Quantum-Based Binary Classification of Histological Images of Salivary Glands with Sjögren Syndrome

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Quantum Computer Programming – 2023-2

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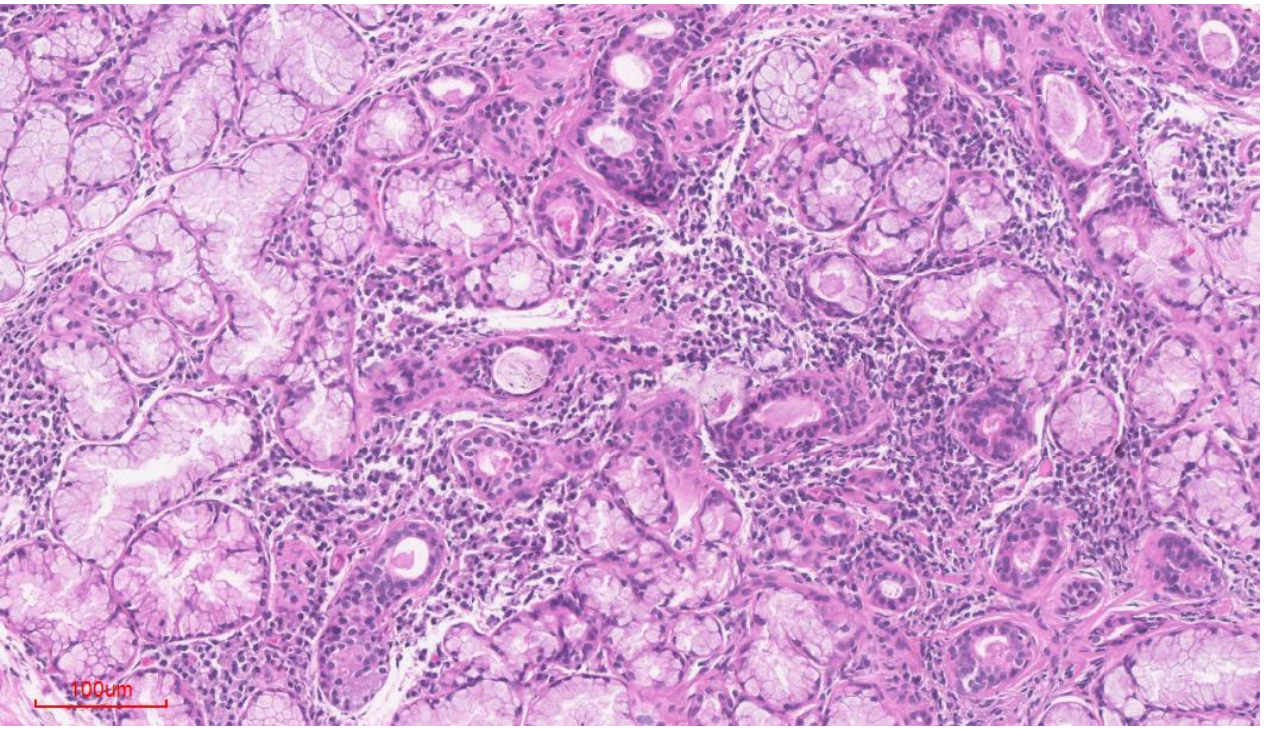
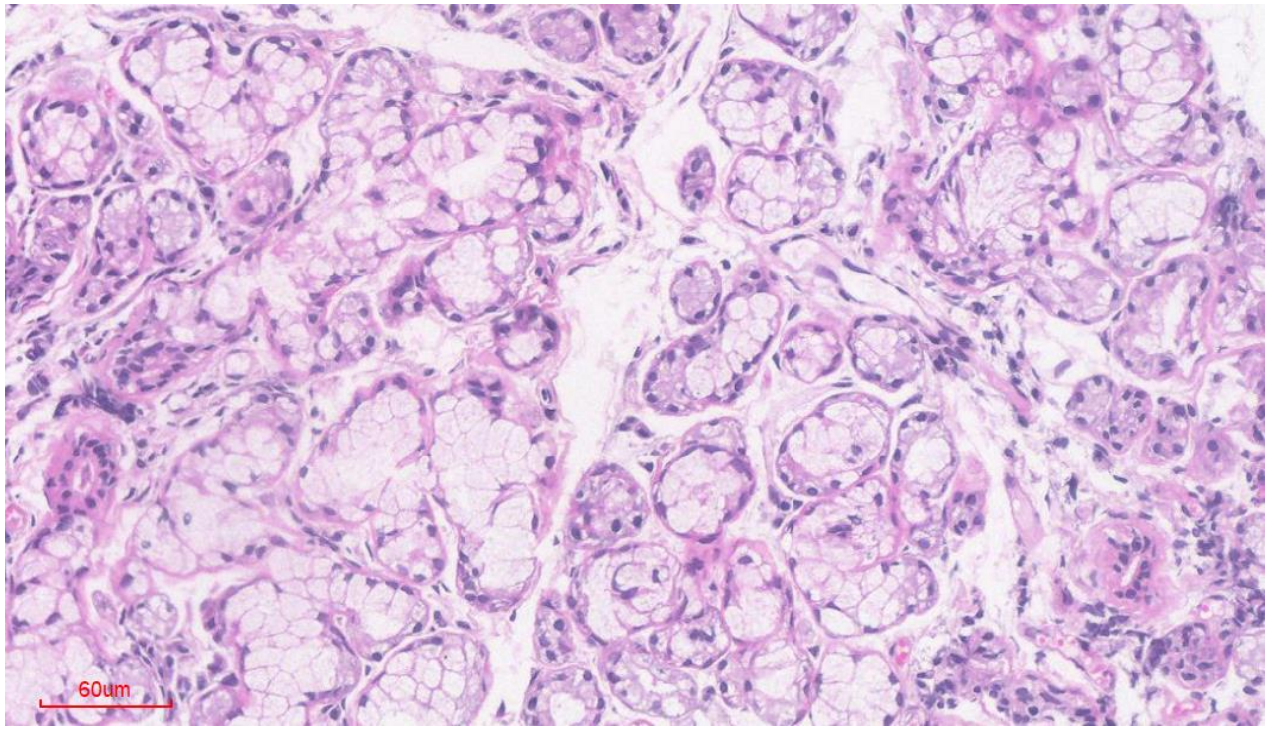
Dataset



Syndrome
200 images



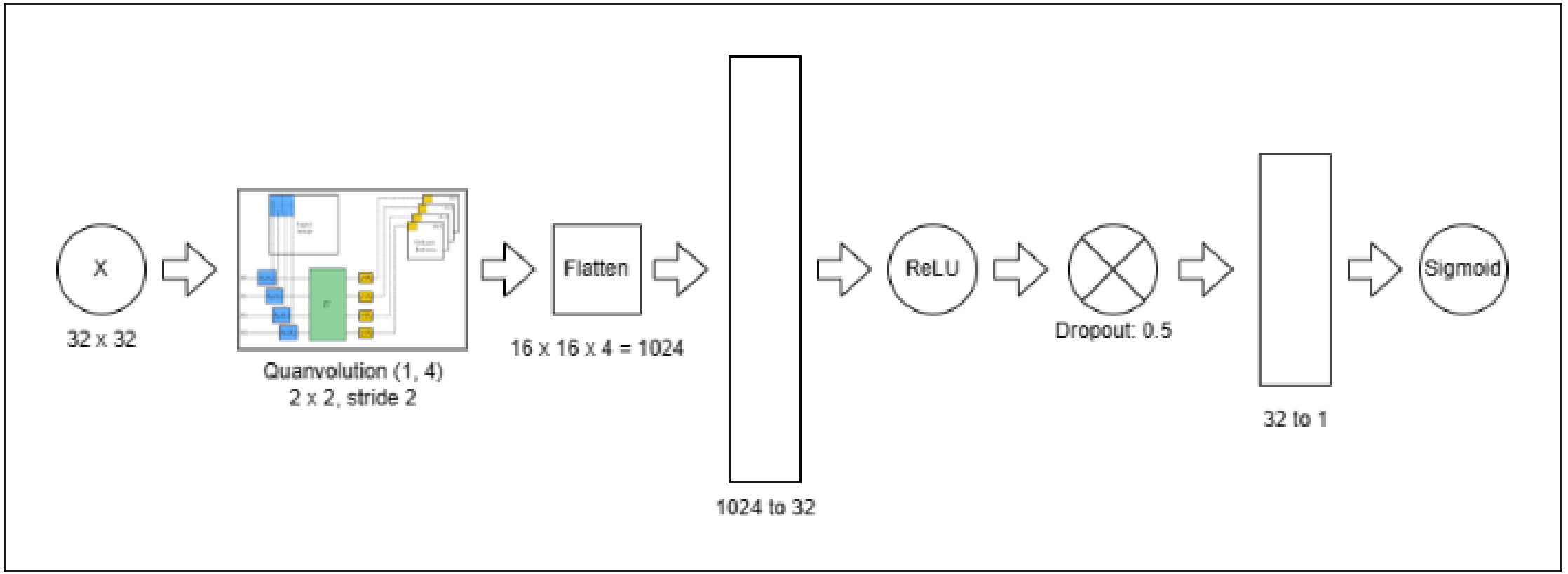
Non-Syndrome
200 images

Objectives

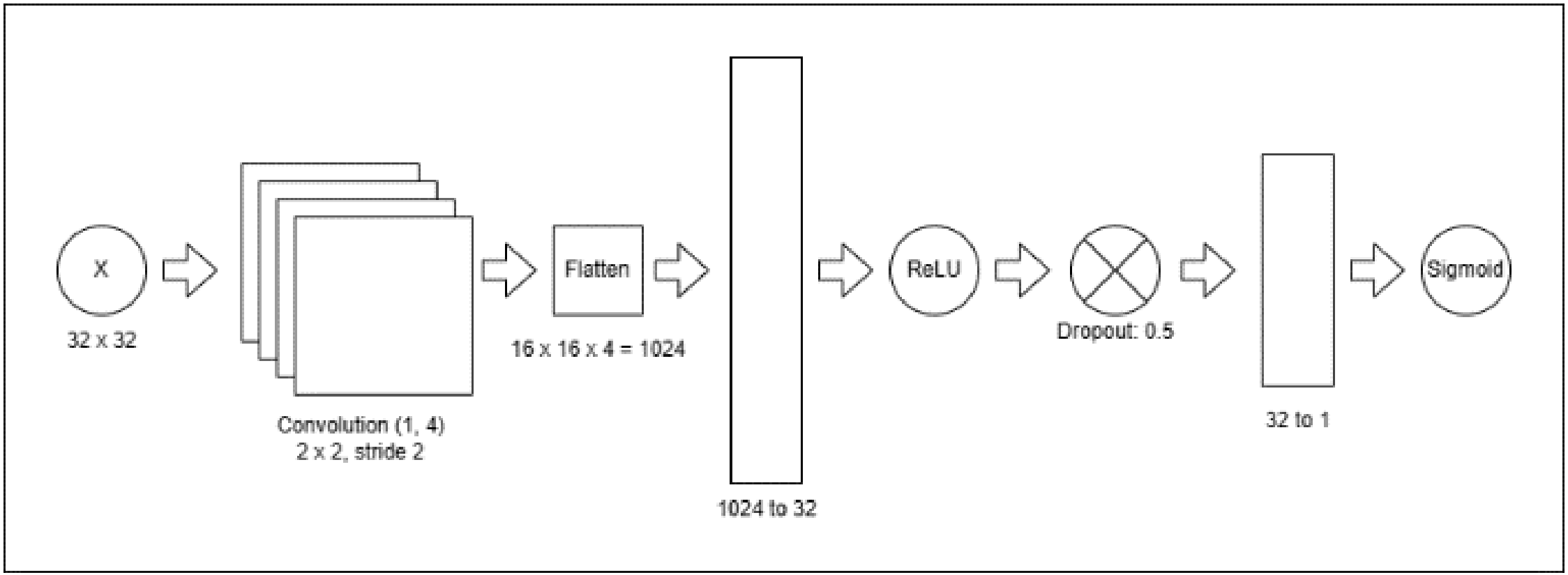
1. Evaluate and contrast the performance of two neural networks architectures –QNN and CNN– for classifying the dataset

2. Explore quantum transfer learning approaches for classifying the dataset

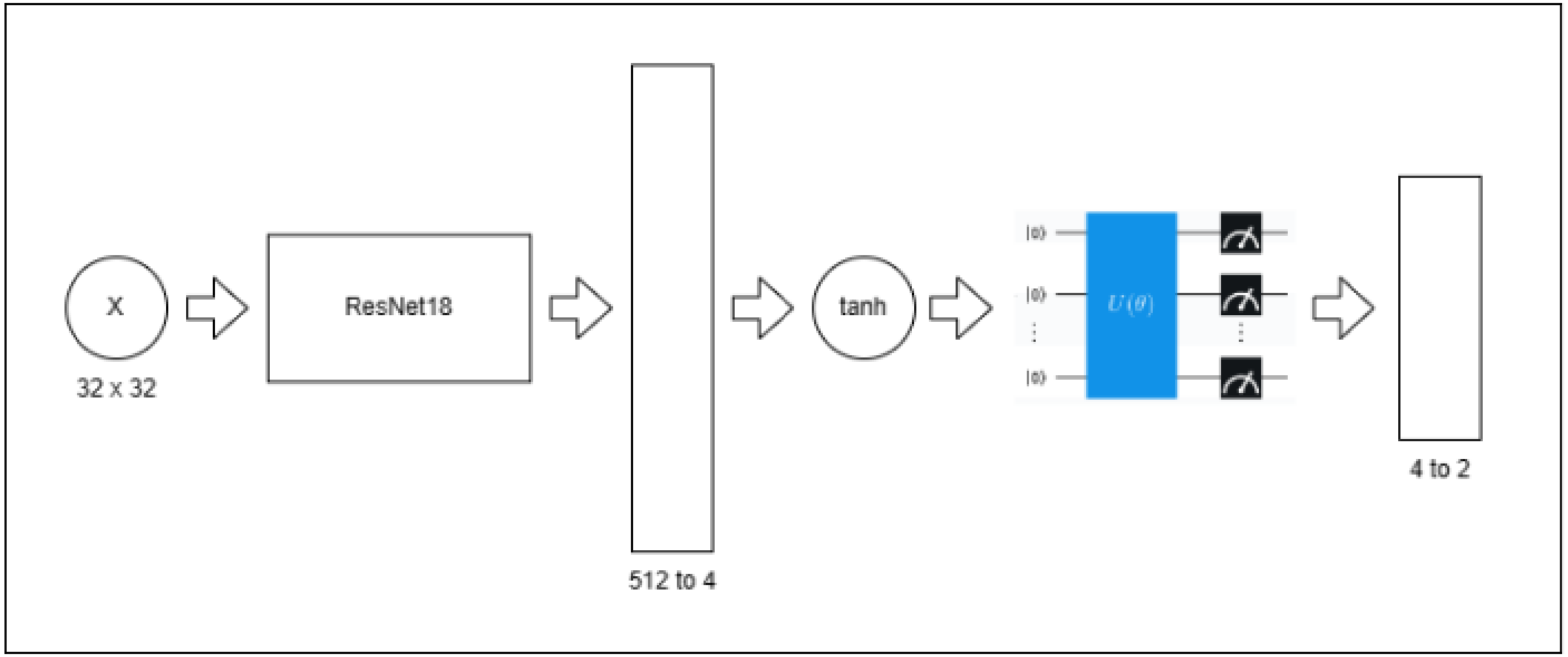
Architectures: QNN



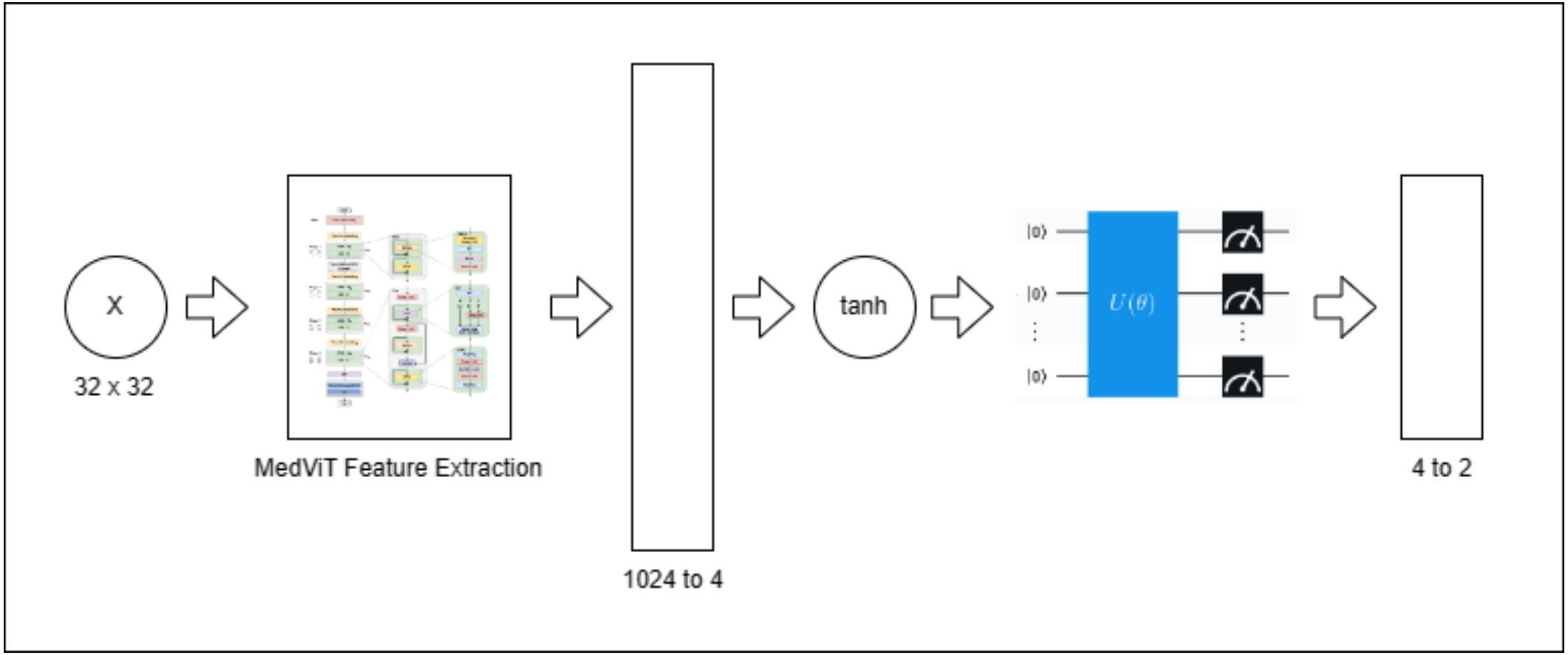
Architectures: CNN



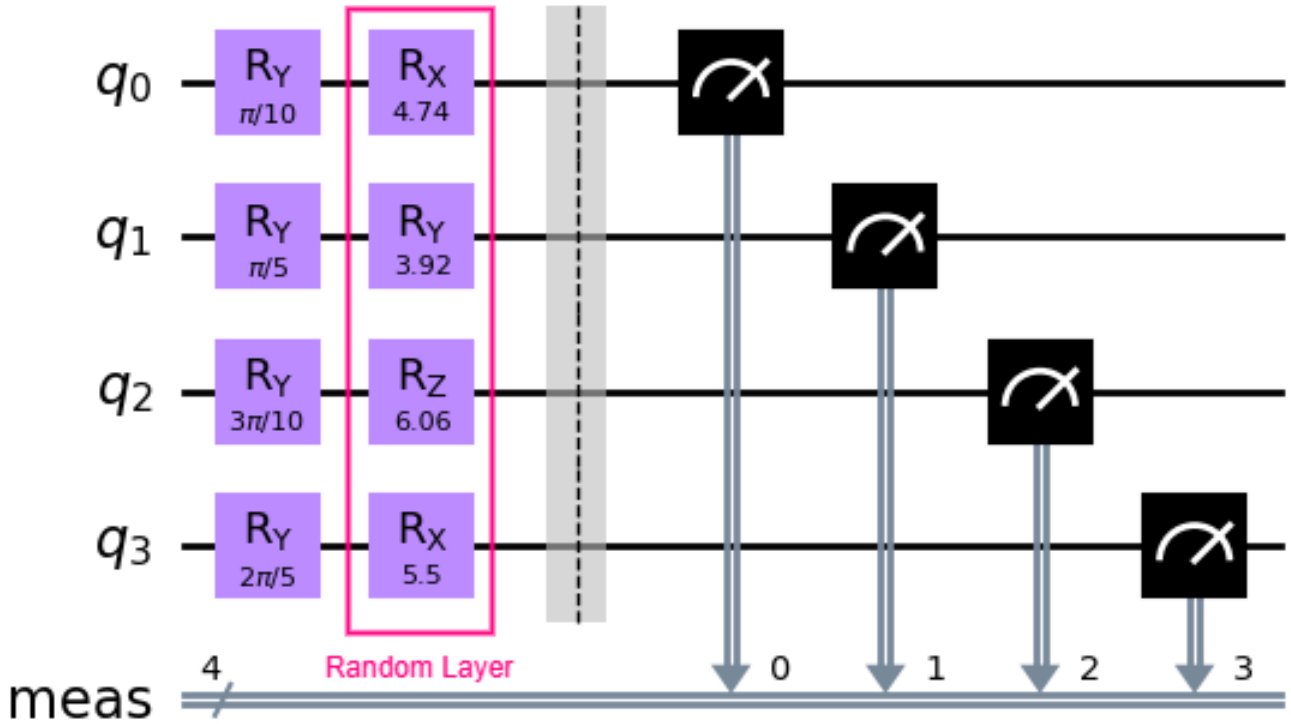
Architectures: ResNet18 Transfer Learning



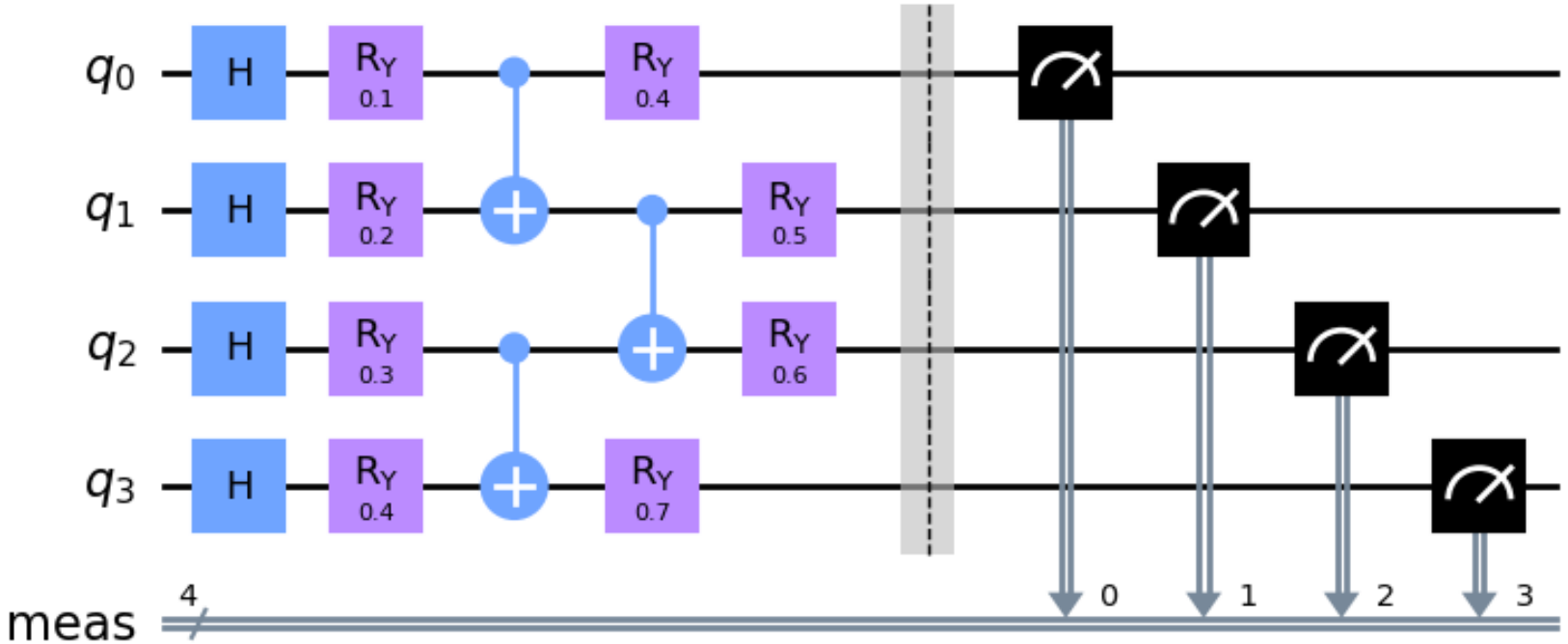
Architectures: MedViT Transfer Learning



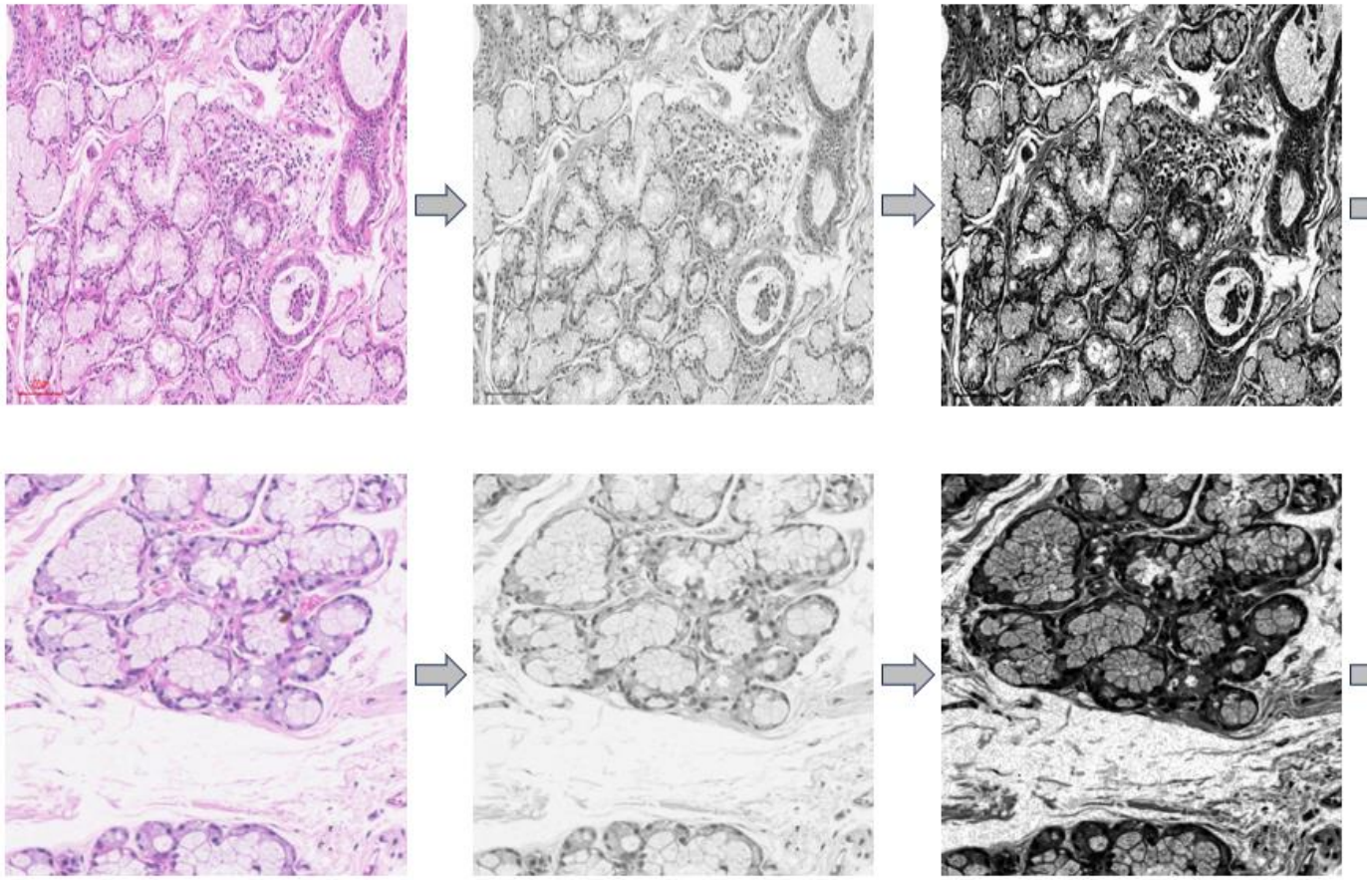
Quantum Circuits: Quanvolutional Layer



Quantum Circuits: Transfer Learning VQC

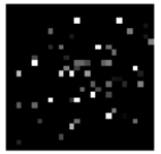
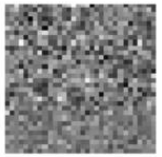


Data Preprocessing

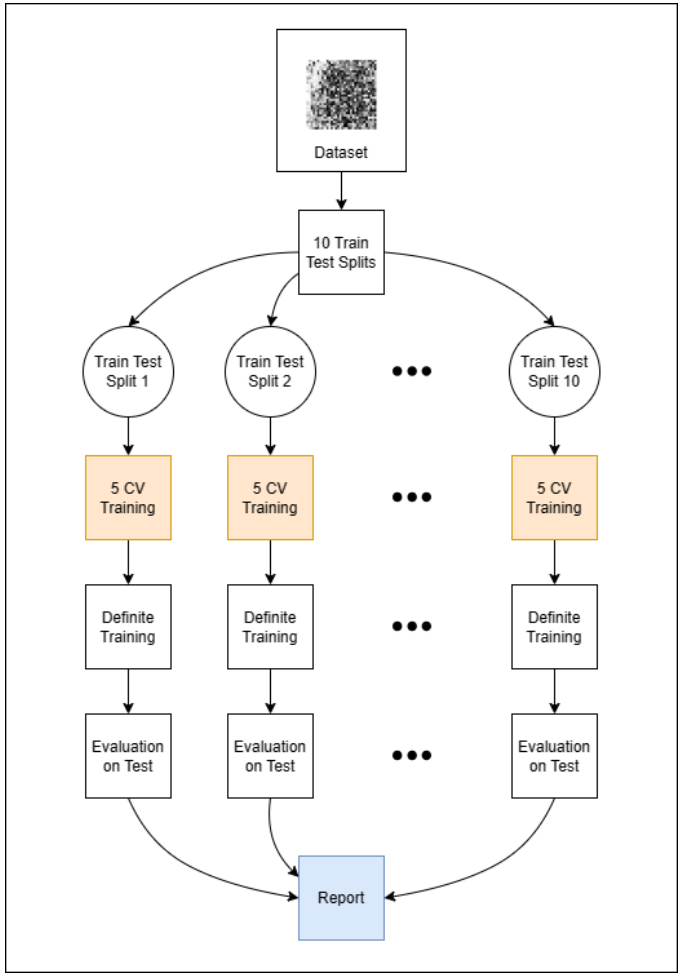


Resize Grayscale Histogram Equalization

Experiments

Exp.	Dataset	Conv. Layers
1	Downsampled (28 x 28) 	1
2	Original (32 x 32) 	1
3	MedViT Features (32 x 32) 	1
4	Original Augmented (32 x 32)	1
5	Original (32 x 32)	2

QNN/CNN Training



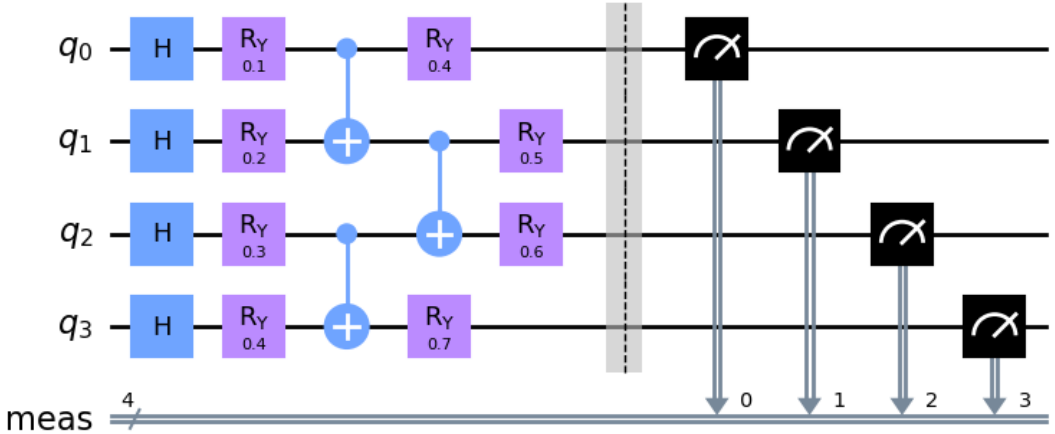
Hyperparameter	Value
Training Data Proportion	80%
Test Data Proportion	20%
Different Train Test Splits	10
Train Test Splits Seeds	1, 2, …, 10
Folds (K)	5
Loss Function	Binary Cross Entropy
Optimizer	Adam
Cross-Validation (CV) Epochs	30
Definite Training Epochs	CV Minimum Loss Epoch
Cross-Validation Folds Seed	42
Batch Size	32
L_2 Regularization Rate	0.01
Learning Rate	0.001
Dropout Rate	0.5
MLP Hidden Layer Size	32
Convolution 1 Input Channels	1
Conv. 1 Output Channels	4
Q-Circuit Random Layers	1
Q-Circuit Params. Seed	0

QNN/CNN Grid Search

Hyperparameter	Explored Values
L_2 Regularization Rate	0.01, 0.001
Learning Rate	0.001, 0.005
Dropout Rate	0.3, 0.5, 0.7
MLP Hidden Layer Size	32, 64, 128

Exp.	Dataset	Conv. Layers
6	Original (32 x 32)	1

Transfer Learning Training

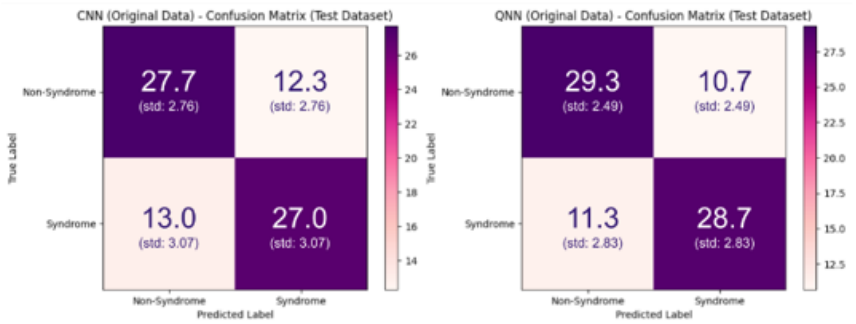


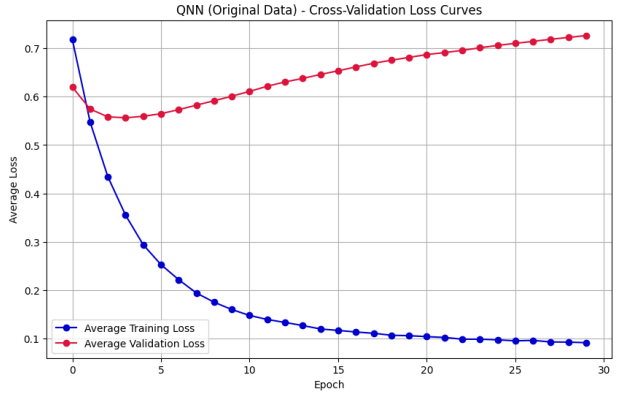
HYPERPARAMETER	VALUE
VQC Qubits	4
Learning Rate	0.0004
Batch Size	4
Epochs	8, 30
VQC Depth	6
Learning Rate Reduction	0.1, 10 epochs
Optimizer	Adam
Loss Function	Binary Cross Entropy
Initial VQC Params. Spread	0.01
Training Data Proportion	80%
Test Data Proportion	20%
Random Numbers Seed	42

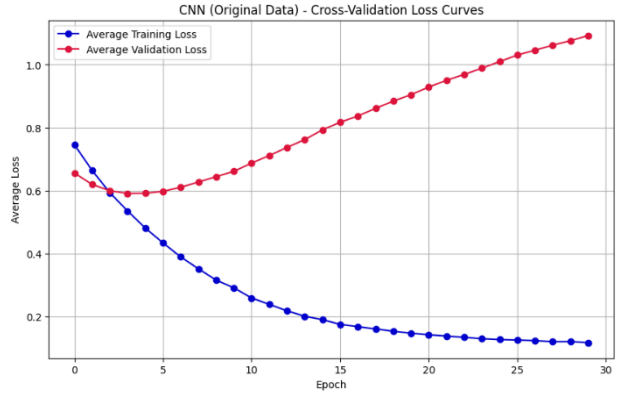
Results: QNN/CNN (Original Data)

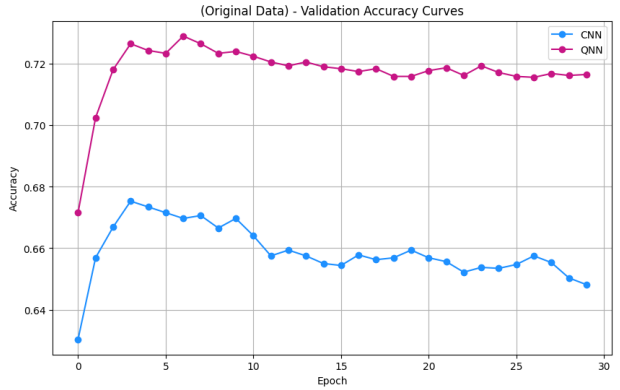
CNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.68375000	0.04403479
Precision	0.68867611	0.04511589
Recall	0.67500000	0.07664855
F1-Measure	0.67943166	0.05205518

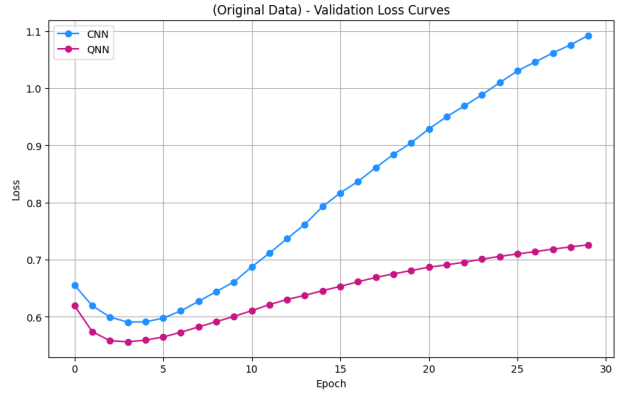
QNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.72500000	0.05031153
Precision	0.72934754	0.05366285
Recall	0.71750000	0.07075486
F1-Measure	0.72203763	0.05587977







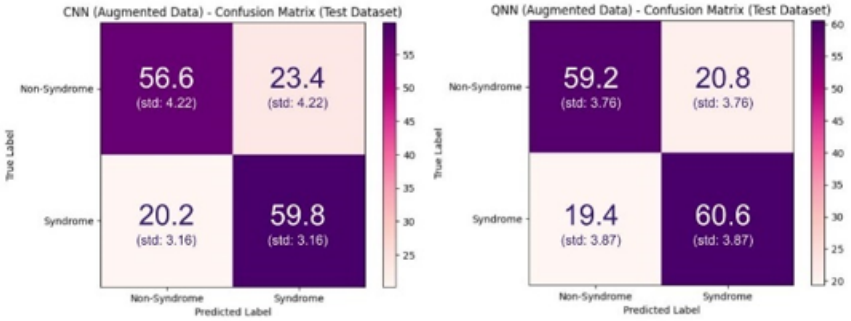


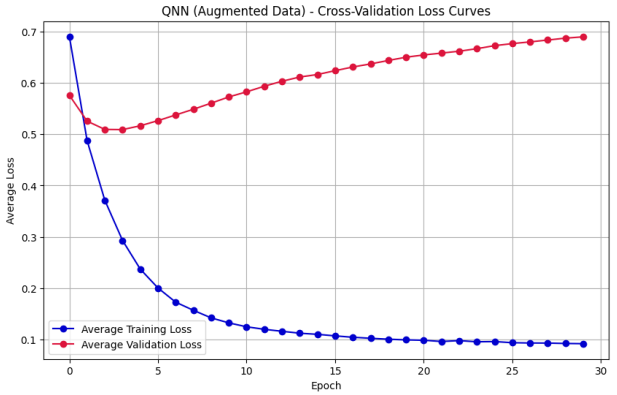


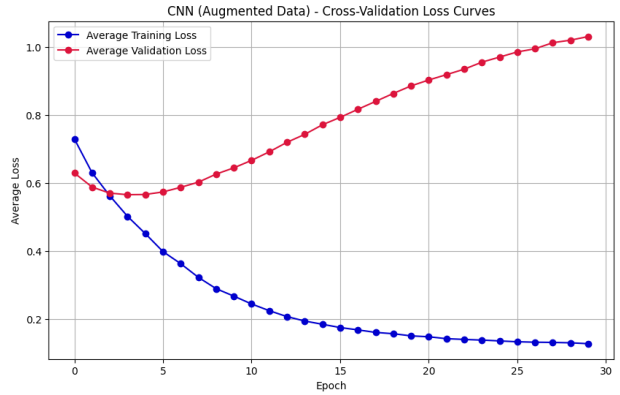
Results: QNN/CNN (Augmented Data)

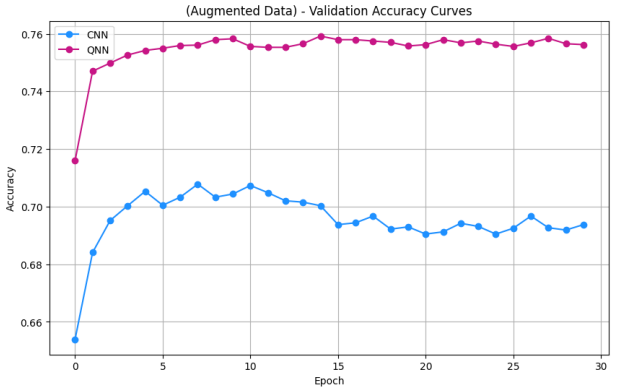
CNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.72750000	0.02549510
Precision	0.72049573	0.03360504
Recall	0.74750000	0.03944933
F1-Measure	0.73274624	0.02445090

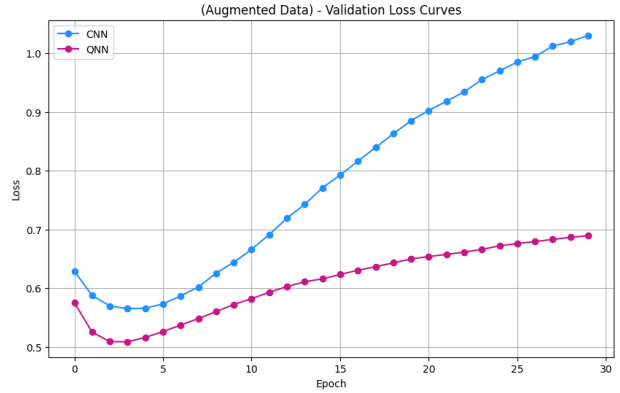
QNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.74875000	0.03398069
Precision	0.74547040	0.03694686
Recall	0.75750000	0.04847680
F1-Measure	0.75062043	0.03507490







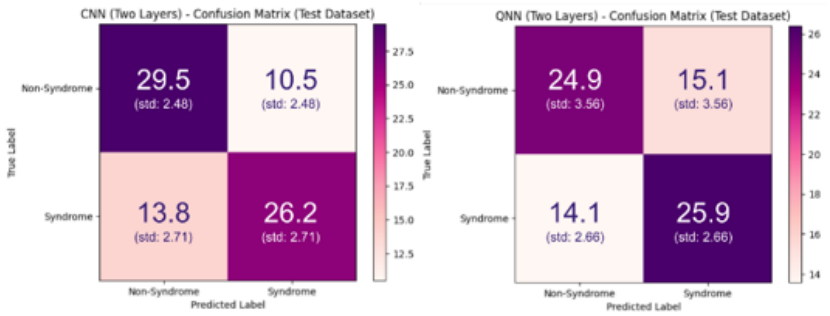


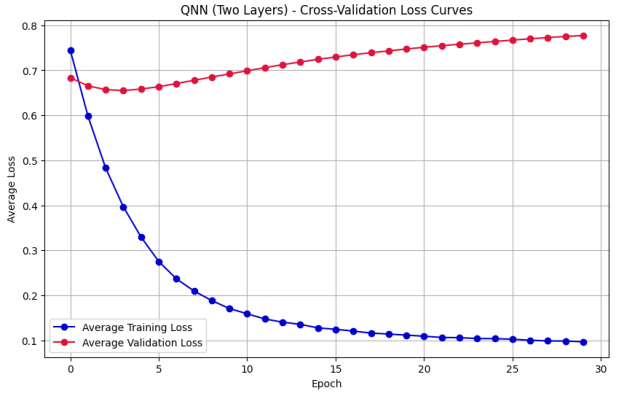


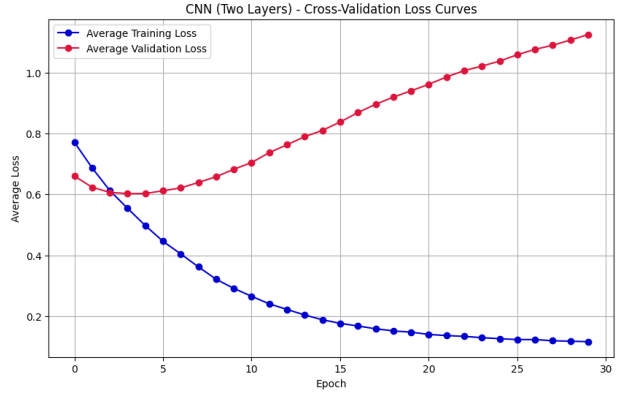
Results: QNN/CNN (Two Layers)

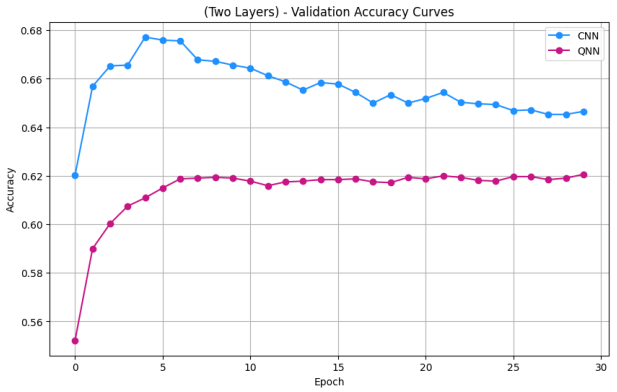
CNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.69625000	0.04147665
Precision	0.71524554	0.04614958
Recall	0.65500000	0.06782330
F1-Measure	0.68199583	0.04917103

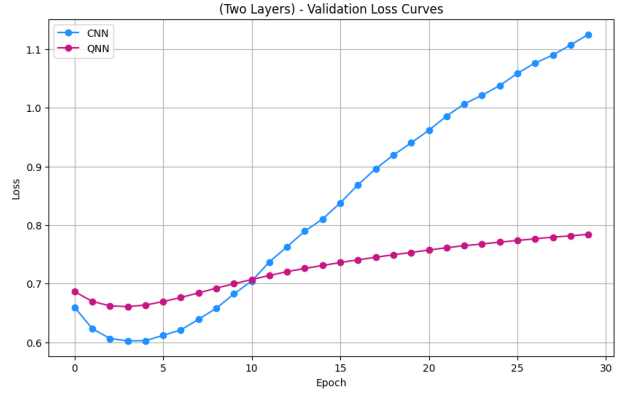
QNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.63500000	0.04286607
Precision	0.63582378	0.05159591
Recall	0.64750000	0.06656763
F1-Measure	0.63882870	0.04160278







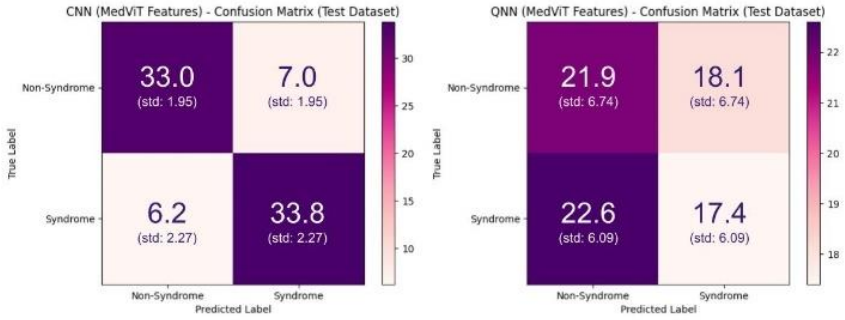


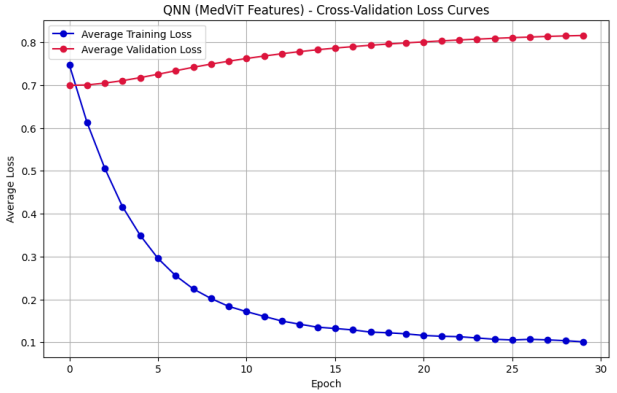


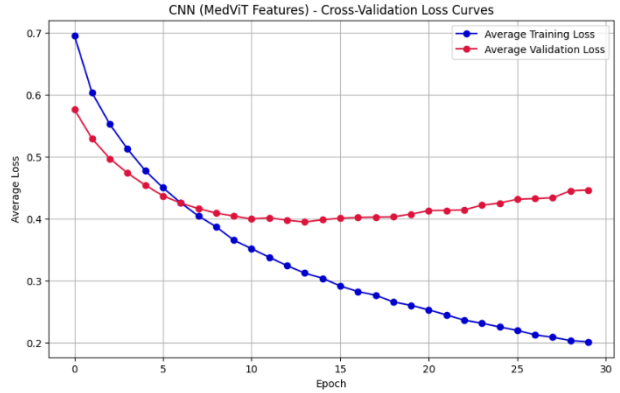
Results: QNN/CNN (MedViT Features)

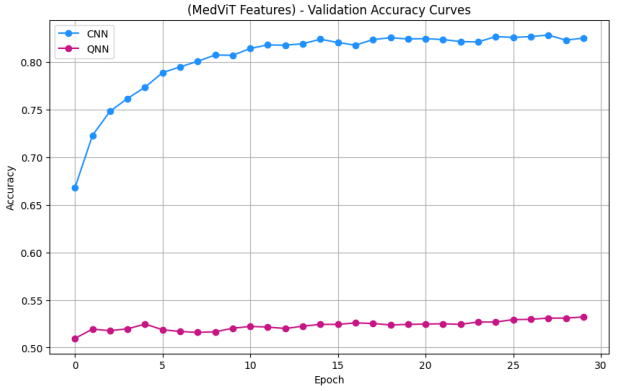
CNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.83500000	0.03000000
Precision	0.83042896	0.03712276
Recall	0.84500000	0.05678908
F1-Measure	0.83610966	0.03178865

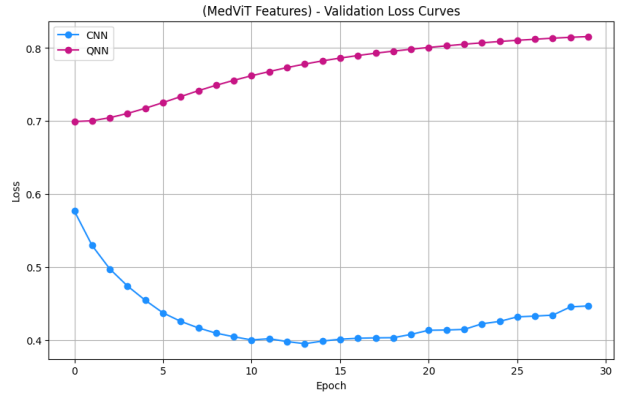
QNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.49125000	0.03012993
Precision	0.49649785	0.05420779
Recall	0.43500000	0.15215124
F1-Measure	0.44762876	0.08414821











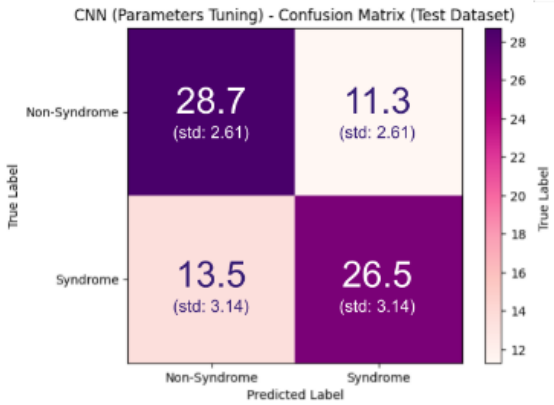
Results: QNN/CNN (Grid Search)

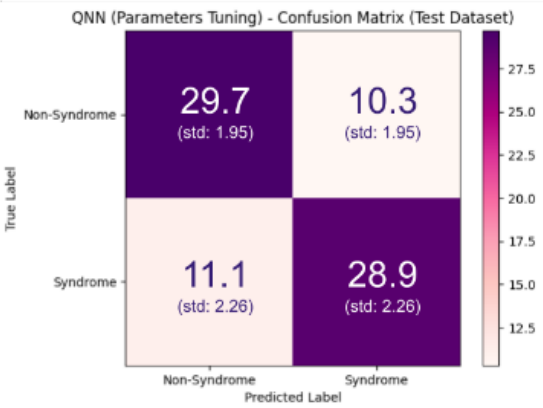
CNN Grid Search Results	
Parameter	**Value**
Learning Rate	0.001
Dropout Rate	0.3
L_2 Regularization Rate	0.01
MLP Hidden Layer Size	128
Best F1-Measure	0.72994769

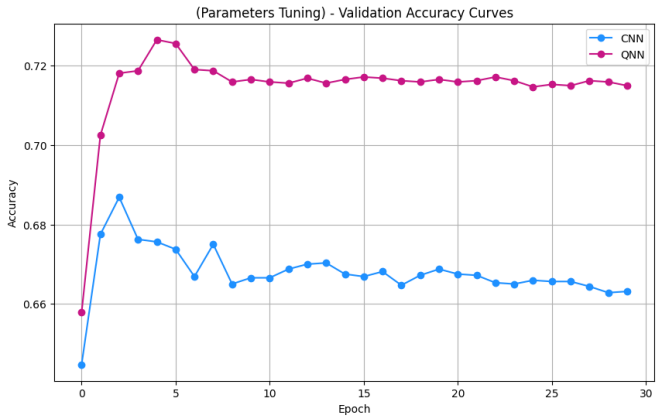
CNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.69000000	0.03699662
Precision	0.70399016	0.04454081
Recall	0.66250000	0.07846177
F1-Measure	0.67933588	0.04724284

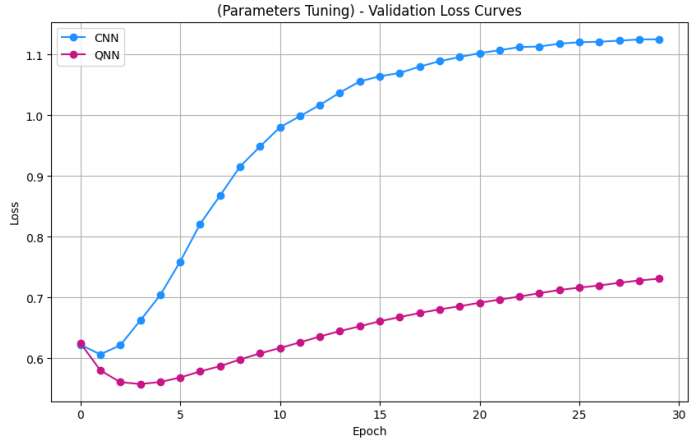
QNN Grid Search Results	
Parameter	**Value**
Learning Rate	0.001
Dropout Rate	0.5
L_2 Regularization Rate	0.01
MLP Hidden Layer Size	32
Best F1-Measure	0.75269634

QNN Average Performance on the Test Dataset		
Metric	**Average**	**Std. Dev.**
Accuracy	0.73250000	0.03674235
Precision	0.73832343	0.04004196
Recall	0.72250000	0.05640257
F1-Measure	0.72920578	0.03978096

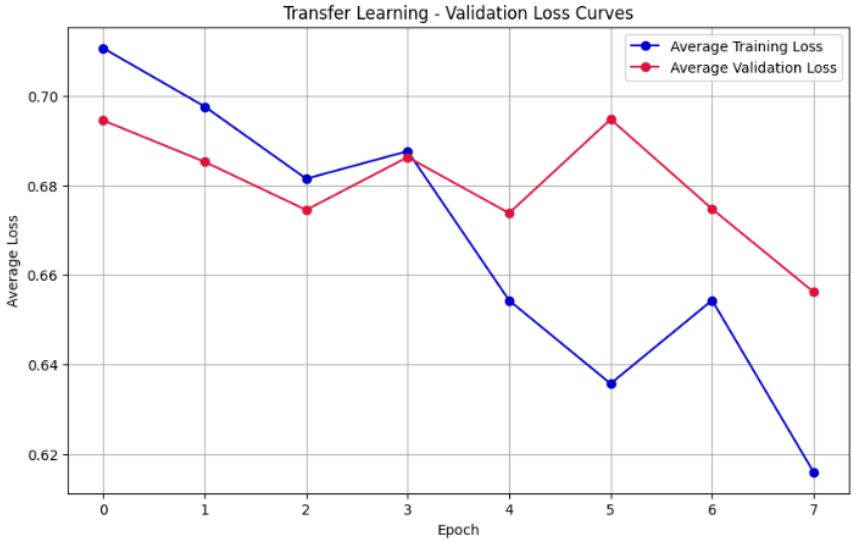


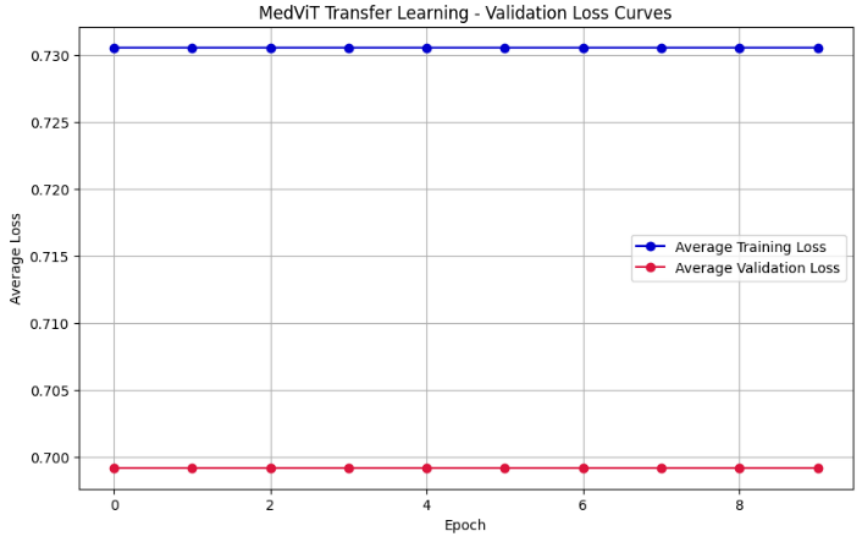


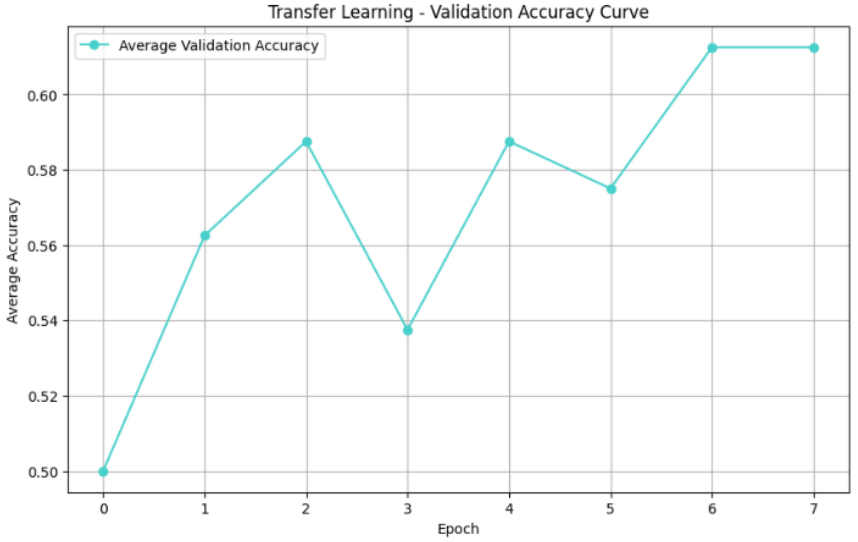


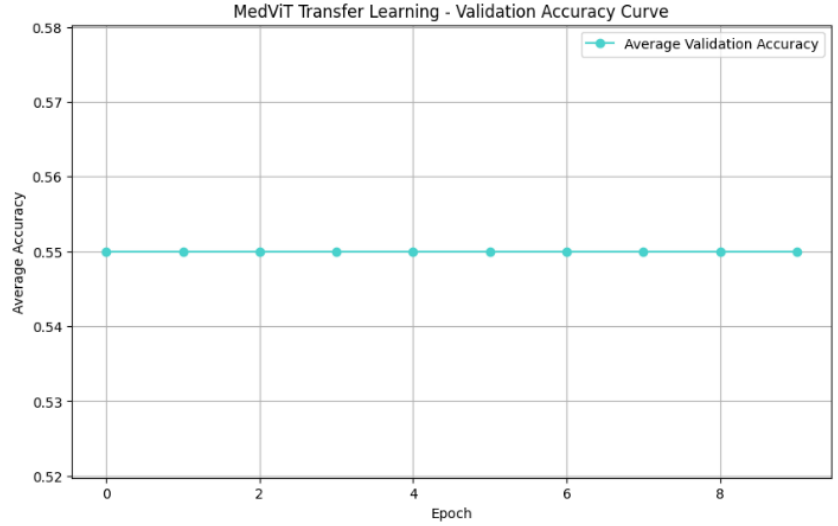


Results: Transfer Learning









Conclusions

- Apparent QNN Superiority
- MedViT Features Not Working in Quantum Approaches
- Data Augmentation Increases QNN Peformance
- Extra Quanvolutional Layer Reduces Performance
- Future Work:
  - Data Augmentation + Tuning,
  - Pre-Set Circuits,
  - QNN Layer Parameters Exploration,
  - MedViT Features Leverage in Quantum Approaches,
  - Transfer Learning Approaches Experimentation