In [16]:
```
import numpy as np
import pandas as pd
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split

# Load the datasets
X_train = pd.read_csv('/Users/ragavi/Downloads/human+activity+recognit
y_train = pd.read_csv('/Users/ragavi/Downloads/human+activity+recognit

X_test = pd.read_csv('/Users/ragavi/Downloads/human+activity+recogniti
y_test = pd.read_csv('//Users/ragavi/Downloads/human+activity+recognit

# Load the activity labels
activity_labels = pd.read_csv('/Users/ragavi/Downloads/human+activity+
activity_labels = activity_labels[1].to_dict()
# Map the activity labels to the y datasets
y_train = y_train[0].map(activity_labels)
y_test = y_test[0].map(activity_labels)

# Standardize the features
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

# Since we will use TensorFlow/Keras, we need to one-hot encode the la
y_train_encoded = pd.get_dummies(y_train)
y_test_encoded = pd.get_dummies(y_test)
```

In [17]:
```
# Convert the pandas DataFrames to numpy arrays if not already done
X_train_scaled = np.array(X_train_scaled)
X_test_scaled = np.array(X_test_scaled)
y_train_encoded = np.array(y_train_encoded)
y_test_encoded = np.array(y_test_encoded)
```

In [18]:
```
!pip install numpy pandas scikit-learn tensorflow tensorflow-privacy
```

```
Requirement already satisfied: numpy in ./anaconda3/lib/python3.11/si
te-packages (1.24.3)
Requirement already satisfied: pandas in ./anaconda3/lib/python3.11/s
ite-packages (2.0.3)
Requirement already satisfied: scikit-learn in ./anaconda3/lib/python
3.11/site-packages (1.3.0)
Requirement already satisfied: tensorflow in ./anaconda3/lib/python3.
11/site-packages (2.15.0)
Requirement already satisfied: tensorflow-privacy in ./anaconda3/lib/
python3.11/site-packages (0.9.0)
Requirement already satisfied: python-dateutil>=2.8.2 in ./anaconda3/
lib/python3.11/site-packages (from pandas) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in ./anaconda3/lib/python
```

```
3.11/site-packages (from pandas) (2022.7)
Requirement already satisfied: tzdata>=2022.1 in ./anaconda3/lib/pyth
on3.11/site-packages (from pandas) (2023.3)
Requirement already satisfied: scipy>=1.5.0 in ./anaconda3/lib/python
3.11/site-packages (from scikit-learn) (1.11.1)
Requirement already satisfied: joblib>=1.1.1 in ./anaconda3/lib/pytho
n3.11/site-packages (from scikit-learn) (1.2.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in ./anaconda3/li
b/python3.11/site-packages (from scikit-learn) (2.2.0)
Requirement already satisfied: tensorflow-macos==2.15.0 in ./anaconda
3/lib/python3.11/site-packages (from tensorflow) (2.15.0)
Requirement already satisfied: absl-py>=1.0.0 in ./anaconda3/lib/pyth
on3.11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (1.
4.0)
Requirement already satisfied: astunparse>=1.6.0 in ./anaconda3/lib/p
ython3.11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (
1.6.3)
Requirement already satisfied: flatbuffers>=23.5.26 in ./anaconda3/li
b/python3.11/site-packages (from tensorflow-macos==2.15.0->tensorflo
w) (23.5.26)
Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 in
./anaconda3/lib/python3.11/site-packages (from tensorflow-macos==2.1
5.0->tensorflow) (0.5.4)
Requirement already satisfied: google-pasta>=0.1.1 in ./anaconda3/li
b/python3.11/site-packages (from tensorflow-macos==2.15.0->tensorflo
w) (0.2.0)
Requirement already satisfied: h5py>=2.9.0 in ./anaconda3/lib/python
3.11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (3.9.
0)
Requirement already satisfied: libclang>=13.0.0 in ./anaconda3/lib/py
thon3.11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (1
6.0.6)
Requirement already satisfied: ml-dtypes~=0.2.0 in ./anaconda3/lib/py
thon3.11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (
0.2.0)
Requirement already satisfied: opt-einsum>=2.3.2 in ./anaconda3/lib/p
ython3.11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (
3.3.0)
Requirement already satisfied: packaging in ./anaconda3/lib/python3.1
1/site-packages (from tensorflow-macos==2.15.0->tensorflow) (22.0)
Requirement already satisfied: protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=
4.21.3,!=4.21.4,!=4.21.5,<5.0.0dev,>=3.20.3 in ./anaconda3/lib/python
3.11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (4.25.
3)
Requirement already satisfied: setuptools in ./anaconda3/lib/python3.
11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (68.0.0)
Requirement already satisfied: six>=1.12.0 in ./anaconda3/lib/python
3.11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (1.16.
0)
Requirement already satisfied: termcolor>=1.1.0 in ./anaconda3/lib/py
thon3.11/site-packages (from tensorflow-macos==2.15.0->tensorflow) (
2.4.0)
Requirement already satisfied: typing-extensions>=3.6.6 in ./anaconda
```

```
3/lib/python3.11/site-packages (from tensorflow-macos==2.15.0->tensor
flow) (4.7.1)
Requirement already satisfied: wrapt<1.15,>=1.11.0 in ./anaconda3/li
b/python3.11/site-packages (from tensorflow-macos==2.15.0->tensorflo
w) (1.14.1)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 i
n ./anaconda3/lib/python3.11/site-packages (from tensorflow-macos==2.
15.0->tensorflow) (0.36.0)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in ./anaconda3/li
b/python3.11/site-packages (from tensorflow-macos==2.15.0->tensorflo
w) (1.62.0)
Requirement already satisfied: tensorboard<2.16,>=2.15 in ./anaconda
3/lib/python3.11/site-packages (from tensorflow-macos==2.15.0->tensor
flow) (2.15.2)
Requirement already satisfied: tensorflow-estimator<2.16,>=2.15.0 in
./anaconda3/lib/python3.11/site-packages (from tensorflow-macos==2.1
5.0->tensorflow) (2.15.0)
Requirement already satisfied: keras<2.16,>=2.15.0 in ./anaconda3/li
b/python3.11/site-packages (from tensorflow-macos==2.15.0->tensorflo
w) (2.15.0)
Requirement already satisfied: dm-tree==0.1.8 in ./anaconda3/lib/pyth
on3.11/site-packages (from tensorflow-privacy) (0.1.8)
Requirement already satisfied: dp-accounting==0.4.3 in ./anaconda3/li
b/python3.11/site-packages (from tensorflow-privacy) (0.4.3)
Requirement already satisfied: tensorflow-probability~=0.22.0 in ./an
aconda3/lib/python3.11/site-packages (from tensorflow-privacy) (0.22.
1)
Requirement already satisfied: attrs>=22 in ./anaconda3/lib/python3.1
1/site-packages (from dp-accounting==0.4.3->tensorflow-privacy) (22.
1.0)
Requirement already satisfied: mpmath~=1.2 in ./anaconda3/lib/python
3.11/site-packages (from dp-accounting==0.4.3->tensorflow-privacy) (
1.3.0)
Requirement already satisfied: decorator in ./anaconda3/lib/python3.1
1/site-packages (from tensorflow-probability~=0.22.0->tensorflow-priv
acy) (5.1.1)
Requirement already satisfied: cloudpickle>=1.3 in ./anaconda3/lib/py
thon3.11/site-packages (from tensorflow-probability~=0.22.0->tensorfl
ow-privacy) (2.2.1)
Requirement already satisfied: wheel<1.0,>=0.23.0 in ./anaconda3/lib/
python3.11/site-packages (from astunparse>=1.6.0->tensorflow-macos==
2.15.0->tensorflow) (0.38.4)
Requirement already satisfied: google-auth<3,>=1.6.3 in ./anaconda3/l
ib/python3.11/site-packages (from tensorboard<2.16,>=2.15->tensorflow
-macos==2.15.0->tensorflow) (2.28.1)
Requirement already satisfied: google-auth-oauthlib<2,>=0.5 in ./anac
onda3/lib/python3.11/site-packages (from tensorboard<2.16,>=2.15->ten
sorflow-macos==2.15.0->tensorflow) (1.2.0)
Requirement already satisfied: markdown>=2.6.8 in ./anaconda3/lib/pyt
hon3.11/site-packages (from tensorboard<2.16,>=2.15->tensorflow-macos
==2.15.0->tensorflow) (3.4.1)
Requirement already satisfied: requests<3,>=2.21.0 in ./anaconda3/li
b/python3.11/site-packages (from tensorboard<2.16,>=2.15->tensorflow-
```

```
macos==2.15.0->tensorflow) (2.31.0)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0
in ./anaconda3/lib/python3.11/site-packages (from tensorboard<2.16,>=
2.15->tensorflow-macos==2.15.0->tensorflow) (0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in ./anaconda3/lib/pyth
on3.11/site-packages (from tensorboard<2.16,>=2.15->tensorflow-macos
==2.15.0->tensorflow) (2.2.3)
Requirement already satisfied: cachetools<6.0,>=2.0.0 in ./anaconda3/
lib/python3.11/site-packages (from google-auth<3,>=1.6.3->tensorboard
<2.16,>=2.15->tensorflow-macos==2.15.0->tensorflow) (5.3.3)
Requirement already satisfied: pyasn1-modules>=0.2.1 in ./anaconda3/l
ib/python3.11/site-packages (from google-auth<3,>=1.6.3->tensorboard<
2.16,>=2.15->tensorflow-macos==2.15.0->tensorflow) (0.2.8)
Requirement already satisfied: rsa<5,>=3.1.4 in ./anaconda3/lib/pytho
n3.11/site-packages (from google-auth<3,>=1.6.3->tensorboard<2.16,>=
2.15->tensorflow-macos==2.15.0->tensorflow) (4.9)
Requirement already satisfied: requests-oauthlib>=0.7.0 in ./anaconda
3/lib/python3.11/site-packages (from google-auth-oauthlib<2,>=0.5->te
nsorboard<2.16,>=2.15->tensorflow-macos==2.15.0->tensorflow) (1.3.1)
Requirement already satisfied: charset-normalizer<4,>=2 in ./anaconda
3/lib/python3.11/site-packages (from requests<3,>=2.21.0->tensorboard
<2.16,>=2.15->tensorflow-macos==2.15.0->tensorflow) (2.0.4)
Requirement already satisfied: idna<4,>=2.5 in ./anaconda3/lib/python
3.11/site-packages (from requests<3,>=2.21.0->tensorboard<2.16,>=2.15
->tensorflow-macos==2.15.0->tensorflow) (3.4)
Requirement already satisfied: urllib3<3,>=1.21.1 in ./anaconda3/lib/
python3.11/site-packages (from requests<3,>=2.21.0->tensorboard<2.16,
>=2.15->tensorflow-macos==2.15.0->tensorflow) (1.26.16)
Requirement already satisfied: certifi>=2017.4.17 in ./anaconda3/lib/
python3.11/site-packages (from requests<3,>=2.21.0->tensorboard<2.16,
>=2.15->tensorflow-macos==2.15.0->tensorflow) (2023.7.22)
Requirement already satisfied: MarkupSafe>=2.1.1 in ./anaconda3/lib/p
ython3.11/site-packages (from werkzeug>=1.0.1->tensorboard<2.16,>=2.1
5->tensorflow-macos==2.15.0->tensorflow) (2.1.1)

Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in ./anaconda3/li
b/python3.11/site-packages (from pyasn1-modules>=0.2.1->google-auth<
3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow-macos==2.15.0->tensorf
low) (0.4.8)
Requirement already satisfied: oauthlib>=3.0.0 in ./anaconda3/lib/pyt
hon3.11/site-packages (from requests-oauthlib>=0.7.0->google-auth-oau
thlib<2,>=0.5->tensorboard<2.16,>=2.15->tensorflow-macos==2.15.0->ten
sorflow) (3.2.2)
```

In [19]:

```
import tensorflow as tf
from tensorflow_privacy.privacy.optimizers.dp_optimizer_keras import D
from sklearn.metrics import classification_report, accuracy_score
```

In [20]:
```
import tensorflow as tf

def create_model(input_shape, num_classes):
    model = tf.keras.Sequential([
        tf.keras.layers.Dense(64, activation='relu', input_shape=input
        tf.keras.layers.Dropout(0.5),
        tf.keras.layers.Dense(64, activation='relu'),
        tf.keras.layers.Dropout(0.5),
        tf.keras.layers.Dense(num_classes, activation='softmax')
    ])
    return model

# Create the model
num_features = X_train_scaled.shape[1]
num_classes = y_train_encoded.shape[1]
model = create_model((num_features,), num_classes)
```

In [21]:
```
from tensorflow_privacy.privacy.optimizers.dp_optimizer_keras import D

# Define the optimizer with differential privacy
optimizer = DPKerasSGDOptimizer(
    l2_norm_clip=1.0,
    noise_multiplier=0.1,  # The amount of noise, adjust as necessary
    num_microbatches=1,  # The number of microbatches (for efficiency)
    learning_rate=0.01
)

loss = tf.keras.losses.CategoricalCrossentropy(from_logits=True, reduc
model.compile(optimizer=optimizer, loss=loss, metrics=['accuracy'])
```

In [22]:
```
model.fit(X_train_scaled, y_train_encoded, epochs=10, batch_size=32, v
```

```
Epoch 1/10

/Users/ragavi/anaconda3/lib/python3.11/site-packages/keras/src/backen
d.py:5575: UserWarning: "`categorical_crossentropy` received `from_lo
gits=True`, but the `output` argument was produced by a Softmax activ
ation and thus does not represent logits. Was this intended?
  output, from_logits = _get_logits(

230/230 [==============================] - 1s 1ms/step - loss: 1.8826
- accuracy: 0.2924 - val_loss: 1.1807 - val_accuracy: 0.5310
Epoch 2/10
230/230 [==============================] - 0s 903us/step - loss: 1.44
54 - accuracy: 0.4023 - val_loss: 0.9926 - val_accuracy: 0.6586
Epoch 3/10
230/230 [==============================] - 0s 894us/step - loss: 1.21
43 - accuracy: 0.4942 - val_loss: 0.8438 - val_accuracy: 0.6970
Epoch 4/10
230/230 [==============================] - 0s 881us/step - loss: 1.06
55 - accuracy: 0.5547 - val_loss: 0.7126 - val_accuracy: 0.7550
Epoch 5/10
230/230 [==============================] - 0s 973us/step - loss: 0.95
81 - accuracy: 0.5898 - val_loss: 0.6384 - val_accuracy: 0.7747
Epoch 6/10
230/230 [==============================] - 0s 950us/step - loss: 0.84
70 - accuracy: 0.6337 - val_loss: 0.5529 - val_accuracy: 0.8086
Epoch 7/10
230/230 [==============================] - 0s 946us/step - loss: 0.78
52 - accuracy: 0.6635 - val_loss: 0.5038 - val_accuracy: 0.7995
Epoch 8/10
230/230 [==============================] - 0s 932us/step - loss: 0.71
82 - accuracy: 0.6991 - val_loss: 0.4683 - val_accuracy: 0.8249
Epoch 9/10
230/230 [==============================] - 0s 886us/step - loss: 0.68
47 - accuracy: 0.7062 - val_loss: 0.4278 - val_accuracy: 0.8463
Epoch 10/10
230/230 [==============================] - 0s 876us/step - loss: 0.64
93 - accuracy: 0.7244 - val_loss: 0.4160 - val_accuracy: 0.8364
```

Out[22]:
```
<keras.src.callbacks.History at 0x294b7cbd0>
```

In [23]:
```
evaluation = model.evaluate(X_test_scaled, y_test_encoded)

print(f"Test loss: {evaluation[0]}, Test accuracy: {evaluation[1]}")
```

```
93/93 [==============================] - 0s 400us/step - loss: 0.4160
- accuracy: 0.8364
Test loss: 0.4160018265247345, Test accuracy: 0.8364438414573669
```

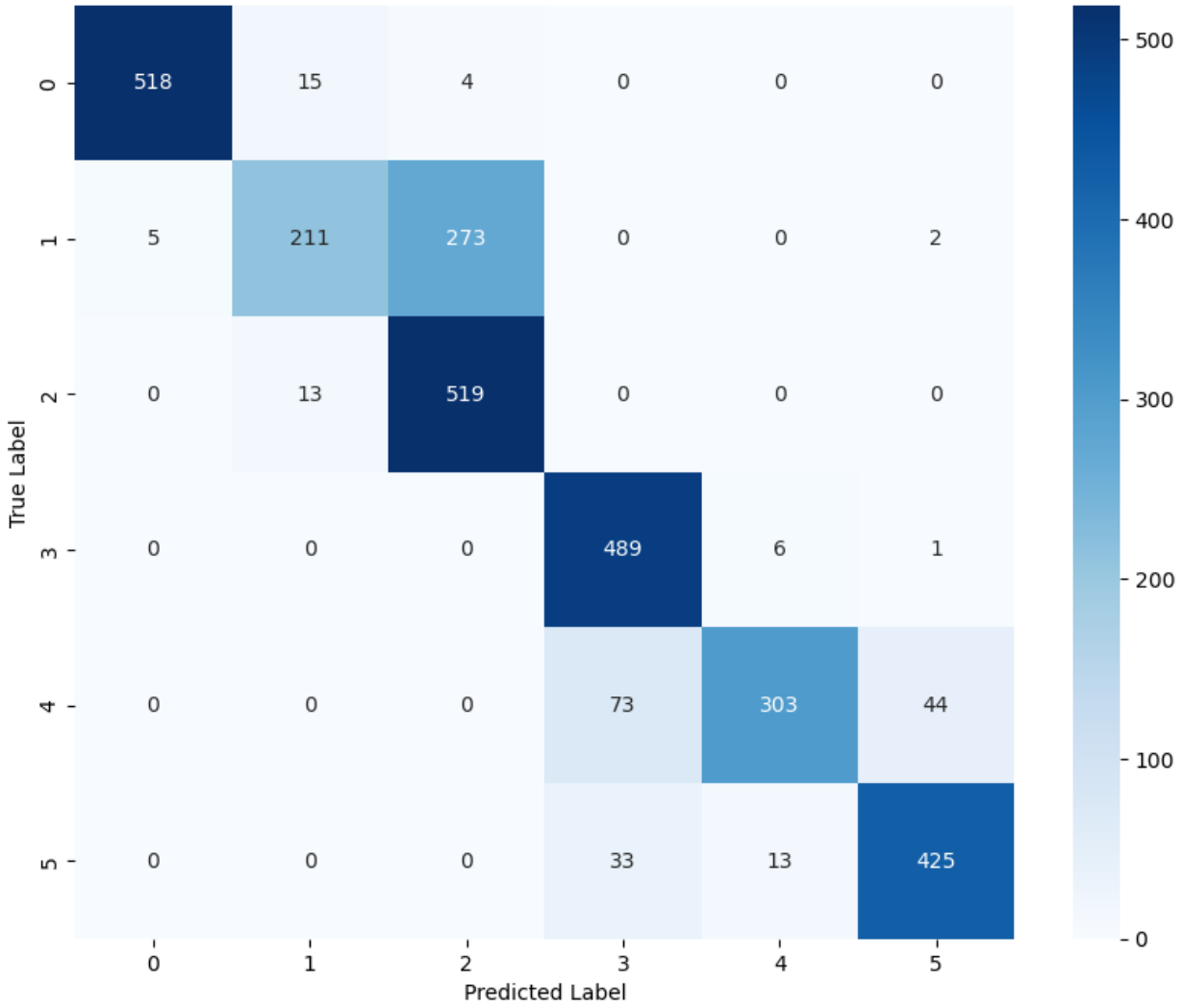
In [24]:
```
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix

# Assuming you have the y_test and y_pred from the model's predictions
y_pred = np.argmax(model.predict(X_test_scaled), axis=1)
y_true = np.argmax(y_test_encoded, axis=1)

conf_mat = confusion_matrix(y_true, y_pred)

plt.figure(figsize=(10, 8))
sns.heatmap(conf_mat, annot=True, fmt='d', cmap='Blues')
plt.ylabel('True Label')
plt.xlabel('Predicted Label')
plt.show()
```

```
93/93 [==============================] - 0s 364us/step
```

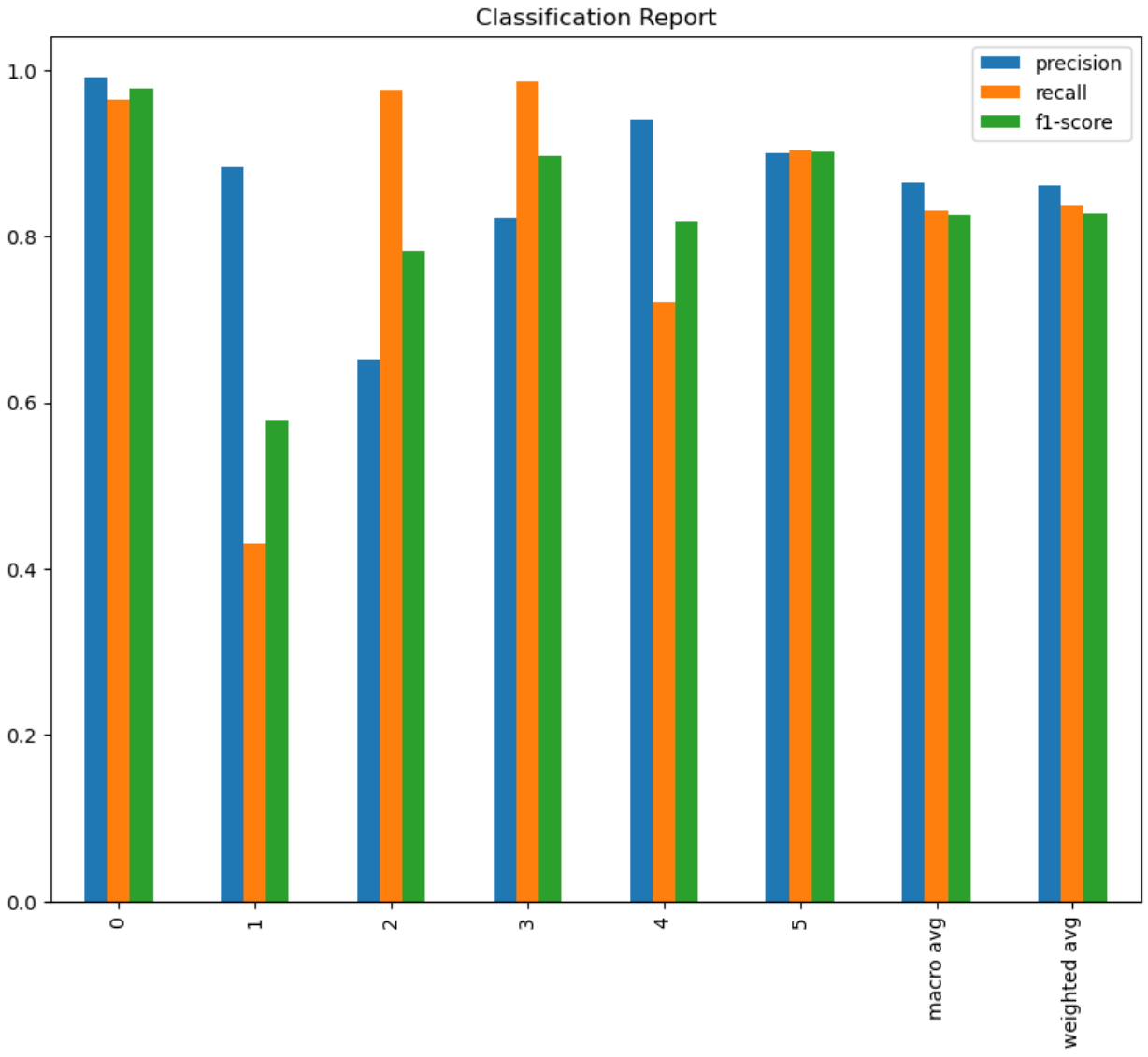


In [25]:
```
from sklearn.metrics import classification_report
import pandas as pd

# Get the classification report
report = classification_report(y_true, y_pred, output_dict=True)

# Convert the report to a DataFrame
report_df = pd.DataFrame(report).transpose()

# Plot a bar chart for the precision, recall, and f1-score of each cla
report_df.drop(['accuracy'], inplace=True)
report_df['support'] = report_df['support'].apply(int)
report_df[['precision', 'recall', 'f1-score']].plot(kind='bar', figsiz
plt.title('Classification Report')
plt.show()
```



In [ ]: