MACHINE LEARNING LAB

5th Semester, Academic Year 2025

Date:19-09-2025
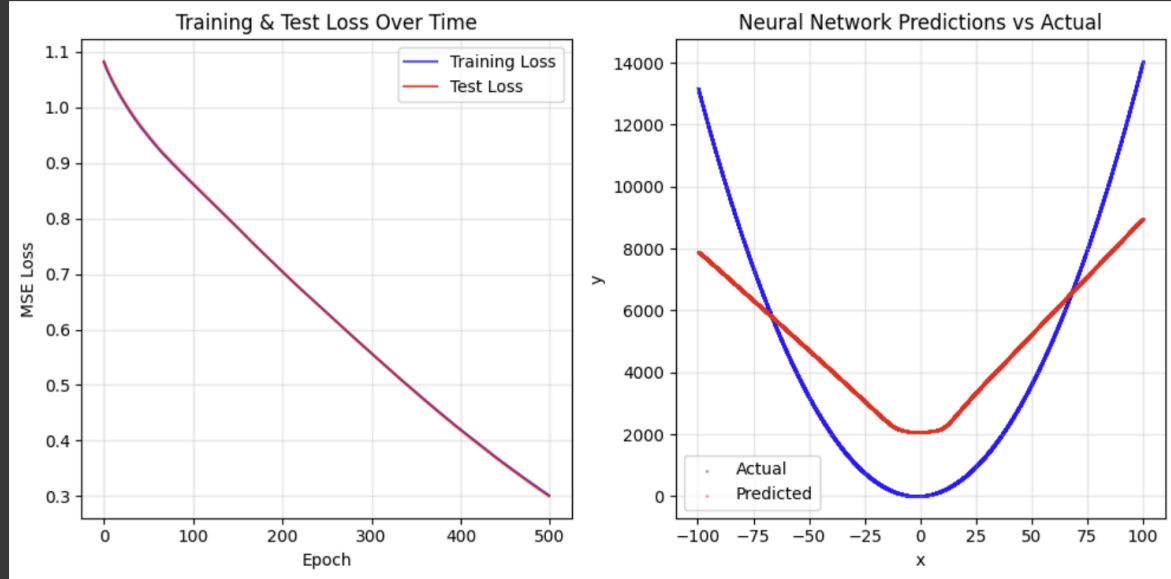
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ReLu(baseline)

Training & Test Loss Over Time

Neural Network Predictions vs Actual

```
================================================================
PREDICTION RESULTS FOR x = 90.2
================================================================
Neural Network Prediction: 8,246.71
Ground Truth (formula):    11,478.02
Absolute Error:            3,231.30
Relative Error:            28.152%
```

```
================================================================
FINAL PERFORMANCE SUMMARY
================================================================
Final Training Loss: 0.301565
Final Test Loss:     0.299981
R² Score:            0.7013
Total Epochs Run:    500
```

ReLu 300 epochs

```
print("Training Neural Network with your specific configuration...")
weights, train_losses, test_losses = train_neural_network(
    X_train_scaled, Y_train_scaled, X_test_scaled, Y_test_scaled,
    epochs=300, patience=10
)
```

```
Training Neural Network with your specific configuration...
Starting training...
Architecture: 1 → 96 → 96 → 1
Learning Rate: 0.003
Max Epochs: 300, Early Stopping Patience: 10
--------------------------------------------------
Epoch  20: Train Loss = 1.018489, Test Loss = 1.021008
Epoch  40: Train Loss = 0.969659, Test Loss = 0.971934
Epoch  60: Train Loss = 0.929711, Test Loss = 0.931603
Epoch  80: Train Loss = 0.895185, Test Loss = 0.896887
Epoch 100: Train Loss = 0.863207, Test Loss = 0.864600
Epoch 120: Train Loss = 0.831969, Test Loss = 0.833054
Epoch 140: Train Loss = 0.800543, Test Loss = 0.801376
Epoch 160: Train Loss = 0.768616, Test Loss = 0.769140
Epoch 180: Train Loss = 0.736913, Test Loss = 0.737347
Epoch 200: Train Loss = 0.705889, Test Loss = 0.706129
Epoch 220: Train Loss = 0.675576, Test Loss = 0.675683
Epoch 240: Train Loss = 0.646297, Test Loss = 0.646247
Epoch 260: Train Loss = 0.617152, Test Loss = 0.616866
Epoch 280: Train Loss = 0.587738, Test Loss = 0.587296
Epoch 300: Train Loss = 0.558904, Test Loss = 0.558295
```
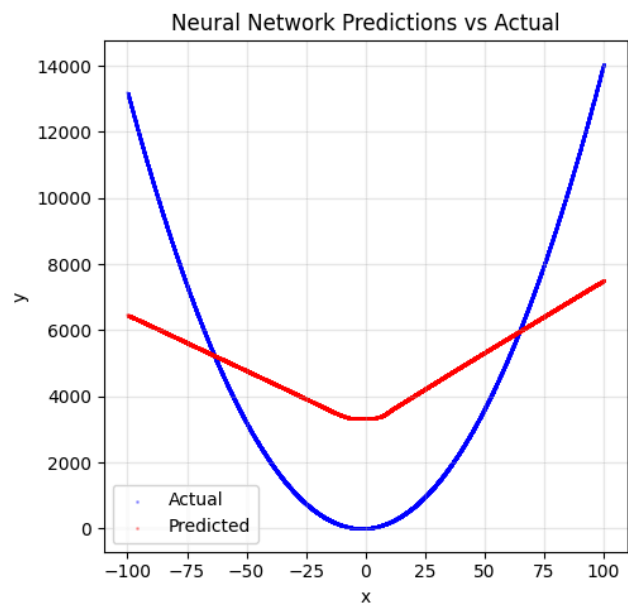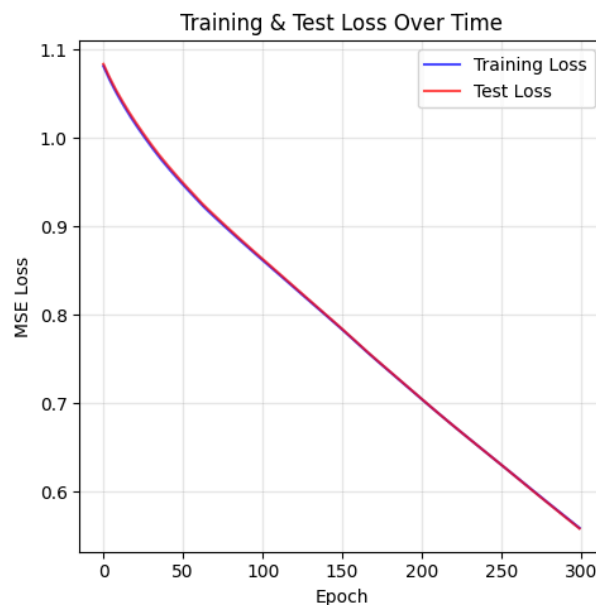
```
==========================================================
PREDICTION RESULTS FOR x = 90.2
==========================================================
Neural Network Prediction: 7,085.01
Ground Truth (formula):    11,478.02
Absolute Error:            4,393.00
Relative Error:            38.273%
```

```
==========================================================
FINAL PERFORMANCE SUMMARY
==========================================================
Final Training Loss: 0.558904
Final Test Loss:     0.558295
R² Score:            0.4441
Total Epochs Run:    300
```
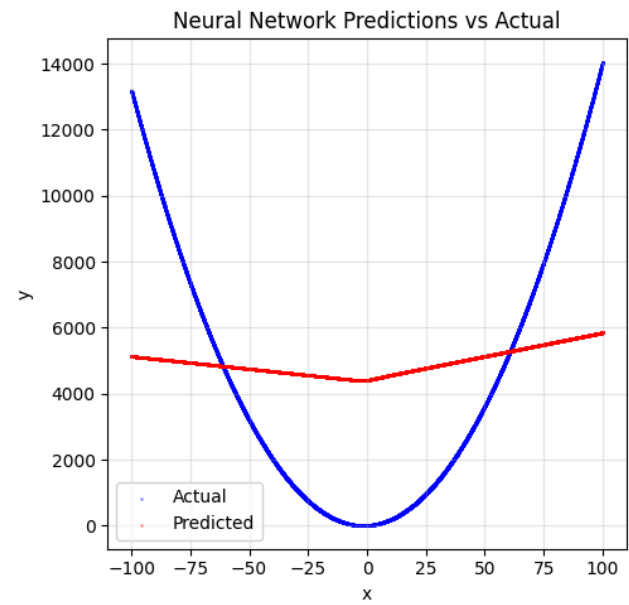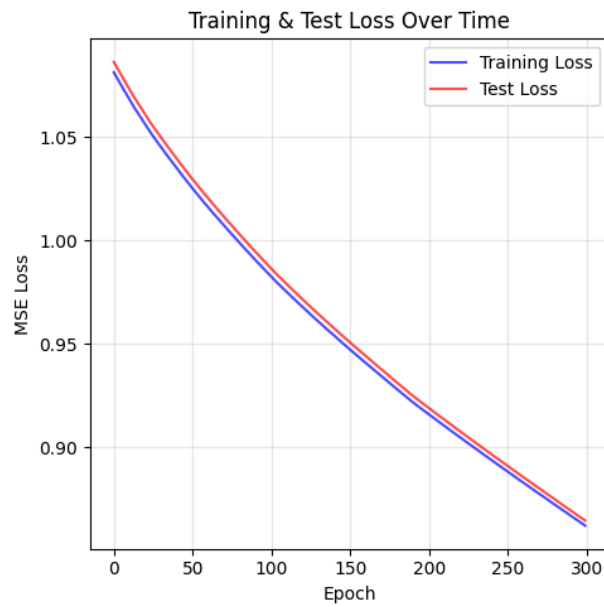
ReLu lr 0.001 300 epoch

```
)
Training Neural Network with your specific configuration...
Starting training...
Architecture: 1 → 96 → 96 → 1
Learning Rate: 0.001
Max Epochs: 300, Early Stopping Patience: 10
-------------------------------------------------
Epoch  20: Train Loss = 1.057201, Test Loss = 1.061987
Epoch  40: Train Loss = 1.035831, Test Loss = 1.040399
Epoch  60: Train Loss = 1.016770, Test Loss = 1.021118
Epoch  80: Train Loss = 0.999482, Test Loss = 1.003591
Epoch 100: Train Loss = 0.983173, Test Loss = 0.987056
Epoch 120: Train Loss = 0.968329, Test Loss = 0.972043
Epoch 140: Train Loss = 0.954498, Test Loss = 0.958025
Epoch 160: Train Loss = 0.941286, Test Loss = 0.944640
Epoch 180: Train Loss = 0.928504, Test Loss = 0.931674
Epoch 200: Train Loss = 0.916393, Test Loss = 0.919465
Epoch 220: Train Loss = 0.905145, Test Loss = 0.908074
Epoch 240: Train Loss = 0.894138, Test Loss = 0.896934
Epoch 260: Train Loss = 0.883318, Test Loss = 0.885988
Epoch 280: Train Loss = 0.872661, Test Loss = 0.875216
Epoch 300: Train Loss = 0.862119, Test Loss = 0.864564
```

Training & Test Loss Over Time

Neural Network Predictions vs Actual

```
================================================================
PREDICTION RESULTS FOR x = 90.2
================================================================
Neural Network Prediction: 5,713.29
Ground Truth (formula):    11,478.02
Absolute Error:            5,764.72
Relative Error:            50.224%
```

```
================================================================
FINAL PERFORMANCE SUMMARY
================================================================
Final Training Loss: 0.862119
Final Test Loss:     0.864564
R² Score:            0.1391
Total Epochs Run:    300
```

ReLu 0.01 100 epochs

```
Training Neural Network with your specific configuration...
Starting training...
Architecture: 1 → 96 → 96 → 1
Learning Rate: 0.01
Max Epochs: 100, Early Stopping Patience: 10
--------------------------------------------------------
Epoch  20: Train Loss = 0.921234, Test Loss = 0.919085
Epoch  40: Train Loss = 0.815125, Test Loss = 0.812463
Epoch  60: Train Loss = 0.710431, Test Loss = 0.707059
Epoch  80: Train Loss = 0.611627, Test Loss = 0.607842
Epoch 100: Train Loss = 0.515813, Test Loss = 0.511717
```
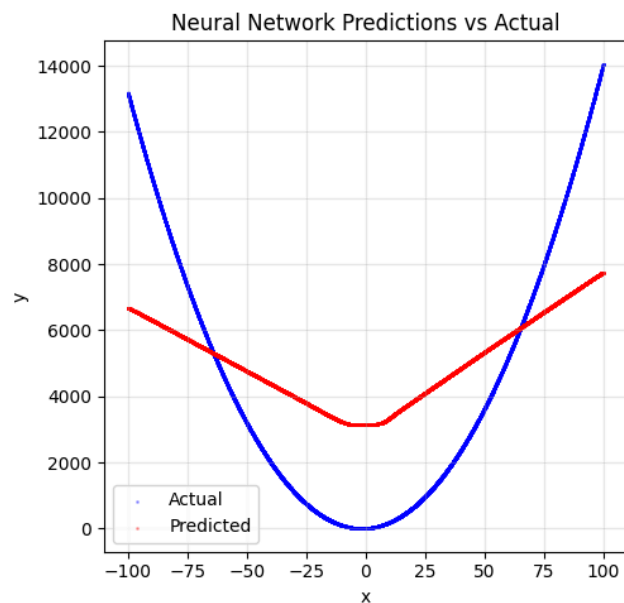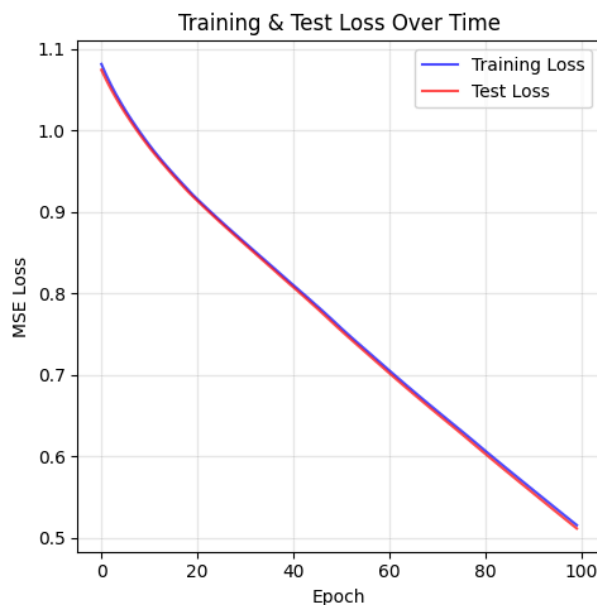


```
============================================================
PREDICTION RESULTS FOR x = 90.2
============================================================
Neural Network Prediction: 7,290.78
Ground Truth (formula):    11,478.02
Absolute Error:            4,187.23
Relative Error:            36.480%
```
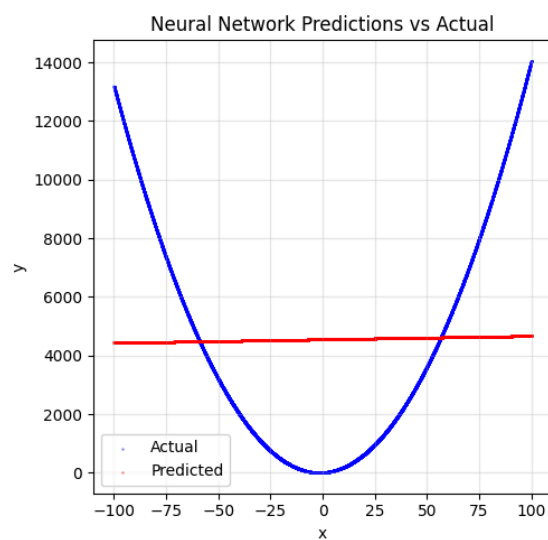
```
================================================================
FINAL PERFORMANCE SUMMARY
================================================================
Final Training Loss: 0.515813
Final Test Loss:     0.511717
R² Score:            0.4905
Total Epochs Run:    100
```

Sigmoid lr 0.01 epochs 100

```
print("Training Neural Network with your specific configuration...")
weights, train_losses, test_losses = train_neural_network(
    X_train_scaled, Y_train_scaled, X_test_scaled, Y_test_scaled,
    epochs=100, patience=10
)
```

```
Training Neural Network with your specific configuration...
Starting training...
Architecture: 1 → 96 → 96 → 1
Learning Rate: 0.01
Max Epochs: 100, Early Stopping Patience: 10
-------------------------------------------------
Epoch  20: Train Loss = 0.998492, Test Loss = 1.003125
Epoch  40: Train Loss = 0.998441, Test Loss = 1.003086
Epoch  60: Train Loss = 0.998391, Test Loss = 1.003048
Epoch  80: Train Loss = 0.998342, Test Loss = 1.003011
Epoch 100: Train Loss = 0.998295, Test Loss = 1.002974
```
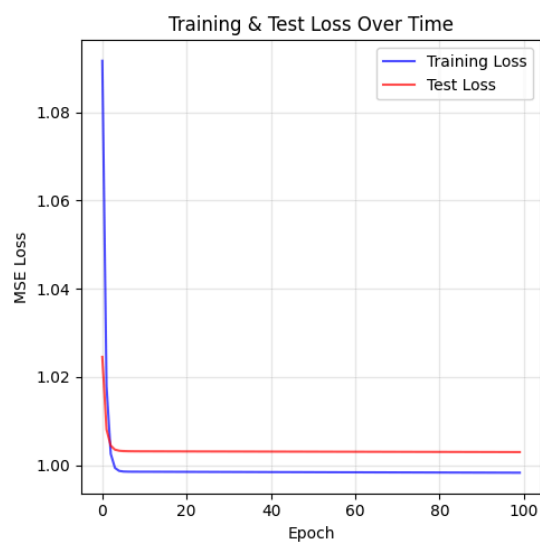
```
================================================================
PREDICTION RESULTS FOR x = 90.2
================================================================
Neural Network Prediction: 4,659.55
Ground Truth (formula):    11,478.02
Absolute Error:            6,818.47
Relative Error:            59.405%
```

```
===============================================================
FINAL PERFORMANCE SUMMARY
===============================================================
Final Training Loss: 0.998295
Final Test Loss:     1.002974
R² Score:            0.0013
Total Epochs Run:    100
```

Sigmoid lr 0.001 epochs 400

```
⇥  Training Neural Network with your specific configuration...
   Starting training...
   Architecture: 1 → 96 → 96 → 1
   Learning Rate: 0.001
   Max Epochs: 400, Early Stopping Patience: 10
   --------------------------------------------------
   Epoch  20: Train Loss = 1.009672, Test Loss = 1.014539
   Epoch  40: Train Loss = 0.999721, Test Loss = 1.004686
   Epoch  60: Train Loss = 0.998653, Test Loss = 1.003419
   Epoch  80: Train Loss = 0.998534, Test Loss = 1.003211
   Epoch 100: Train Loss = 0.998517, Test Loss = 1.003162
   Epoch 120: Train Loss = 0.998510, Test Loss = 1.003146
   Epoch 140: Train Loss = 0.998505, Test Loss = 1.003139
   Epoch 160: Train Loss = 0.998500, Test Loss = 1.003134
   Epoch 180: Train Loss = 0.998494, Test Loss = 1.003129
   Epoch 200: Train Loss = 0.998489, Test Loss = 1.003125
   Epoch 220: Train Loss = 0.998484, Test Loss = 1.003121
   Epoch 240: Train Loss = 0.998479, Test Loss = 1.003117
   Epoch 260: Train Loss = 0.998474, Test Loss = 1.003113
   Epoch 280: Train Loss = 0.998469, Test Loss = 1.003109
   Epoch 300: Train Loss = 0.998464, Test Loss = 1.003105
   Epoch 320: Train Loss = 0.998459, Test Loss = 1.003102
   Epoch 340: Train Loss = 0.998454, Test Loss = 1.003098
   Epoch 360: Train Loss = 0.998449, Test Loss = 1.003094
   Epoch 380: Train Loss = 0.998444, Test Loss = 1.003090
   Epoch 400: Train Loss = 0.998438, Test Loss = 1.003086
```
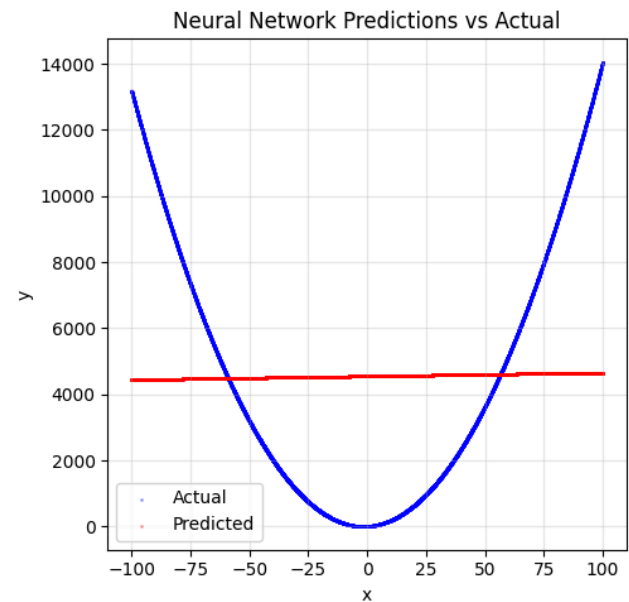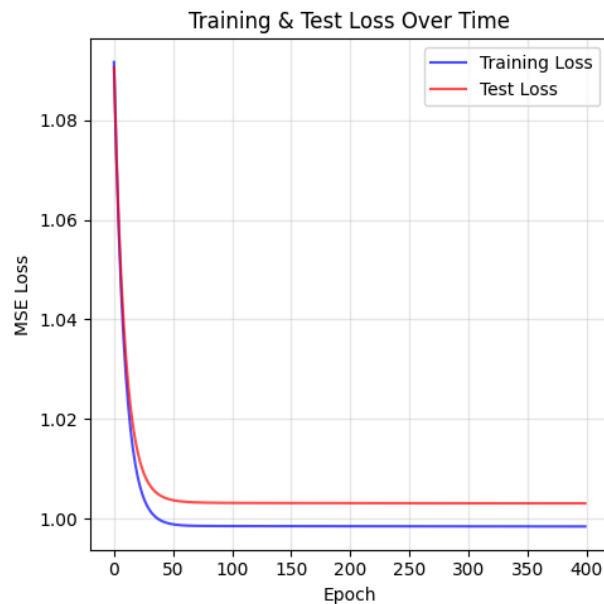
```
============================================================
PREDICTION RESULTS FOR x = 90.2
============================================================
Neural Network Prediction: 4,649.68
Ground Truth (formula):    11,478.02
Absolute Error:            6,828.33
Relative Error:            59.491%
```

```
============================================================
FINAL PERFORMANCE SUMMARY
============================================================
Final Training Loss: 0.998438
Final Test Loss:     1.003086
R² Score:            0.0012
Total Epochs Run:    400
```

experiments results:

	A	B	C	D	E	F	G	H
1	Experiment	Learning Rate	No. of Epochs	Optimizer (if use	Activation Functi	Final Training Lo	Final Test Loss	R² Score
2	ReLU (baseline)	0.003	500	Gradient Descen	ReLU	0.301565	0.299981	0.7013
3	ReLU (300 epocl	0.003	300	Gradient Descen	ReLU	0.558904	0.558295	0.4441
4	ReLU (lr=0.001,	0.001	300	Gradient Descen	ReLU	0.862119	0.864564	0.1391
5	ReLU (lr=0.01, 1	0.01	100	Gradient Descen	ReLU	0.515813	0.511717	0.4985
6	Sigmoid (lr=0.01	0.01	100	Gradient Descen	Sigmoid	0.998295	1.002974	0.0013
7	Sigmoid (lr=0.00	0.001	400	Gradient Descen	Sigmoid	0.998438	1.003086	0.0012

Key Insights

Best Performing Model → ReLU (baseline, lr=0.003, 500 epochs)

Final Training Loss: 0.3016

Final Test Loss: 0.3000

R² Score: 0.7013 (highest of all)

This shows the best fit and generalization.

Reason:

ReLU avoids saturation (unlike Sigmoid).

Adequate epochs (500) allowed the network to converge steadily.

Learning rate of 0.003 was neither too high nor too low, providing a good balance.

Worst Performing Models → Sigmoid activations

Sigmoid (lr=0.01, 100 epochs): R² = 0.0013

Sigmoid (lr=0.001, 400 epochs): R² = 0.0012

These essentially failed to learn.

Reason:

Sigmoid suffers from the vanishing gradient problem, especially with deeper networks (2 hidden layers here).

Gradients become tiny for large |z|, slowing down or stopping learning.

Even with more epochs (400), the loss stayed ~1.0, showing the model didn't improve.