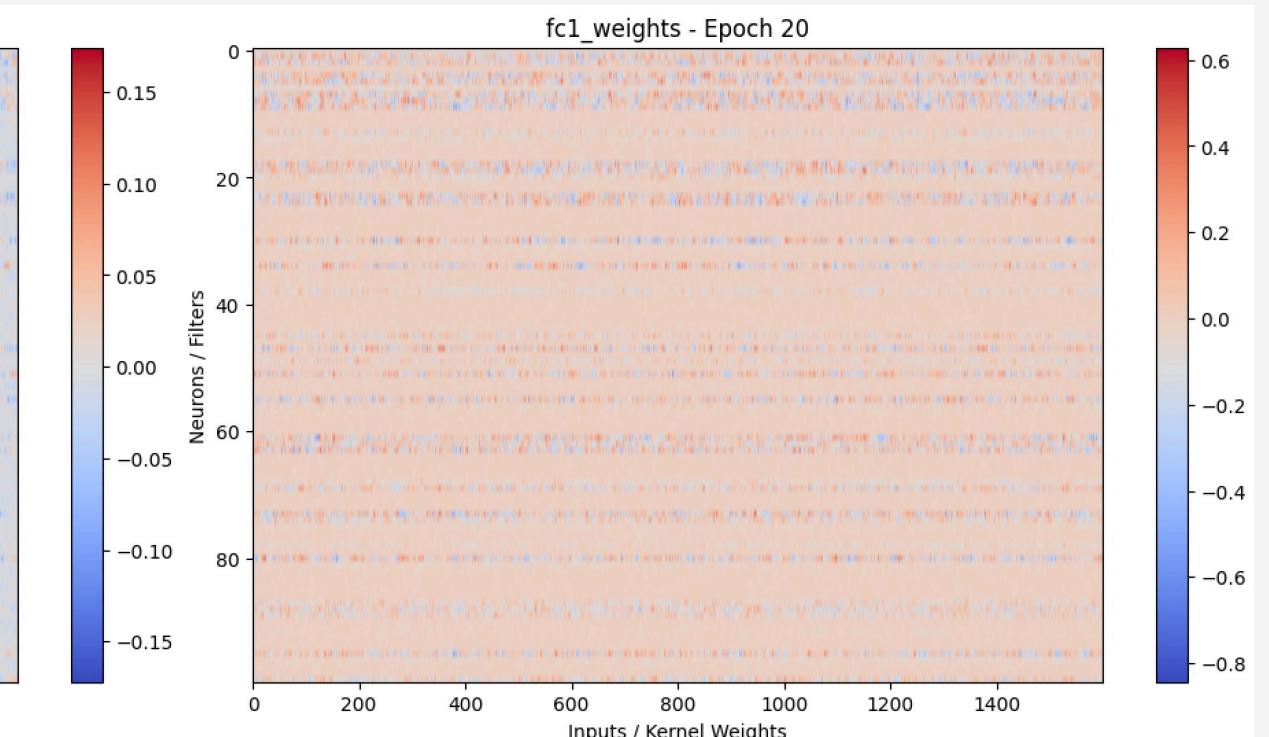
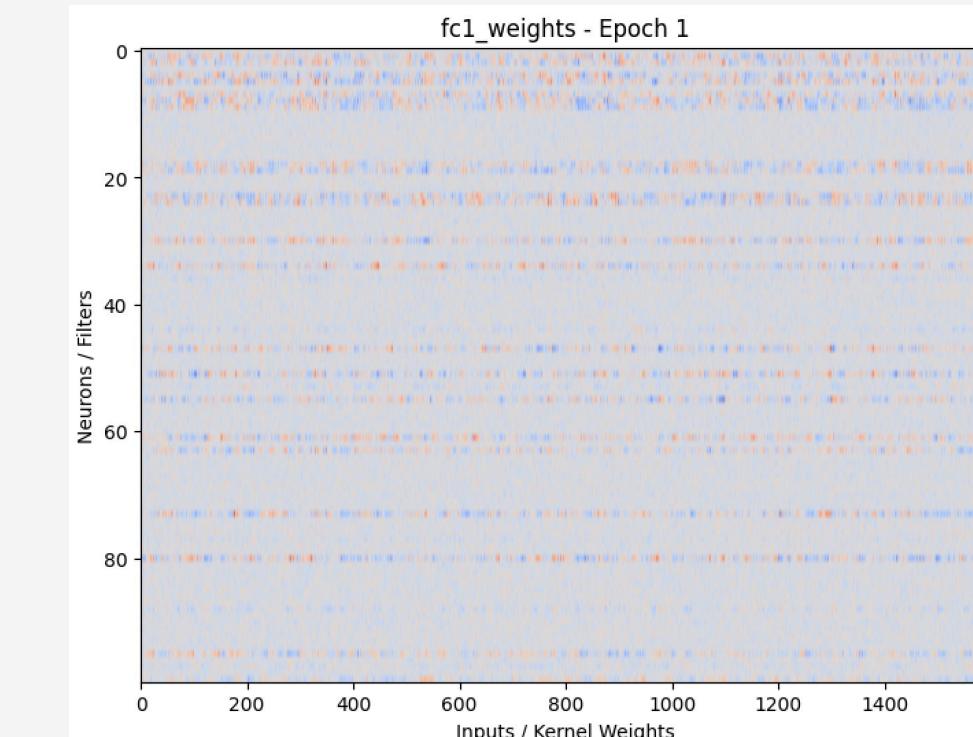
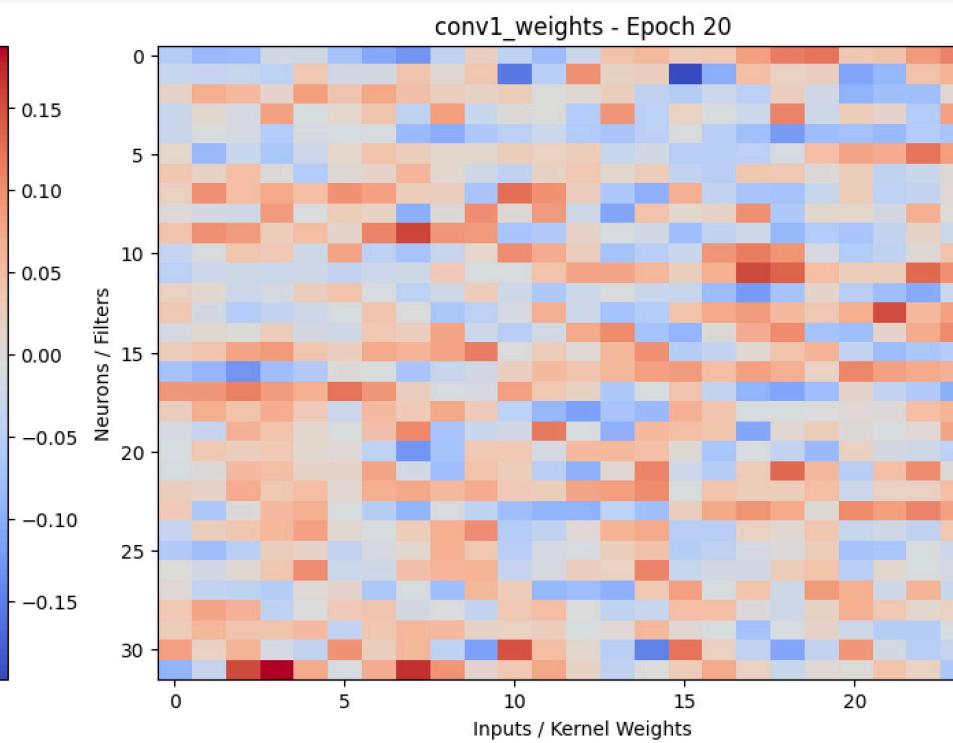
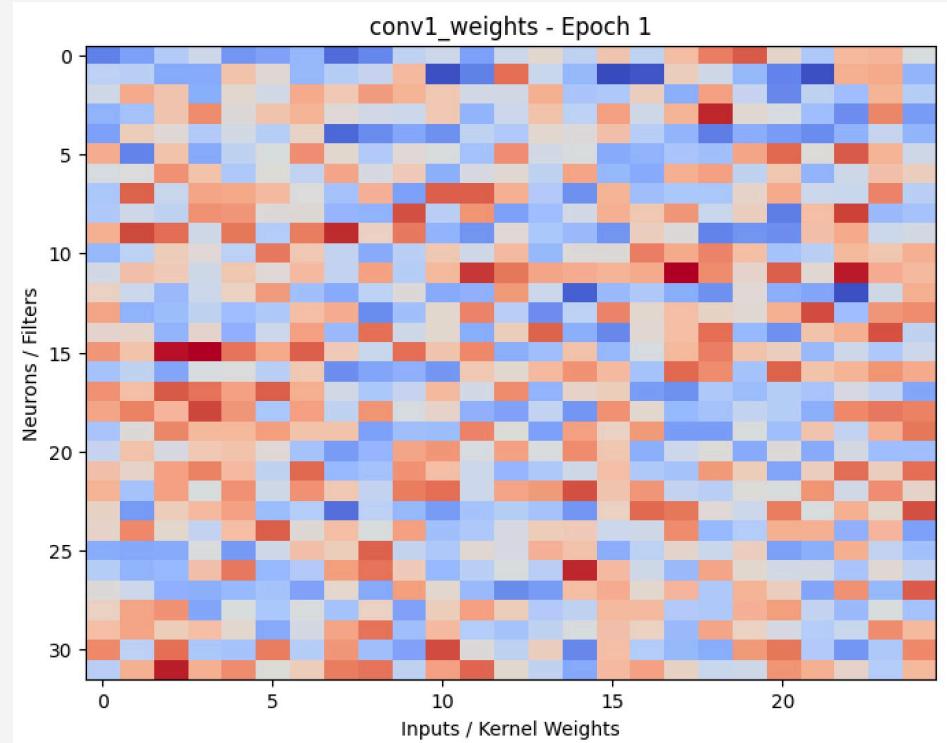
Confusion Matrix:

```
[[809  20  38  19  5  5  7  12  50  35]
 [ 15 854   8   3   5   5   3   1   26   80]
 [ 66  3 691  49  68  50  24  25  16   8]
 [ 28   8  73 535  63 193  40  21  18  21]
 [ 24   2  75  41 735  35  18  50  15   5]
 [ 13   4  69 141  40 676  10  32   9   6]
 [  7   5  56  52  40  36 779   8  10   7]
 [ 16   8  39  26  57  66   4 772   0  12]
 [ 53  23  14   6   3   0   2   3 879  17]
 [ 22  54   8   6   5   3   4   7  24 867]]
```

	precision	recall	f1-score	support
0	0.77	0.81	0.79	1000
1	0.87	0.85	0.86	1000
2	0.65	0.69	0.67	1000
3	0.61	0.54	0.57	1000
4	0.72	0.73	0.73	1000
5	0.63	0.68	0.65	1000
6	0.87	0.78	0.82	1000
7	0.83	0.77	0.80	1000
8	0.84	0.88	0.86	1000
9	0.82	0.87	0.84	1000
accuracy			0.76	10000
macro avg	0.76	0.76	0.76	10000
weighted avg	0.76	0.76	0.76	10000

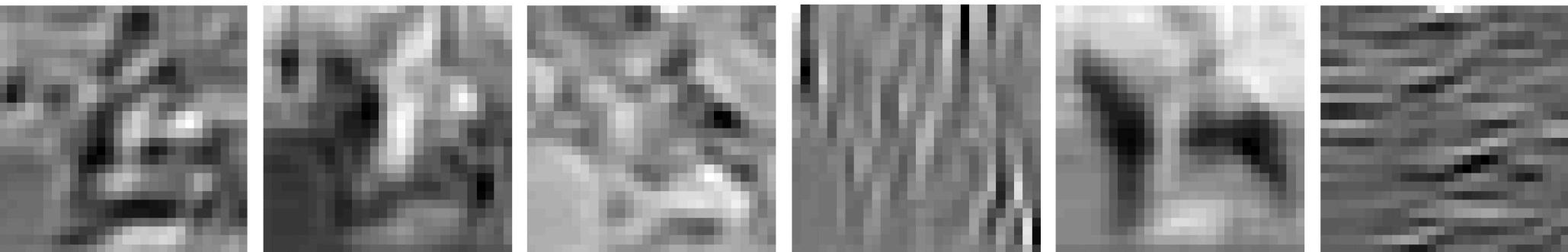
```
:poch [1/20], Loss: 1.559291
:poch [2/20], Loss: 1.244582
:poch [3/20], Loss: 1.092151
:poch [4/20], Loss: 0.995819
:poch [5/20], Loss: 0.928747
:poch [6/20], Loss: 0.863178
:poch [7/20], Loss: 0.816382
:poch [8/20], Loss: 0.774763
:poch [9/20], Loss: 0.733284
:poch [10/20], Loss: 0.706137
:poch [11/20], Loss: 0.682670
:poch [12/20], Loss: 0.657483
:poch [13/20], Loss: 0.631911
:poch [14/20], Loss: 0.607396
:poch [15/20], Loss: 0.585241
:poch [16/20], Loss: 0.563728
:poch [17/20], Loss: 0.540057
:poch [18/20], Loss: 0.532817
:poch [19/20], Loss: 0.514417
:poch [20/20], Loss: 0.499898
```

Weight Plots

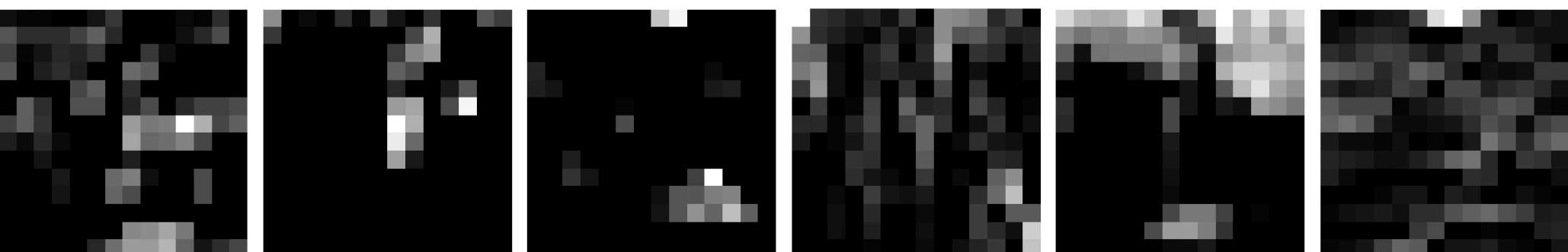


Visualizing Feature Maps

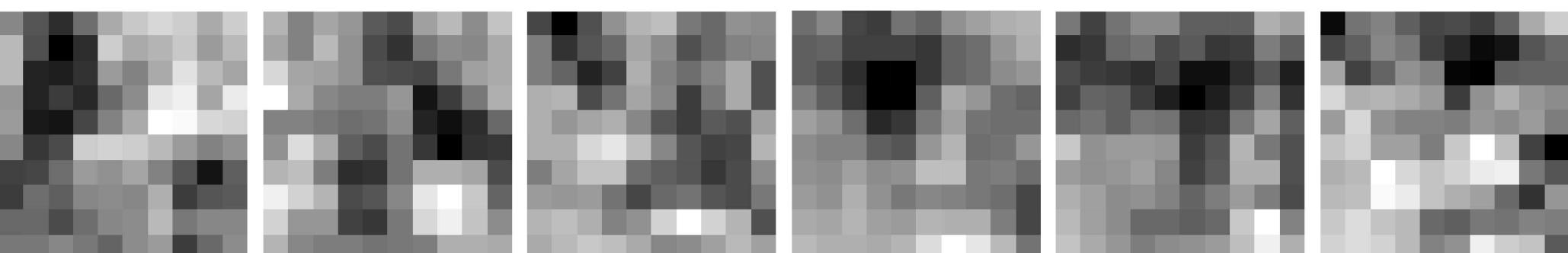
Feature Maps after Conv1



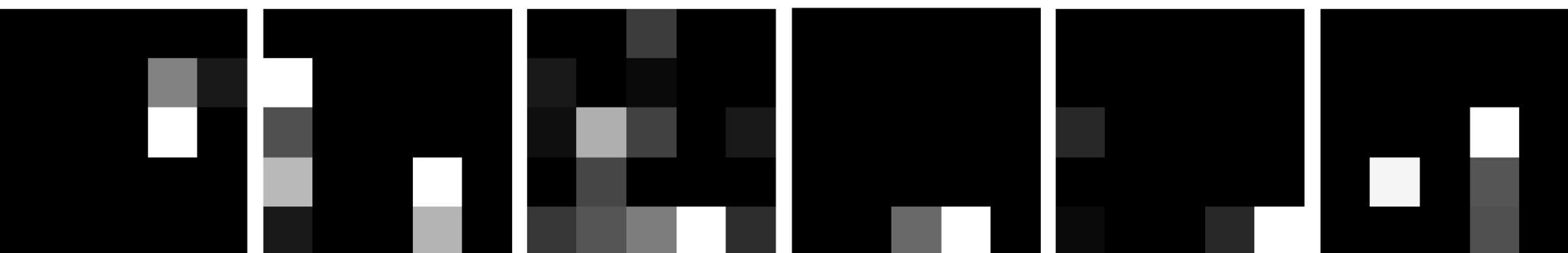
Feature Maps after Pool1



Feature Maps after Conv2



Feature Maps after Pool2



Results

Set Up	Model	Accuracy
Initial Set Up	2 Conv2D layers (6, 16 filters, ReLU). 2 MaxPool2D layers. 3 Dense layers (120, 84, 10 units, ReLU/Softmax).	63.01 %
Set Up 1	3 Conv2D layers (32, 64, 128 filters, ReLU). 2 MaxPool2D layers. Global Average Pooling. 3 Dense layers (512, 256, 10 units, ReLU/Softmax)	71.87 %
Set Up 2	3 Conv2D layers (32, 64, 128 filters, 3×3 kernel, ReLU). 2 MaxPool2D layers. Global Average Pooling. 3 Dense layers (512, 256, 10 units, ReLU/Softmax).	72.58 %
Set Up 3	2 Conv2D (5×5, ReLU, 32 & 64 filters). 2 BatchNorm2D layers. 2 MaxPool2D layers. Flatten. 3 Dense layers (512, 256, 10 units, ReLU/Softmax). 2 Dropout layers (0.5).	75.97 %