In [1]:
```
# Import Packages
import keras
from keras.datasets import mnist
from keras.models import Sequential
from keras.optimizers import RMSprop
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPooling2D
from keras import backend
```

In [2]:
```
# Import For Plotting (not part of assignment - for my own personal reference)
import matplotlib.pyplot as  plt
%matplotlib inline
```

In [3]:
```
%%capture
# Create Data
# input image dimensions
img_rows, img_cols = 28, 28

# the data, shuffled and split between train and test sets
(x_train, y_train), (x_test, y_test) = mnist.load_data()

if backend.image_data_format() == 'channels_first':
    x_train = x_train.reshape(x_train.shape[0], 1, img_rows, img_cols)
    x_test = x_test.reshape(x_test.shape[0], 1, img_rows, img_cols)
    input_shape = (1, img_rows, img_cols)
else:
    x_train = x_train.reshape(x_train.shape[0], img_rows, img_cols, 1)
    x_test = x_test.reshape(x_test.shape[0], img_rows, img_cols, 1)
    input_shape = (img_rows, img_cols, 1)

x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
x_train /= 255
x_test /= 255
print('x_train shape:', x_train.shape)
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')
```

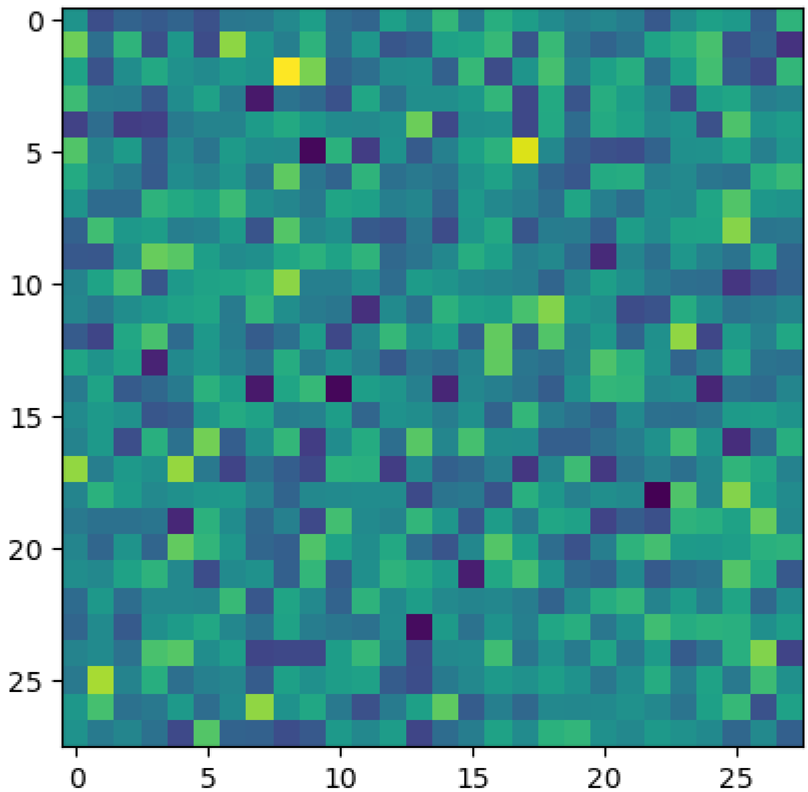
In [4]:
```
import numpy as np
# Normalization
mean = np.mean(x_train)
std = np.std(x_train)
x_train_norm = (x_train - mean) / std

mean = np.mean(x_test)
std = np.std(x_test)
x_test_norm = (x_test - mean) / std
```

In [5]:
```
%%capture
## Add Noise to Dataset
# Noise is added here

# Generate random noise with the same shape as the image
import numpy as np
mean = 0.0
stddev = 3.0
noise = np.random.normal(mean, stddev, x_train.shape)
```

```
# Generate random noise with the same shape as the image
x_train_noise = np.random.normal(mean, stddev, x_train.shape)
x_test_noise = np.random.normal(mean, stddev, x_test.shape)

# Add noise
x_train_noise_added = x_train_noise + x_train_noise
x_test_noise_added  = x_test_noise  + x_test_noise

# Add noise
x_test_noise[1]
```

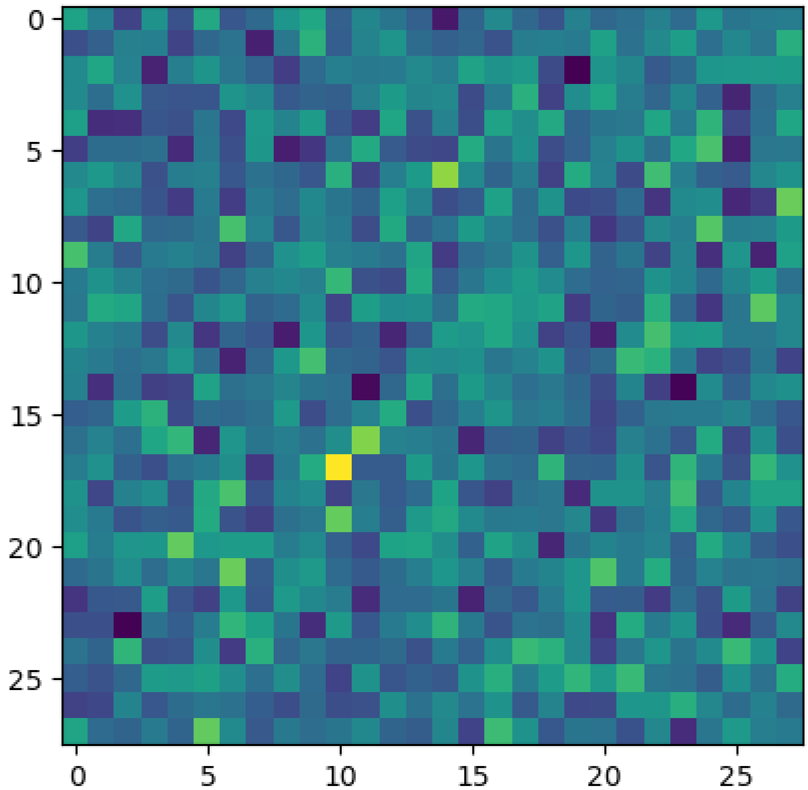
In [6]:
```
# Verify noises themselves are different
plt.imshow(x_train_noise[1])
```

Out[6]: <matplotlib.image.AxesImage at 0x255f0afcdc0>



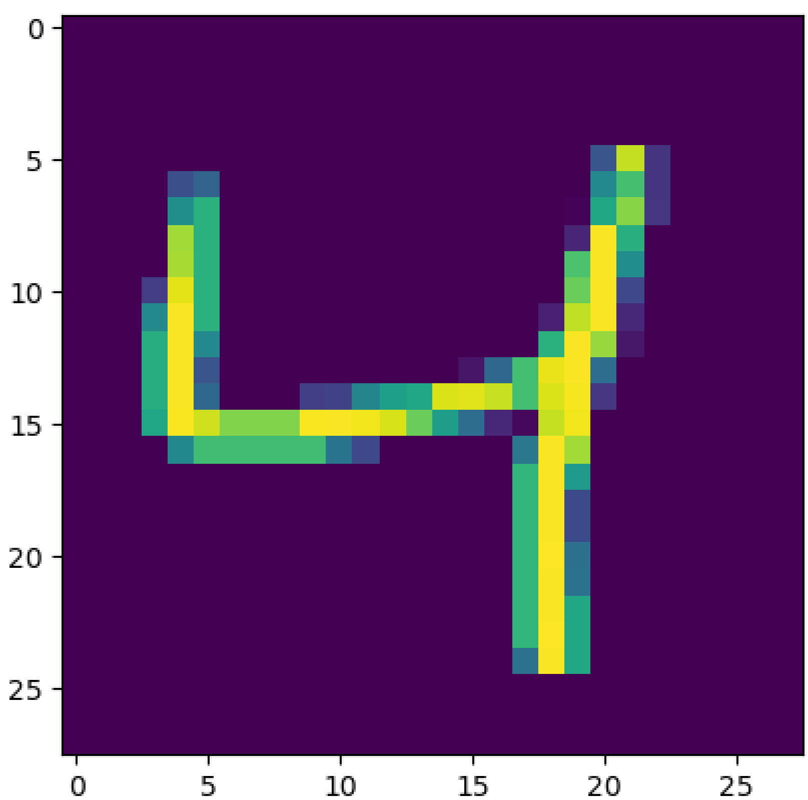
In [7]:
```
# Comparison to next 'frame' of noise
plt.imshow(x_train_noise[2])
```

Out[7]: <matplotlib.image.AxesImage at 0x255800b0160>



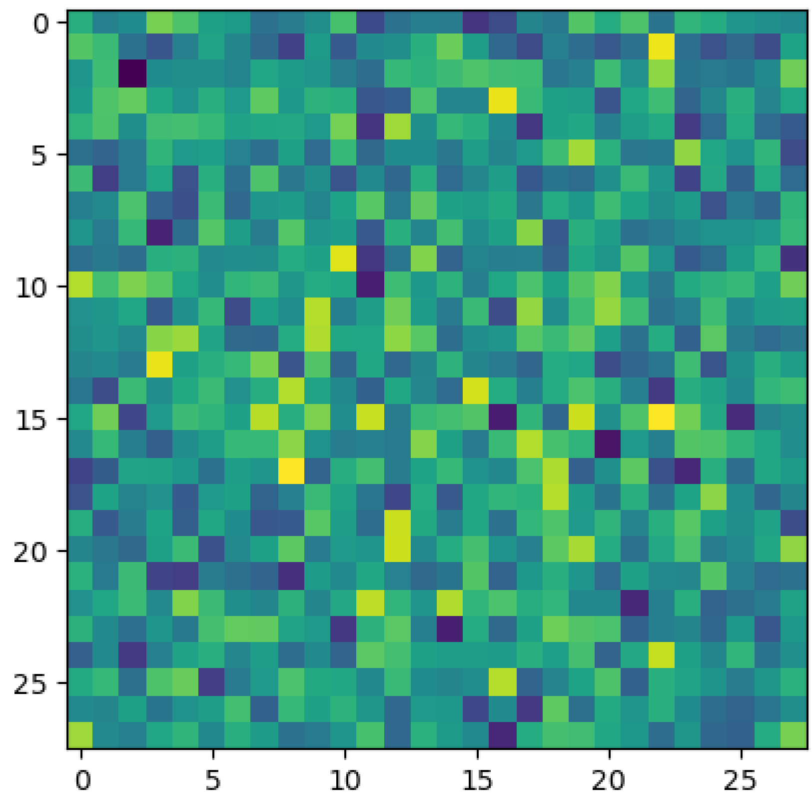
In [8]:
```
# Compare No-Noise to Noise Image
# Image without noise
plt.imshow(x_train[2])
```

Out[8]: <matplotlib.image.AxesImage at 0x255802616f0>



In [23]:
```
# Same image with noise
# Noting that I added a significant amount of noise (stddev = 3) to highlight the diff
plt.imshow(x_train_noise_added[2])
```

Out[23]: <matplotlib.image.AxesImage at 0x256226f5690>



In [10]:
```
# Setup Variables
batch_size = 128
num_classes = 10
epochs = 12
```

In [11]:
```
def convolutional_model(batch_size, num_classes, epochs, x_train, x_test, y_train, y_t

    # convert class vectors to binary class matrices
    y_train = keras.utils.to_categorical(y_train, num_classes)
    y_test = keras.utils.to_categorical(y_test, num_classes)

    model = Sequential()
    model.add(Conv2D(32, kernel_size=(3, 3),
                     activation='relu',
                     input_shape=input_shape))
    model.add(Conv2D(64, (3, 3), activation='relu'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Dropout(0.25))
    model.add(Flatten())
    model.add(Dense(128, activation='relu'))
    model.add(Dropout(0.5))
    model.add(Dense(num_classes, activation='softmax'))

    model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])
```

```
    model.fit(x_train, y_train,
              batch_size=batch_size,
              epochs=epochs,
              verbose=1,
              validation_data=(x_test, y_test))
    score = model.evaluate(x_test, y_test, verbose=0)
    print('Test loss:', score[0])
    print('Test accuracy:', score[1])
```

In [12]:

```
# Run Model With Noise
convolutional_model(batch_size, num_classes, epochs, x_train_noise_added, x_test_noise
```

```
Epoch 1/12
469/469 [==============================] - 46s 96ms/step - loss: 3.0367 - accuracy:
0.1004 - val_loss: 2.3446 - val_accuracy: 0.1022
Epoch 2/12
469/469 [==============================] - 43s 91ms/step - loss: 2.4623 - accuracy:
0.0999 - val_loss: 2.3068 - val_accuracy: 0.1000
Epoch 3/12
469/469 [==============================] - 43s 91ms/step - loss: 2.3459 - accuracy:
0.1019 - val_loss: 2.3030 - val_accuracy: 0.1052
Epoch 4/12
469/469 [==============================] - 43s 91ms/step - loss: 2.3199 - accuracy:
0.1022 - val_loss: 2.3026 - val_accuracy: 0.1079
Epoch 5/12
469/469 [==============================] - 43s 92ms/step - loss: 2.3123 - accuracy:
0.1026 - val_loss: 2.3026 - val_accuracy: 0.1102
Epoch 6/12
469/469 [==============================] - 43s 92ms/step - loss: 2.3089 - accuracy:
0.1054 - val_loss: 2.3026 - val_accuracy: 0.1117
Epoch 7/12
469/469 [==============================] - 44s 93ms/step - loss: 2.3064 - accuracy:
0.1054 - val_loss: 2.3026 - val_accuracy: 0.1134
Epoch 8/12
469/469 [==============================] - 52s 110ms/step - loss: 2.3062 - accuracy:
0.1046 - val_loss: 2.3026 - val_accuracy: 0.1131
Epoch 9/12
469/469 [==============================] - 49s 104ms/step - loss: 2.3052 - accuracy:
0.1073 - val_loss: 2.3026 - val_accuracy: 0.1135
Epoch 10/12
469/469 [==============================] - 42s 90ms/step - loss: 2.3048 - accuracy:
0.1073 - val_loss: 2.3026 - val_accuracy: 0.1134
Epoch 11/12
469/469 [==============================] - 48s 103ms/step - loss: 2.3045 - accuracy:
0.1100 - val_loss: 2.3026 - val_accuracy: 0.1135
Epoch 12/12
469/469 [==============================] - 43s 91ms/step - loss: 2.3043 - accuracy:
0.1093 - val_loss: 2.3025 - val_accuracy: 0.1137
Test loss: 2.302541732788086
Test accuracy: 0.1137000024318695
```

In [13]:

```
# Run Model Without Noise
convolutional_model(batch_size, num_classes, epochs, x_train, x_test, y_train, y_test)
```

```
Epoch 1/12
469/469 [==============================] - 44s 91ms/step - loss: 2.2963 - accuracy: 
0.1206 - val_loss: 2.2755 - val_accuracy: 0.2495
Epoch 2/12
469/469 [==============================] - 43s 91ms/step - loss: 2.2632 - accuracy: 
0.2123 - val_loss: 2.2356 - val_accuracy: 0.4507
Epoch 3/12
469/469 [==============================] - 44s 95ms/step - loss: 2.2222 - accuracy: 
0.3080 - val_loss: 2.1848 - val_accuracy: 0.5364
Epoch 4/12
469/469 [==============================] - 42s 90ms/step - loss: 2.1691 - accuracy: 
0.3835 - val_loss: 2.1180 - val_accuracy: 0.6024
Epoch 5/12
469/469 [==============================] - 42s 90ms/step - loss: 2.0970 - accuracy: 
0.4409 - val_loss: 2.0255 - val_accuracy: 0.6666
Epoch 6/12
469/469 [==============================] - 45s 97ms/step - loss: 1.9993 - accuracy: 
0.4884 - val_loss: 1.8985 - val_accuracy: 0.7083
Epoch 7/12
469/469 [==============================] - 47s 100ms/step - loss: 1.8672 - accuracy: 
0.5346 - val_loss: 1.7317 - val_accuracy: 0.7423
Epoch 8/12
469/469 [==============================] - 42s 89ms/step - loss: 1.7058 - accuracy: 
0.5703 - val_loss: 1.5299 - val_accuracy: 0.7664
Epoch 9/12
469/469 [==============================] - 51s 110ms/step - loss: 1.5306 - accuracy: 
0.6030 - val_loss: 1.3198 - val_accuracy: 0.7837
Epoch 10/12
469/469 [==============================] - 46s 98ms/step - loss: 1.3687 - accuracy: 
0.6294 - val_loss: 1.1320 - val_accuracy: 0.7989
Epoch 11/12
469/469 [==============================] - 42s 90ms/step - loss: 1.2259 - accuracy: 
0.6561 - val_loss: 0.9802 - val_accuracy: 0.8118
Epoch 12/12
469/469 [==============================] - 42s 90ms/step - loss: 1.1146 - accuracy: 
0.6775 - val_loss: 0.8622 - val_accuracy: 0.8232
Test loss: 0.8621631860733032
Test accuracy: 0.823199987411499
```

Comparing the two models, we see that the addition of noise resultls in a model with a significantly reduced accuracy. In this one, we have an accuracy of .113 with noise and .823 without noise, for the same number of epochs, batch size, etc- the only difference is the noise. As a note, I added a high level of noise (scale of 3.0) to emphasize the difference in the models.

Variance Over Different Scale Values

In [14]:

```
## Add Noise to Dataset
# Noise is added here

def noise_adder(mean, scale_values, x_train, x_test, y_train, y_test):

    # Normalization
    mean_norm = np.mean(x_train)
    std = np.std(x_train)
    x_train_norm = (x_train - mean) / std
```

```
    mean = np.mean(x_test)
    std = np.std(x_test)
    x_test_norm = (x_test - mean) / std

    # Generate random noise with the same shape as the image
    x_train_noise = np.random.normal(loc, scale_values, x_train.shape)
    x_test_noise = np.random.normal(loc, scale_values, x_test.shape)

    # Add noise
    x_train_noise_added = x_train_norm + x_train_noise
    x_test_noise_added  = x_test_norm  + x_test_noise

    return x_train_noise_added, x_test_noise_added, y_train, y_test
```

In [15]:
```
def convolutional_model_recorder(batch_size, num_classes, epochs, x_train, x_test, y_t

    # convert class vectors to binary class matrices
    y_train = keras.utils.to_categorical(y_train, num_classes)
    y_test = keras.utils.to_categorical(y_test, num_classes)

    model = Sequential()
    model.add(Conv2D(32, kernel_size=(3, 3),
                     activation='relu',
                     input_shape=input_shape))
    model.add(Conv2D(64, (3, 3), activation='relu'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Dropout(0.25))
    model.add(Flatten())
    model.add(Dense(128, activation='relu'))
    model.add(Dropout(0.5))
    model.add(Dense(num_classes, activation='softmax'))

    model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

    model.fit(x_train, y_train,
              batch_size=batch_size,
              epochs=epochs,
              verbose=1,
              validation_data=(x_test, y_test))
    score = model.evaluate(x_test, y_test, verbose=0)
    print('Test loss:', score[0])
    print('Test accuracy:', score[1])
    # Append Loss & Accuracy To List
    test_loss = score[0]
    test_accuracy = score[1]
    loss_values.append(test_loss)
    accuracy_values.append(test_accuracy)
```

In [16]:
```
scale_values = [0.1, 0.5, 1.0, 2.0, 4.0]  # Values given
loc = 0 # For the noise_adder function
# Initializing Lists
loss_values = []
accuracy_values = []
```

In [17]:
```
# Loop:
for scale in scale_values:
```

```
    x_train_noise_added, x_test_noise_added, _, _ = noise_adder(loc, scale, x_train, x
    convolutional_model_recorder(batch_size, num_classes, epochs, x_train_noise_added,
```

```
Epoch 1/12
469/469 [==============================] - 50s 105ms/step - loss: 2.2025 - accuracy:
0.1934 - val_loss: 2.0304 - val_accuracy: 0.5327
Epoch 2/12
469/469 [==============================] - 50s 107ms/step - loss: 1.9506 - accuracy:
0.3642 - val_loss: 1.7752 - val_accuracy: 0.6816
Epoch 3/12
469/469 [==============================] - 46s 98ms/step - loss: 1.7042 - accuracy:
0.4857 - val_loss: 1.5104 - val_accuracy: 0.7511
Epoch 4/12
469/469 [==============================] - 43s 92ms/step - loss: 1.4767 - accuracy:
0.5657 - val_loss: 1.2693 - val_accuracy: 0.7851
Epoch 5/12
469/469 [==============================] - 42s 91ms/step - loss: 1.2820 - accuracy:
0.6235 - val_loss: 1.0770 - val_accuracy: 0.8095
Epoch 6/12
469/469 [==============================] - 42s 90ms/step - loss: 1.1369 - accuracy:
0.6611 - val_loss: 0.9297 - val_accuracy: 0.8296
Epoch 7/12
469/469 [==============================] - 41s 87ms/step - loss: 1.0243 - accuracy:
0.6920 - val_loss: 0.8212 - val_accuracy: 0.8429
Epoch 8/12
469/469 [==============================] - 42s 90ms/step - loss: 0.9407 - accuracy:
0.7141 - val_loss: 0.7379 - val_accuracy: 0.8542
Epoch 9/12
469/469 [==============================] - 42s 89ms/step - loss: 0.8708 - accuracy:
0.7348 - val_loss: 0.6728 - val_accuracy: 0.8640
Epoch 10/12
469/469 [==============================] - 42s 89ms/step - loss: 0.8189 - accuracy:
0.7512 - val_loss: 0.6216 - val_accuracy: 0.8706
Epoch 11/12
469/469 [==============================] - 42s 89ms/step - loss: 0.7729 - accuracy:
0.7647 - val_loss: 0.5812 - val_accuracy: 0.8766
Epoch 12/12
469/469 [==============================] - 41s 87ms/step - loss: 0.7342 - accuracy:
0.7748 - val_loss: 0.5468 - val_accuracy: 0.8823
Test loss: 0.5467995405197144
Test accuracy: 0.8823000192642212
Epoch 1/12
469/469 [==============================] - 42s 88ms/step - loss: 2.2635 - accuracy:
0.1732 - val_loss: 2.1053 - val_accuracy: 0.4827
Epoch 2/12
469/469 [==============================] - 43s 91ms/step - loss: 2.0477 - accuracy:
0.3169 - val_loss: 1.8802 - val_accuracy: 0.6626
Epoch 3/12
469/469 [==============================] - 45s 97ms/step - loss: 1.8360 - accuracy:
0.4316 - val_loss: 1.6407 - val_accuracy: 0.7227
Epoch 4/12
469/469 [==============================] - 47s 100ms/step - loss: 1.6321 - accuracy:
0.5122 - val_loss: 1.4169 - val_accuracy: 0.7597
Epoch 5/12
469/469 [==============================] - 46s 98ms/step - loss: 1.4454 - accuracy:
0.5717 - val_loss: 1.2249 - val_accuracy: 0.7826
Epoch 6/12
469/469 [==============================] - 46s 99ms/step - loss: 1.2924 - accuracy:
0.6149 - val_loss: 1.0693 - val_accuracy: 0.8026
Epoch 7/12
469/469 [==============================] - 47s 101ms/step - loss: 1.1721 - accuracy:
0.6477 - val_loss: 0.9483 - val_accuracy: 0.8160
Epoch 8/12
```

```
469/469 [==============================] - 49s 105ms/step - loss: 1.0766 - accuracy: 0.6709 - val_loss: 0.8518 - val_accuracy: 0.8286
Epoch 9/12
469/469 [==============================] - 51s 108ms/step - loss: 0.9968 - accuracy: 0.6938 - val_loss: 0.7775 - val_accuracy: 0.8387
Epoch 10/12
469/469 [==============================] - 50s 107ms/step - loss: 0.9337 - accuracy: 0.7102 - val_loss: 0.7161 - val_accuracy: 0.8471
Epoch 11/12
469/469 [==============================] - 48s 103ms/step - loss: 0.8743 - accuracy: 0.7316 - val_loss: 0.6658 - val_accuracy: 0.8540
Epoch 12/12
469/469 [==============================] - 50s 107ms/step - loss: 0.8362 - accuracy: 0.7390 - val_loss: 0.6266 - val_accuracy: 0.8601
Test loss: 0.6266005635261536
Test accuracy: 0.8600999712944031
Epoch 1/12
469/469 [==============================] - 48s 100ms/step - loss: 2.2985 - accuracy: 0.1441 - val_loss: 2.1761 - val_accuracy: 0.3700
Epoch 2/12
469/469 [==============================] - 49s 104ms/step - loss: 2.1846 - accuracy: 0.2193 - val_loss: 2.0674 - val_accuracy: 0.5296
Epoch 3/12
469/469 [==============================] - 50s 107ms/step - loss: 2.0747 - accuracy: 0.2952 - val_loss: 1.9323 - val_accuracy: 0.6236
Epoch 4/12
469/469 [==============================] - 50s 108ms/step - loss: 1.9585 - accuracy: 0.3643 - val_loss: 1.7793 - val_accuracy: 0.6584
Epoch 5/12
469/469 [==============================] - 47s 100ms/step - loss: 1.8222 - accuracy: 0.4273 - val_loss: 1.6176 - val_accuracy: 0.7094
Epoch 6/12
469/469 [==============================] - 47s 99ms/step - loss: 1.6859 - accuracy: 0.4815 - val_loss: 1.4607 - val_accuracy: 0.7286
Epoch 7/12
469/469 [==============================] - 47s 101ms/step - loss: 1.5525 - accuracy: 0.5295 - val_loss: 1.3139 - val_accuracy: 0.7486
Epoch 8/12
469/469 [==============================] - 49s 105ms/step - loss: 1.4262 - accuracy: 0.5706 - val_loss: 1.1848 - val_accuracy: 0.7638
Epoch 9/12
469/469 [==============================] - 44s 94ms/step - loss: 1.3220 - accuracy: 0.5990 - val_loss: 1.0732 - val_accuracy: 0.7806
Epoch 10/12
469/469 [==============================] - 48s 103ms/step - loss: 1.2197 - accuracy: 0.6293 - val_loss: 0.9756 - val_accuracy: 0.7960
Epoch 11/12
469/469 [==============================] - 45s 95ms/step - loss: 1.1428 - accuracy: 0.6529 - val_loss: 0.9012 - val_accuracy: 0.8009
Epoch 12/12
469/469 [==============================] - 46s 98ms/step - loss: 1.0713 - accuracy: 0.6713 - val_loss: 0.8345 - val_accuracy: 0.8125
Test loss: 0.8344602584838867
Test accuracy: 0.8125
Epoch 1/12
469/469 [==============================] - 44s 93ms/step - loss: 2.3885 - accuracy: 0.1212 - val_loss: 2.2119 - val_accuracy: 0.2549
Epoch 2/12
469/469 [==============================] - 44s 95ms/step - loss: 2.2467 - accuracy: 0.1719 - val_loss: 2.1336 - val_accuracy: 0.3521
```

```
Epoch 3/12
469/469 [==============================] - 81s 173ms/step - loss: 2.1681 - accuracy: 
0.2183 - val_loss: 2.0426 - val_accuracy: 0.4144
Epoch 4/12
469/469 [==============================] - 81s 172ms/step - loss: 2.0840 - accuracy: 
0.2654 - val_loss: 1.9328 - val_accuracy: 0.4592
Epoch 5/12
469/469 [==============================] - 90s 192ms/step - loss: 1.9908 - accuracy: 
0.3141 - val_loss: 1.8113 - val_accuracy: 0.5112
Epoch 6/12
469/469 [==============================] - 88s 188ms/step - loss: 1.8903 - accuracy: 
0.3562 - val_loss: 1.6895 - val_accuracy: 0.5355
Epoch 7/12
469/469 [==============================] - 88s 188ms/step - loss: 1.7909 - accuracy: 
0.3965 - val_loss: 1.5653 - val_accuracy: 0.5784
Epoch 8/12
469/469 [==============================] - 87s 186ms/step - loss: 1.6878 - accuracy: 
0.4346 - val_loss: 1.4587 - val_accuracy: 0.5983
Epoch 9/12
469/469 [==============================] - 91s 195ms/step - loss: 1.5934 - accuracy: 
0.4697 - val_loss: 1.3562 - val_accuracy: 0.6261
Epoch 10/12
469/469 [==============================] - 90s 193ms/step - loss: 1.5039 - accuracy: 
0.5008 - val_loss: 1.2724 - val_accuracy: 0.6418
Epoch 11/12
469/469 [==============================] - 97s 206ms/step - loss: 1.4232 - accuracy: 
0.5277 - val_loss: 1.1926 - val_accuracy: 0.6593
Epoch 12/12
469/469 [==============================] - 94s 201ms/step - loss: 1.3538 - accuracy: 
0.5500 - val_loss: 1.1275 - val_accuracy: 0.6738
Test loss: 1.12745201587677
Test accuracy: 0.673799991607666
Epoch 1/12
469/469 [==============================] - 89s 188ms/step - loss: 2.6358 - accuracy: 
0.1039 - val_loss: 2.2857 - val_accuracy: 0.1350
Epoch 2/12
469/469 [==============================] - 80s 171ms/step - loss: 2.3697 - accuracy: 
0.1193 - val_loss: 2.2725 - val_accuracy: 0.1597
Epoch 3/12
469/469 [==============================] - 78s 166ms/step - loss: 2.3121 - accuracy: 
0.1261 - val_loss: 2.2709 - val_accuracy: 0.1749
Epoch 4/12
469/469 [==============================] - 78s 167ms/step - loss: 2.2908 - accuracy: 
0.1353 - val_loss: 2.2635 - val_accuracy: 0.1855
Epoch 5/12
469/469 [==============================] - 82s 174ms/step - loss: 2.2788 - accuracy: 
0.1434 - val_loss: 2.2518 - val_accuracy: 0.2050
Epoch 6/12
469/469 [==============================] - 73s 156ms/step - loss: 2.2686 - accuracy: 
0.1512 - val_loss: 2.2346 - val_accuracy: 0.2303
Epoch 7/12
469/469 [==============================] - 80s 171ms/step - loss: 2.2562 - accuracy: 
0.1574 - val_loss: 2.2136 - val_accuracy: 0.2531
Epoch 8/12
469/469 [==============================] - 46s 99ms/step - loss: 2.2424 - accuracy: 
0.1687 - val_loss: 2.1871 - val_accuracy: 0.2720
Epoch 9/12
469/469 [==============================] - 42s 90ms/step - loss: 2.2243 - accuracy: 
0.1789 - val_loss: 2.1523 - val_accuracy: 0.2893
Epoch 10/12
```

```
469/469 [==============================] - 42s 91ms/step - loss: 2.2055 - accuracy:
0.1920 - val_loss: 2.1182 - val_accuracy: 0.3137
Epoch 11/12
469/469 [==============================] - 43s 91ms/step - loss: 2.1804 - accuracy:
0.2031 - val_loss: 2.0771 - val_accuracy: 0.3371
Epoch 12/12
469/469 [==============================] - 43s 91ms/step - loss: 2.1549 - accuracy:
0.2210 - val_loss: 2.0374 - val_accuracy: 0.3513
Test loss: 2.037432909011841
Test accuracy: 0.3513000011444092
```

In [18]:

```
loss_values
```

Out[18]:

```
[0.5467995405197144,
 0.6266005635261536,
 0.8344602584838867,
 1.12745201587677,
 2.037432909011841]
```

In [19]:

```
accuracy_values
```

Out[19]:

```
[0.8823000192642212,
 0.8600999712944031,
 0.8125,
 0.673799991607666,
 0.3513000011444092]
```

In [20]:

```
# Compile Loss and Accuracy statistics for the models into a single data frame
import pandas as pd
accuracy_loss_results_dataframe = pd.DataFrame({'scale_values': scale_values, 'loss_va
accuracy_loss_results_dataframe
```

Out[20]:

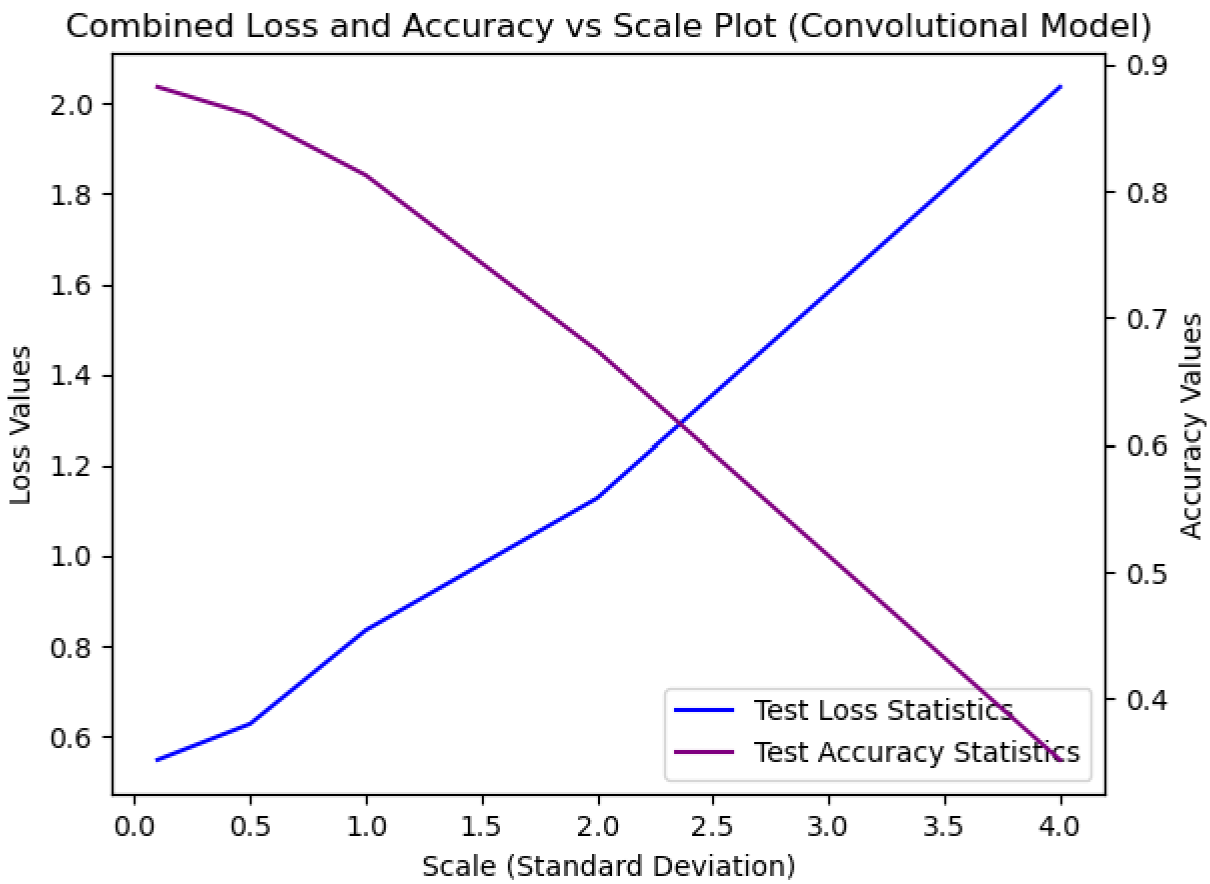
	scale_values	loss_values	accuracy_values
0	0.1	0.546800	0.8823
1	0.5	0.626601	0.8601
2	1.0	0.834460	0.8125
3	2.0	1.127452	0.6738
4	4.0	2.037433	0.3513

In [21]:

```
# Plotting Results
fig, ax1 = plt.subplots()
loss_line = ax1.plot(scale_values, loss_values, color = 'blue', label = 'Test Loss Sta

# Loss line Plot
ax1.set_xlabel('Scale (Standard Deviation)')
ax1.set_ylabel('Loss Values')
ax1.set_title('Combined Loss and Accuracy vs Scale Plot (Convolutional Model)')

# Accuracy line Plot
ax2 = ax1.twinx()
accuracy_line = ax2.plot(scale_values, accuracy_values, color='purple', label='Test Ac
ax2.set_ylabel('Accuracy Values')

# Combine Both Lines Into One Plot
lines = loss_line + accuracy_line
```

```
labels = [l.get_label() for l in lines]
ax1.legend(lines, labels, loc='lower right')
```

Out[21]: <matplotlib.legend.Legend at 0x256258947f0>



We see a pattern in form of an inverse relationship between the scale of the noise and the accuracy of the model; with every gradual increase in noise, the accuracy of the created model becomes less and less. The most notable dropoff comes from the jump from a scale of 2 to 4, where the accuracy declines from just under .7 to less than .4. In last week's results (after revision), we had the same general realtionship, with the acuracy of the model decreasing as the scale of the noise added increased. It is both sound on the basis of the convolutional neural network model that the addition of noise results in a less accurate model, and the accuracy statistics generated by these models are proof of the same.

In [ ]: