EE559 Project Assignment

April 28, 2022

1 *Student Perfromance Dataset / Classification*

Imports

[ ]:
```
from sklearn.preprocessing import StandardScaler
from sklearn.neighbors import NearestCentroid
from sklearn.neighbors import KNeighborsClassifier
from sklearn.neural_network import MLPClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import GridSearchCV
from sklearn.pipeline import Pipeline
from sklearn.svm import SVC
from sklearn.metrics import confusion_matrix
from sklearn.metrics import f1_score
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import random
import seaborn as sns
```

[ ]:
```
import warnings
warnings.filterwarnings('ignore')
```

Functions

[ ]:
```
# Fucntion to convert scores to grades
def get_grade(score):
    if score <= 9:
        grade = 0 #F
    elif 10<=score<=11:
        grade = 1 #D
    elif 12<=score<=13:
        grade = 2 #C
    elif 14<=score<=15:
        grade = 3 #B
    elif score>=16:
        grade = 4 #A
    return grade

# Trivial classifier - randomly outputs class labels with probability based on class priors
def trivial_classifier(Y_train, data):
    y_grades_train = list()
    for i in range(len(Y_train)):
        y_grades_train.append(get_grade(Y_train[i]))
    y_grades_train = np.array(y_grades_train)
    weights = [np.count_nonzero(y_grades_train == 0)/len(Y_train)*100, np.count_nonzero(y_grades_train == 1)/len(Y_train)*100,
    np.count_nonzero(y_grades_train == 2)/len(Y_train)*100, np.count_nonzero(y_grades_train == 3)/len(Y_train)*100,
    np.count_nonzero(y_grades_train == 4)/len(Y_train)*100]
    y_pred = list()
    for i in range(len(data)):
        pred_class = 0
        for j in range(10):
            gradelist = [0, 1, 2, 3, 4]
            pred_class += random.choices(gradelist, weights=weights)[0]
        y_pred.append(round(pred_class/10))
    return np.array(y_pred)

# Baseline Model - Nearest Means Classifier
def nearestMeansClassifier(X_train, Y_train, X_test):
    y_grades_train = list()
    for i in range(len(Y_train)):
        y_grades_train.append(get_grade(Y_train[i]))
    y_grades_train = np.array(y_grades_train)
    clf = NearestCentroid()
    clf.fit(X_train, y_grades_train)
    Y_test_grades_pred = np.zeros(len(X_test))
    for i in range(len(X_test)):
        Y_test_grades_pred[i] = clf.predict(X_test[i].reshape(1, -1))

    return Y_test_grades_pred

# Performance Measures
def get_performance(y, y_pred):
    macro_f1_score = f1_score(y, y_pred, average = 'macro')
    print("The macro F1 score for the classifier is - ", macro_f1_score)
    accuracy = f1_score(y, y_pred, average = 'micro')
    print("The accuracy for the classifier is - ", accuracy)
    cf_matrix = confusion_matrix(y, y_pred)
    labels = ['F', 'D', 'C', 'B', 'A']
    ax = sns.heatmap(cf_matrix, annot=True)
    ax.set_xticklabels(labels)
    ax.set_yticklabels(labels)
    plt.show()
```

```
[ ]: def KNNClassifier(X, y, X_test, Y_test_actual):
         params = {
                     'n_neighbors'    :       [2,3,4,5],
                     'algorithm'      :       ['ball_tree', 'kd_tree', 'brute',␣
       ↪'auto'],
                     'leaf_size'      :       [ 10, 20, 30, 40, 50],
                     'weights'        :       ['uniform', 'distance']
                 }
         neigh = KNeighborsClassifier()
         clf = GridSearchCV(estimator=neigh, param_grid=params, cv=5)
         clf.fit(X, y)
         print('Best parameters from Cross Validation: ', clf.best_params_)
         #print('\n')
         y_train_pred = clf.predict(X)
         accuracy = f1_score(y, y_train_pred, average = 'micro')
         print('Cross Validation Best Score', accuracy)
         print('\n')
         Y_test_grades_pred = clf.predict(X_test)
         get_performance(Y_test_actual, Y_test_grades_pred)

     def LogitClassifier(X, y, X_test, Y_test_actual):
         params= {
                     'tol'    :   [1e-5, 0.5*1e-4, 1e-4, 2*1e-4, 1e-3],
                     'solver':   ['newton-cg', 'lbfgs', 'liblinear']
                 }
         logreg = LogisticRegression(max_iter=100000)
         clf = GridSearchCV(estimator=logreg, param_grid=params, cv=5)
         clf.fit(X, y)
         print('Best parameters from Cross Validation: ', clf.best_params_)
         y_train_pred = clf.predict(X)
         accuracy = f1_score(y, y_train_pred, average = 'micro')
         print('Cross Validation Best Score', accuracy)
         Y_test_grades_pred = clf.predict(X_test)
         get_performance(Y_test_actual, Y_test_grades_pred)

     def KernelSVMClassifier(X, y, X_test, Y_test_actual):
         params= {
                     'C'              :   [0.8, 0.9, 1.0, 1.1, 1.2],
                     'kernel'         :   ['linear', 'poly', 'rbf', 'sigmoid'],
                     'tol'            :   [1e-5, 1e-4, 1e-3],
                     'gamma'          :   ['scale', 'auto'],
                     'class_weight'   :   ['balanced', None]
                 }
```

```
    svc = SVC()
    clf = GridSearchCV(estimator=svc, param_grid=params, cv=5)
    clf.fit(X, y)
    print('Best parameters from Cross Validation: ', clf.best_params_)
    y_train_pred = clf.predict(X)
    accuracy = f1_score(y, y_train_pred, average = 'micro')
    print('Cross Validation Best Score', accuracy)
    Y_test_grades_pred = clf.predict(X_test)
    get_performance(Y_test_actual, Y_test_grades_pred)

def MLPerceptromClassifier(X, y, X_test, Y_test_actual):
    params ={
                'activation'            :   ['tanh', 'relu', 'identity',␣
 ↪'logistic'],
                'solver'                :   ['sgd', 'adam', 'lbfgs'],
                'alpha'                 :   [0.0001, 0.05],
                'learning_rate'         :   ['constant','adaptive'],
            }
    mlp = MLPClassifier(random_state=1, max_iter=2000)
    clf = GridSearchCV(estimator=mlp, param_grid=params, cv=5)
    clf.fit(X, y)
    print('Best parameters from Cross Validation: ', clf.best_params_)
    print('Cross Validation Best Score', clf.best_score_)
    Y_test_grades_pred = clf.predict(X_test)
    get_performance(Y_test_actual, Y_test_grades_pred)
    pass
```

Read in the data

```
[ ]: train_df = pd.read_csv('data/student_performance_train.csv')
     #dataset_train = train_df.to_numpy()
```

```
[ ]: train_df.columns
```

```
[ ]: Index(['school', 'sex', 'age', 'address', 'famsize', 'Pstatus', 'Medu', 'Fedu',
            'Mjob', 'Fjob', 'reason', 'guardian', 'traveltime', 'studytime',
            'failures', 'schoolsup', 'famsup', 'paid', 'activities', 'nursery',
            'higher', 'internet', 'romantic', 'famrel', 'freetime', 'goout', 'Dalc',
            'Walc', 'health', 'absences', 'G1', 'G2', 'G3'],
           dtype='object')
```

1.1 Problem 1

- Predict first-period academic performance without any prior academic performance data: remove the G2 and G3 columns from the original dataset, then predict G1.

Removing categorical non-binary features and grades.

[ ]:

```
selected_columns = train_df.loc[:, ~train_df.columns.isin(['Mjob', 'Fjob',␣
 ↪'reason', 'gaurdian', 'G1', 'G2', 'G3'])]
binary_vals = pd.get_dummies(selected_columns)
X_train = binary_vals.to_numpy() #Converting to numpy array for easier␣
 ↪processing
```

[ ]:

```
y_train = train_df.loc[:, train_df.columns.isin(['G1'])]
Y_train = y_train['G1'].to_numpy()
y_grades_train = list()
for i in range(len(Y_train)):
    y_grades_train.append(get_grade(Y_train[i]))
y_grades_train = np.array(y_grades_train)
```

Reading in test data and processing it

[ ]:

```
test_df = pd.read_csv('data/student_performance_test.csv')
selected_columns = test_df.loc[:, ~test_df.columns.isin(['Mjob', 'Fjob',␣
 ↪'reason', 'gaurdian', 'G1', 'G2', 'G3'])]
binary_vals = pd.get_dummies(selected_columns)
X_test = binary_vals.to_numpy()
```

[ ]:

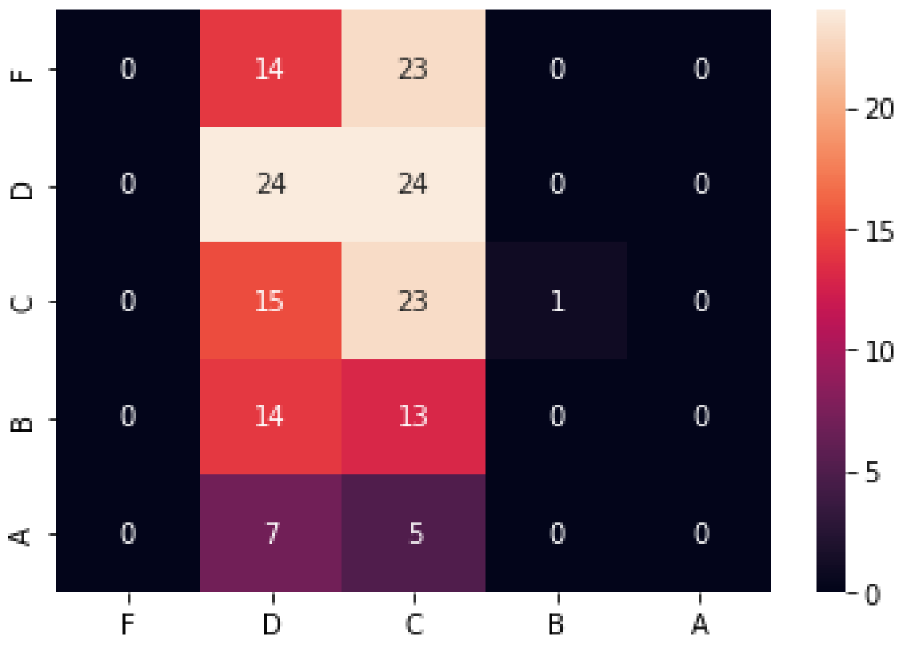
```
y_test = test_df.loc[:, test_df.columns.isin(['G1'])] #Rerun this cell to get␣
 ↪back orginal values of Y_test
Y_test = y_test['G1'].to_numpy()
y_grades_test_actual = list()
for i in range(len(Y_test)):
    y_grades_test_actual.append(get_grade(Y_test[i]))
Y_test_grades_actual = np.array(y_grades_test_actual)
```

1.1.1 Trivial System

[ ]:

```
Y_test_grades_pred = trivial_classifier(Y_train, X_test)
get_performance(Y_test_grades_actual, Y_test_grades_pred)
```

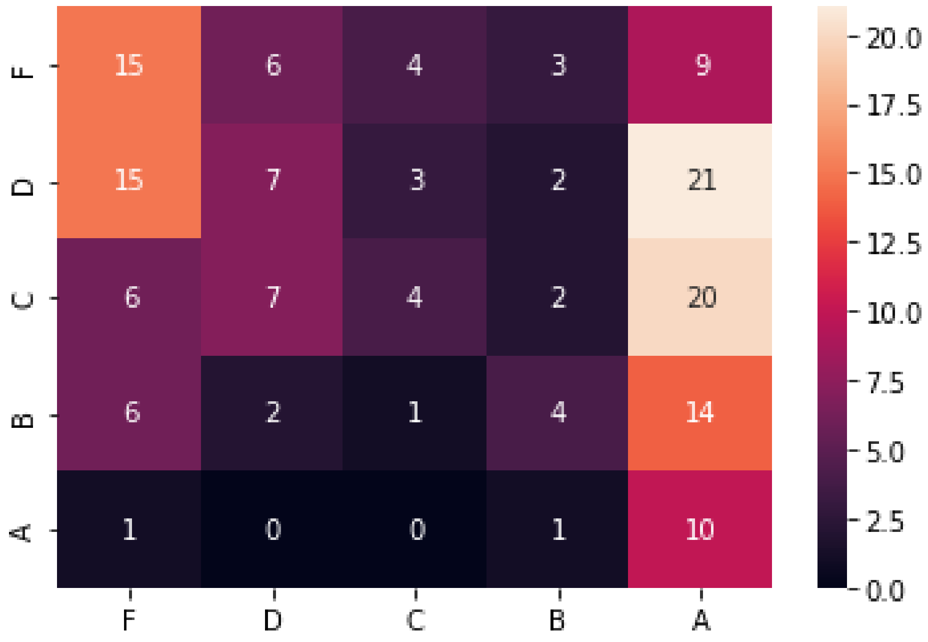
```
The macro F1 score for the classifier is -  0.1511294694720537
The accuracy for the classifier is -  0.2883435582822086
```



1.1.2 Reference System - Nearest Means

```
[ ]: Y_test_grades_pred = nearestMeansClassifier(X_train, Y_train, X_test)
     get_performance(Y_test_grades_actual, Y_test_grades_pred)
```

```
The macro F1 score for the classifier is -  0.2339098179522256
The accuracy for the classifier is -  0.245398773006135
```



Normalizing Data and encoding categorical data

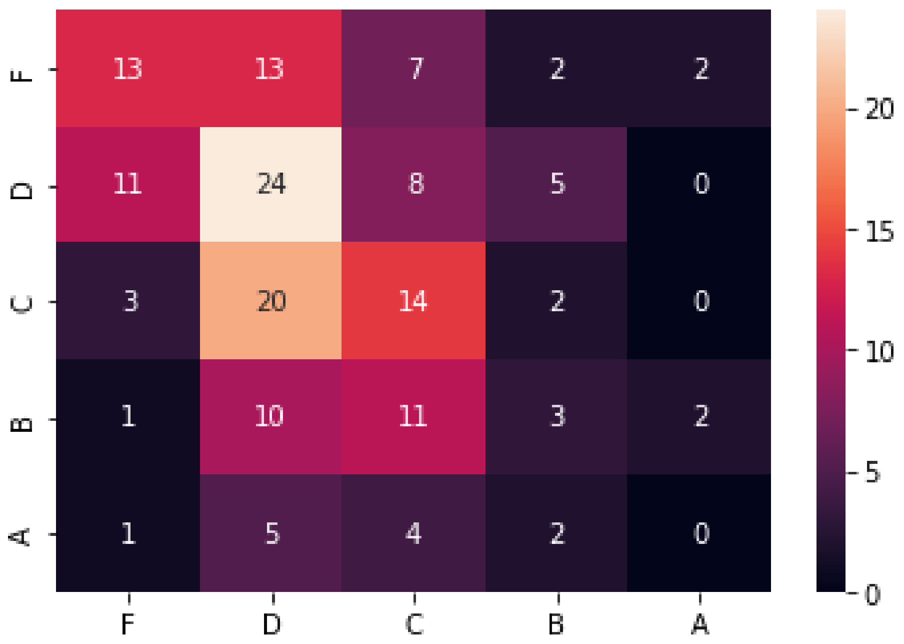
[ ]:
```
selected_columns = train_df.loc[:, ~train_df.columns.isin(['G1', 'G2', 'G3'])]
binary_vals = pd.get_dummies(selected_columns)
X_train = binary_vals.to_numpy()
pipe = Pipeline([('scale', StandardScaler())])
X_train_scaled = pipe.fit_transform(X_train)
```

[ ]:
```
test_df = pd.read_csv('data/student_performance_test.csv')
selected_columns = test_df.loc[:, ~test_df.columns.isin(['G1', 'G2', 'G3'])]
binary_vals = pd.get_dummies(selected_columns)
X_test = binary_vals.to_numpy()
pipe = Pipeline([('scale', StandardScaler())])
X_test_scaled = pipe.fit_transform(X_test)
```

1.1.3 Approach 1: K Nearest Neighbors

[ ]:
```
KNNClassifier(X_train_scaled, y_grades_train, X_test_scaled,␣
 ↪y_grades_test_actual)
```

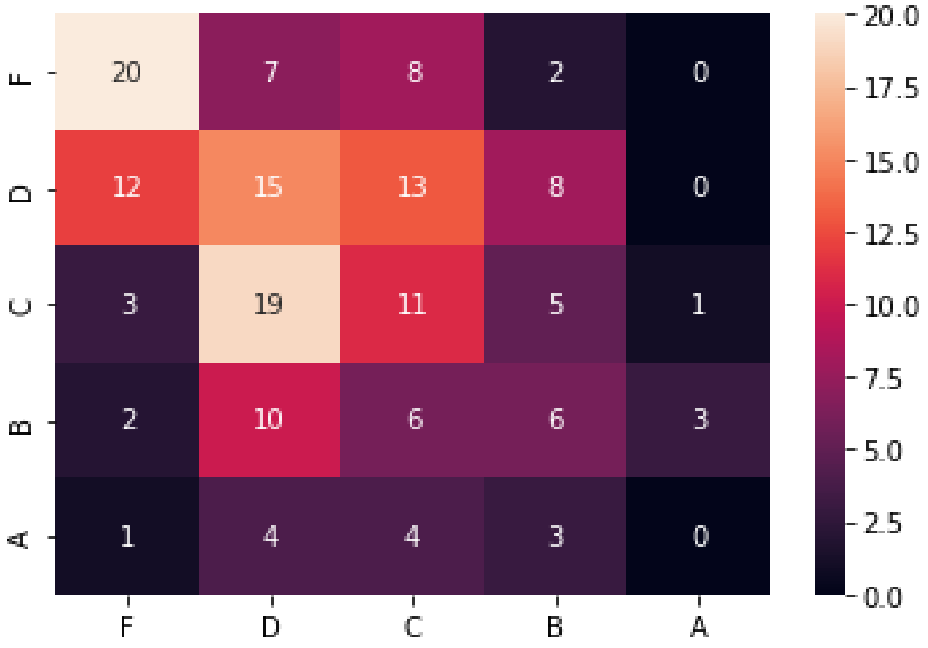
```
Best parameters from Cross Validation:  {'algorithm': 'ball_tree', 'leaf_size':
10, 'n_neighbors': 5, 'weights': 'uniform'}
Cross Validation Best Score 0.5390946502057613


The macro F1 score for the classifier is -  0.2555260509888779
The accuracy for the classifier is -  0.3312883435582822
```



1.1.4 Aproach 2 - Logistic Regression

```
[ ]: LogitClassifier(X_train_scaled, y_grades_train, X_test_scaled,␣
       ↪y_grades_test_actual)
```

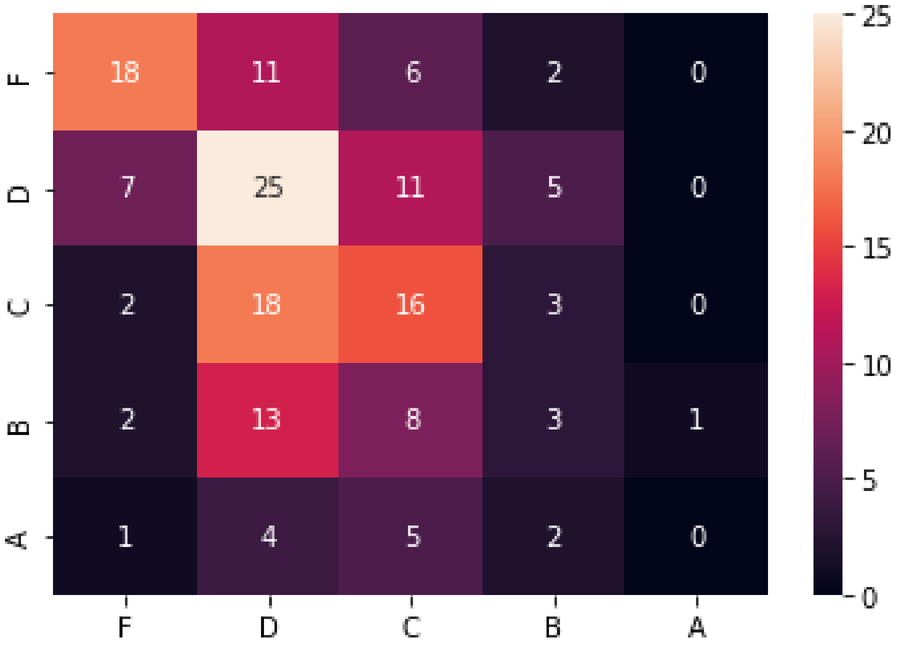
```
Best parameters from Cross Validation:  {'solver': 'liblinear', 'tol': 1e-05}
Cross Validation Best Score 0.5
The macro F1 score for the classifier is -  0.2662989050348655
The accuracy for the classifier is -  0.31901840490797545
```



1.1.5 Approach 3 - Kernel Support Vector Machine

[ ]:
```
KernelSVMClassifier(X_train_scaled, y_grades_train, X_test_scaled,␣
  ↪y_grades_test_actual)
```

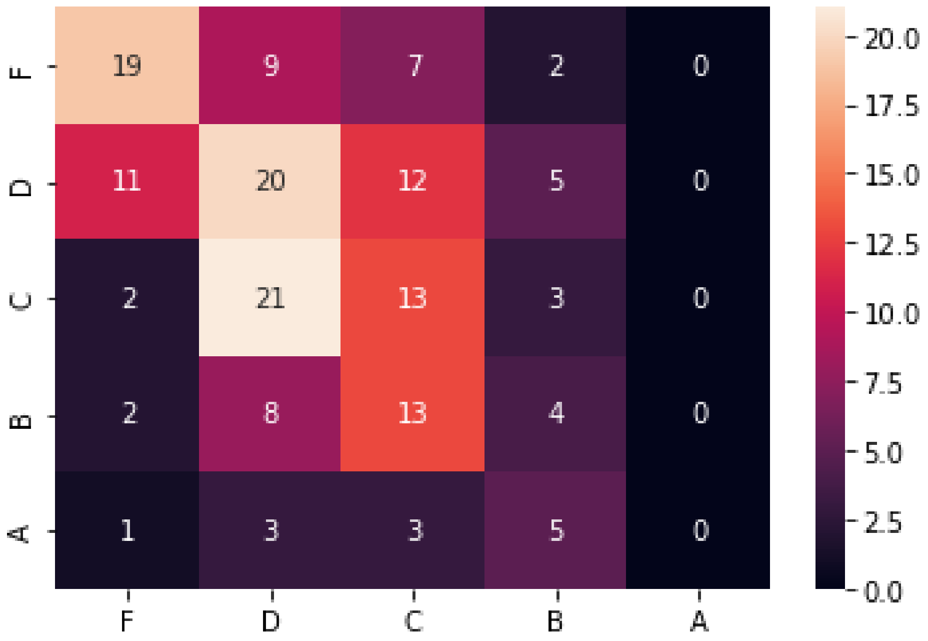
```
Best parameters from Cross Validation:  {'C': 1.2, 'class_weight': None,
'gamma': 'scale', 'kernel': 'rbf', 'tol': 1e-05}
Cross Validation Best Score 0.8086419753086419
The macro F1 score for the classifier is -  0.29536184623102973
The accuracy for the classifier is -  0.3803680981595092
```



1.1.6 Approach 4 - Multi-Layer Perceptron

```
[ ]: MLPerceptromClassifier(X_train_scaled, y_grades_train, X_test_scaled,␣
      ↪y_grades_test_actual)
```

```
Best parameters from Cross Validation:  {'activation': 'logistic', 'alpha':
0.05, 'learning_rate': 'constant', 'solver': 'sgd'}
Cross Validation Best Score 0.3560067325899432
The macro F1 score for the classifier is -  0.27350277460658046
The accuracy for the classifier is -  0.34355828220858897
```



1.2 Problem 2

- Predict final-period academic performance without any prior academic performance data: remove the G1 and G2 columns from the original dataset, then predict G3.

Removing categorical non-binary features and grades.

```
[ ]: selected_columns = train_df.loc[:, ~train_df.columns.isin(['Mjob', 'Fjob',␣
      ↪'reason', 'gaurdian', 'G1', 'G2', 'G3'])]
     binary_vals = pd.get_dummies(selected_columns)
     X_train = binary_vals.to_numpy() #Converting to numpy array for easier␣
      ↪processing

     y_train = train_df.loc[:, train_df.columns.isin(['G3'])] #Getting corresponding␣
      ↪labels
     Y_train = y_train['G3'].to_numpy()
     y_grades_train = list()
     for i in range(len(Y_train)):
         y_grades_train.append(get_grade(Y_train[i]))
     y_grades_train = np.array(y_grades_train)
```

Reading in test data and processing it

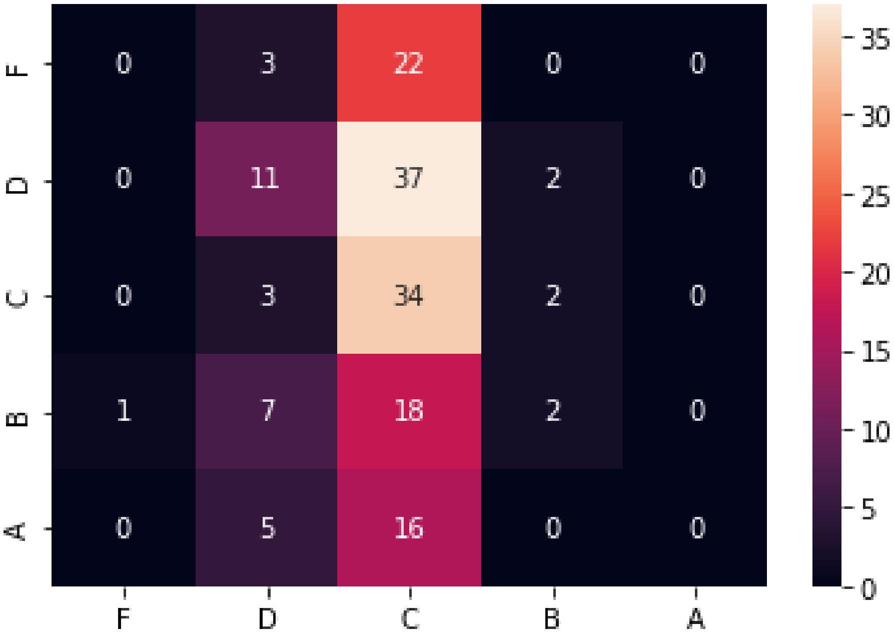
```
[ ]: test_df = pd.read_csv('data/student_performance_test.csv')
     selected_columns = test_df.loc[:, ~test_df.columns.isin(['Mjob', 'Fjob',␣
      ↪'reason', 'gaurdian', 'G1', 'G2', 'G3'])]
```

```
binary_vals = pd.get_dummies(selected_columns)
X_test = binary_vals.to_numpy() #Converting to numpy array for easier processing

y_test = test_df.loc[:, test_df.columns.isin(['G3'])] #Getting corresponding␣
 ↪labels
Y_test = y_test['G3'].to_numpy()
y_grades_test_actual = list()
for i in range(len(Y_test)):
    y_grades_test_actual.append(get_grade(Y_test[i]))
Y_test_grades_actual = np.array(y_grades_test_actual)
```

1.2.1 Trivial System

```
[ ]: Y_test_grades_pred = trivial_classifier(Y_train, X_test)
     get_performance(Y_test_grades_actual, Y_test_grades_pred)
```

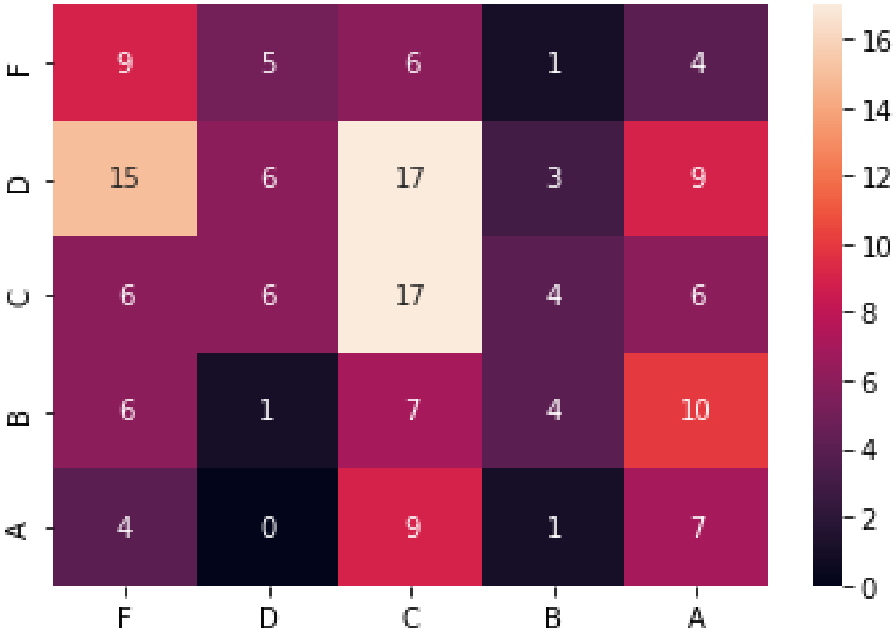
```
The macro F1 score for the classifier is -  0.16115332513972497
The accuracy for the classifier is -  0.2883435582822086
```



1.2.2 Reference System - Nearest Means

```
[ ]: Y_test_grades_pred = nearestMeansClassifier(X_train, Y_train, X_test)
     get_performance(Y_test_grades_actual, Y_test_grades_pred)
```

```
The macro F1 score for the classifier is -  0.25040487766154157
The accuracy for the classifier is -  0.26380368098159507
```

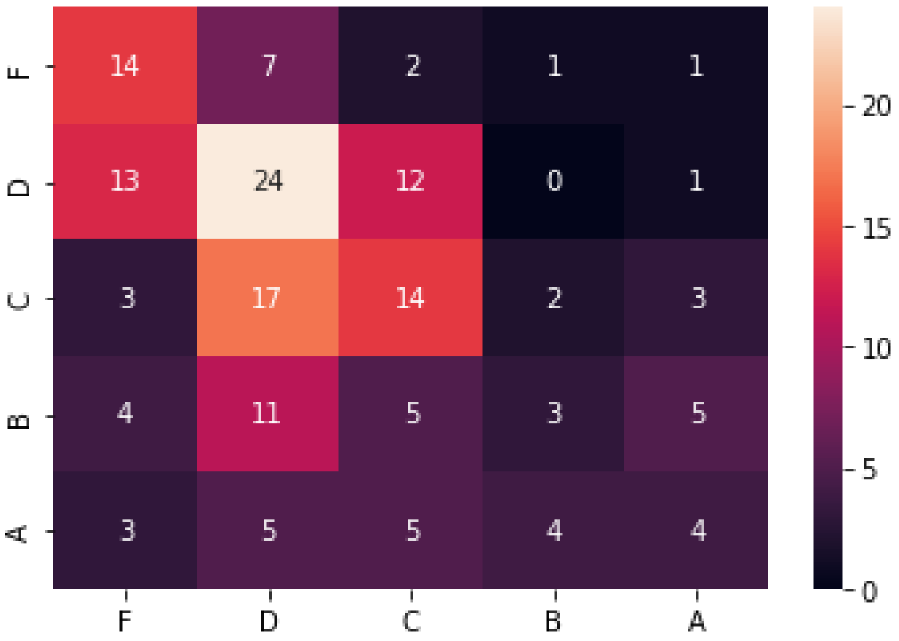


1.2.3 Approach 1: K Nearest Neighbors

[ ]:

```
KNNClassifier(X_train_scaled, y_grades_train, X_test_scaled,
  y_grades_test_actual)
```

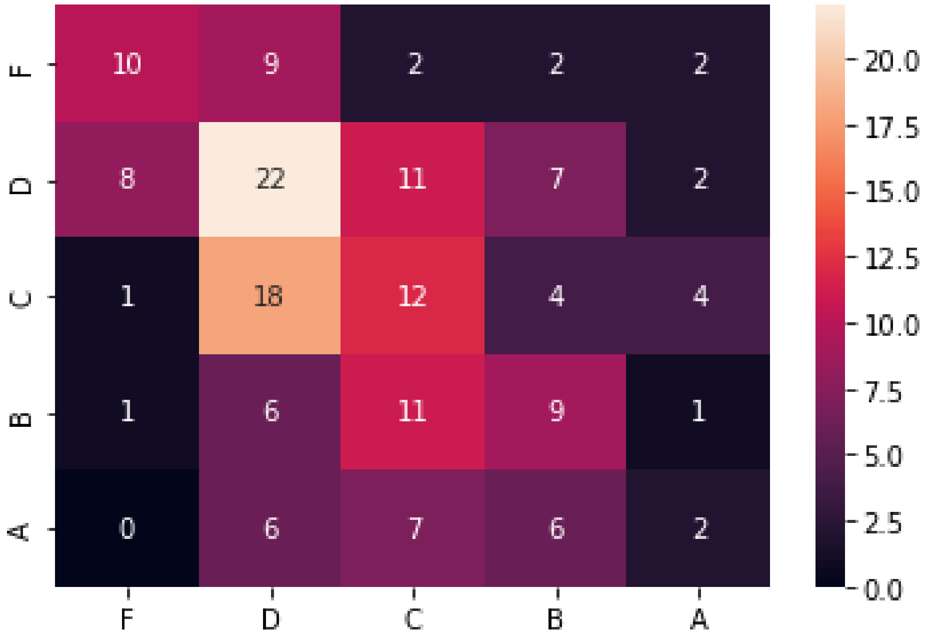
```
Best parameters from Cross Validation:  {'algorithm': 'ball_tree', 'leaf_size':
10, 'n_neighbors': 3, 'weights': 'uniform'}
Cross Validation Best Score 0.6049382716049383


The macro F1 score for the classifier is -  0.3245536127709303
The accuracy for the classifier is -  0.3619631901840491
```



1.2.4 Aproach 2 - Logistic Regression

```
[ ]: LogitClassifier(X_train_scaled, y_grades_train, X_test_scaled,␣
     ↪y_grades_test_actual)
```

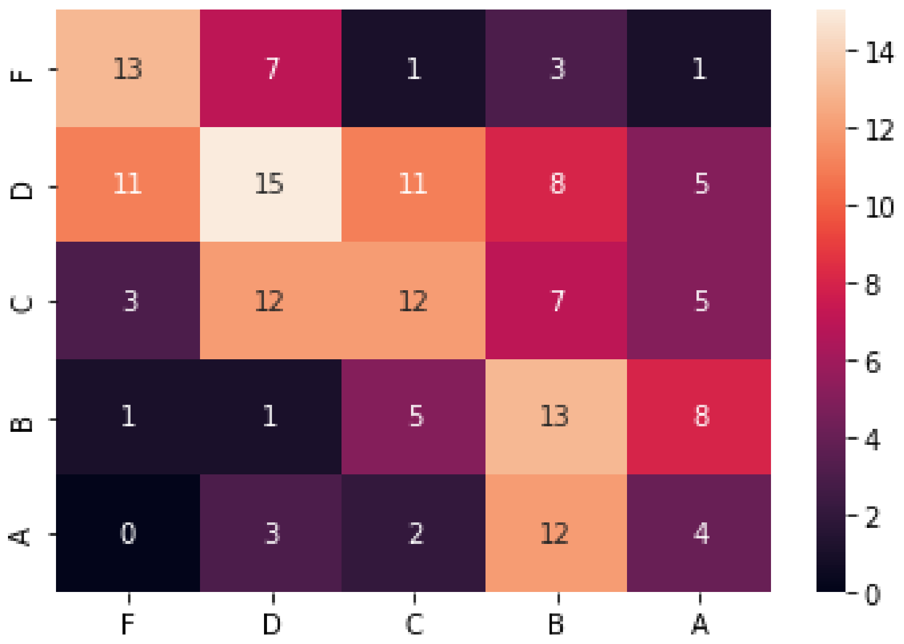
```
Best parameters from Cross Validation:  {'solver': 'liblinear', 'tol': 1e-05}
Cross Validation Best Score 0.5102880658436214
The macro F1 score for the classifier is -  0.3159904678197361
The accuracy for the classifier is -  0.3374233128834356
```



1.2.5 Approach 3 - Kernel Support Vector Machine

```
[ ]: KernelSVMClassifier(X_train_scaled, y_grades_train, X_test_scaled,␣
       ↪y_grades_test_actual)
```

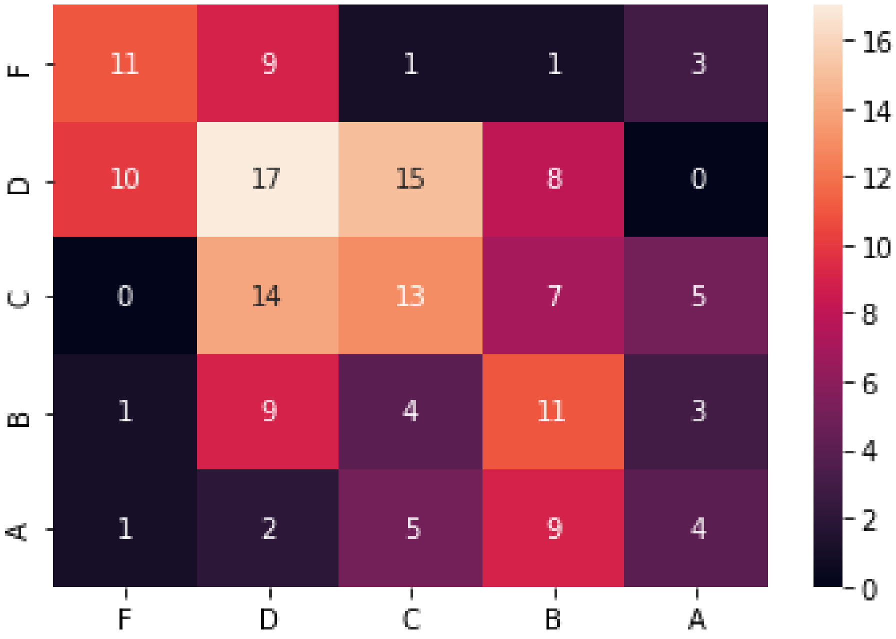
```
Best parameters from Cross Validation:  {'C': 1.0, 'class_weight': 'balanced',
'gamma': 'scale', 'kernel': 'rbf', 'tol': 1e-05}
Cross Validation Best Score 0.8065843621399177
The macro F1 score for the classifier is -  0.3444695272837712
The accuracy for the classifier is -  0.3496932515337423
```



1.2.6 Approach 4 - Multi Layer Perceptron

```
[ ]: MLPerceptromClassifier(X_train_scaled, y_grades_train, X_test_scaled,␣
         ↪y_grades_test_actual)
```

```
Best parameters from Cross Validation:  {'activation': 'relu', 'alpha': 0.0001,
'learning_rate': 'constant', 'solver': 'adam'}
Cross Validation Best Score 0.3496949295181991
The macro F1 score for the classifier is -  0.339720311316846
The accuracy for the classifier is -  0.34355828220858897
```



1.3 Problem 3

- Predict final academic performance using all available prior academic performance data: Keep G1 and G2 columns inside the dataset as features, then predict G3.

Removing categorical non-binary features.

```
[ ]: selected_columns = train_df.loc[:, ~train_df.columns.isin(['Mjob', 'Fjob',␣
      ↪'reason', 'gaurdian', 'G3'])]
     binary_vals = pd.get_dummies(selected_columns)
     X_train = binary_vals.to_numpy() #Converting to numpy array for easier␣
      ↪processing

     y_train = train_df.loc[:, train_df.columns.isin(['G3'])] #Getting corresponding␣
      ↪labels
     Y_train = y_train['G3'].to_numpy()
     y_grades_train = list()
     for i in range(len(Y_train)):
         y_grades_train.append(get_grade(Y_train[i]))
     y_grades_train = np.array(y_grades_train)
```

Reading in test data and processing it

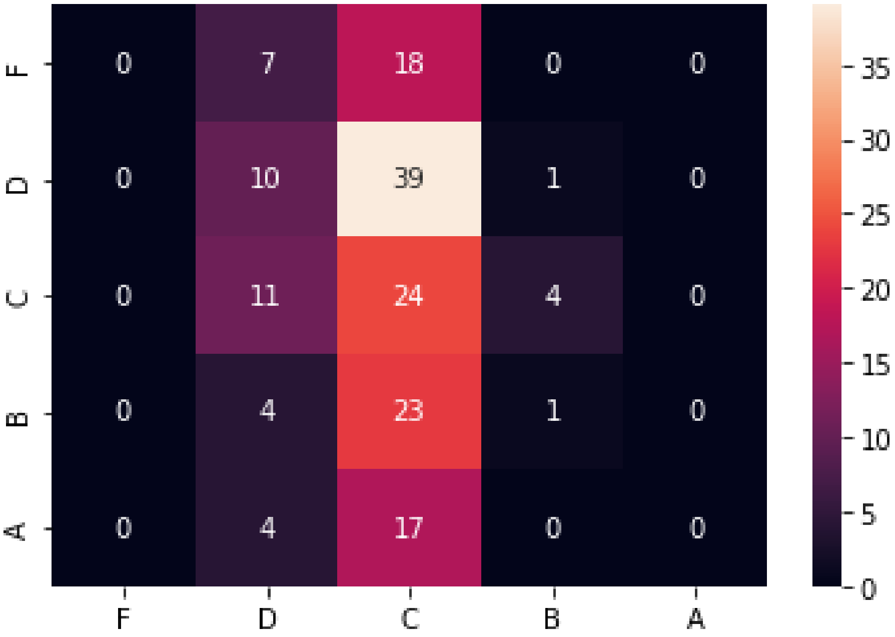
```
[ ]: test_df = pd.read_csv('data/student_performance_test.csv')
     selected_columns = test_df.loc[:, ~test_df.columns.isin(['Mjob', 'Fjob',␣
      ↪'reason', 'gaurdian', 'G3'])]
```

```
binary_vals = pd.get_dummies(selected_columns)
X_test = binary_vals.to_numpy() #Converting to numpy array for easier processing

y_test = test_df.loc[:, test_df.columns.isin(['G3'])] #Getting corresponding␣
 ↪labels
Y_test = y_test['G3'].to_numpy()
y_grades_test_actual = list()
for i in range(len(Y_test)):
    y_grades_test_actual.append(get_grade(Y_test[i]))
Y_test_grades_actual = np.array(y_grades_test_actual)
```

1.3.1 Trivial System

```
[ ]: Y_test_grades_pred = trivial_classifier(Y_train, X_test)
     get_performance(Y_test_grades_actual, Y_test_grades_pred)
```

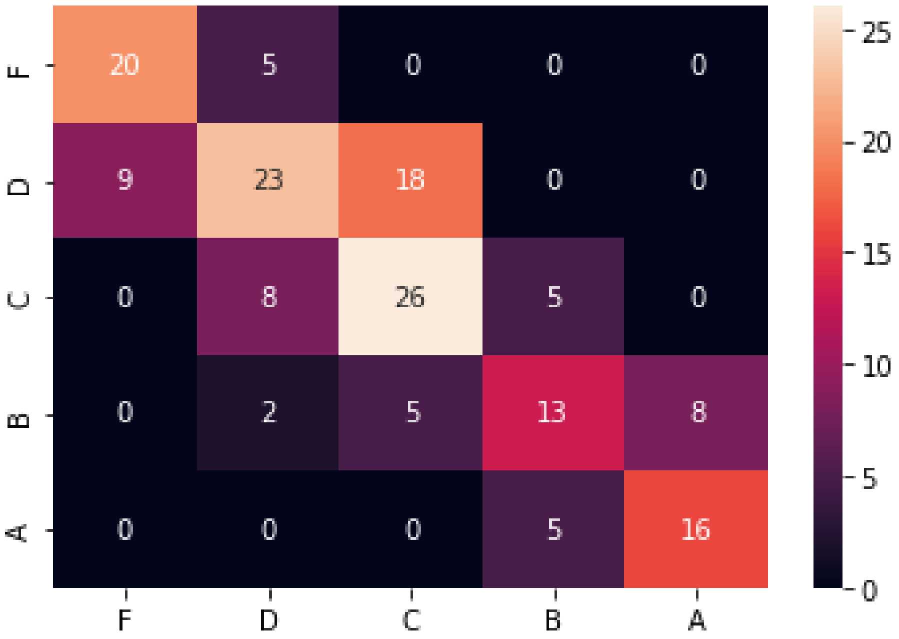
```
The macro F1 score for the classifier is -  0.1182763337893297
The accuracy for the classifier is -  0.2147239263803681
```



1.3.2 Reference System - Nearest Means

```
[ ]: Y_test_grades_pred = nearestMeansClassifier(X_train, Y_train, X_test)
     get_performance(Y_test_grades_actual, Y_test_grades_pred)
```

```
The macro F1 score for the classifier is -  0.6150584274113686
The accuracy for the classifier is -  0.6012269938650306
```



Normalizing data and encoding categorical data

[ ]:
```python
selected_columns = train_df.loc[:, ~train_df.columns.isin(['G3'])]
binary_vals = pd.get_dummies(selected_columns)
X_train = binary_vals.to_numpy()
pipe = Pipeline([('scale', StandardScaler())])
X_train_scaled = pipe.fit_transform(X_train)
```

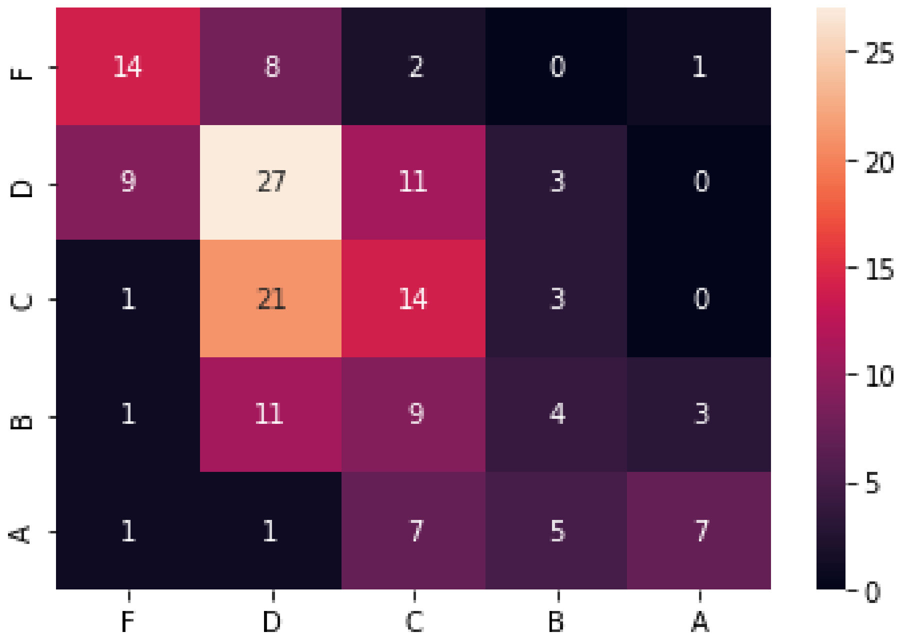
[ ]:
```python
test_df = pd.read_csv('data/student_performance_test.csv')
selected_columns = test_df.loc[:, ~test_df.columns.isin(['G3'])]
binary_vals = pd.get_dummies(selected_columns)
X_test = binary_vals.to_numpy()
pipe = Pipeline([('scale', StandardScaler())])
X_test_scaled = pipe.fit_transform(X_test)
```

1.3.3 Approach 1: K Nearest Neighbors

[ ]:
```python
KNNClassifier(X_train_scaled, y_grades_train, X_test_scaled,␣
  ↪y_grades_test_actual)
```

```
Best parameters from Cross Validation:  {'algorithm': 'ball_tree', 'leaf_size':
10, 'n_neighbors': 5, 'weights': 'uniform'}
Cross Validation Best Score 0.6069958847736625
```

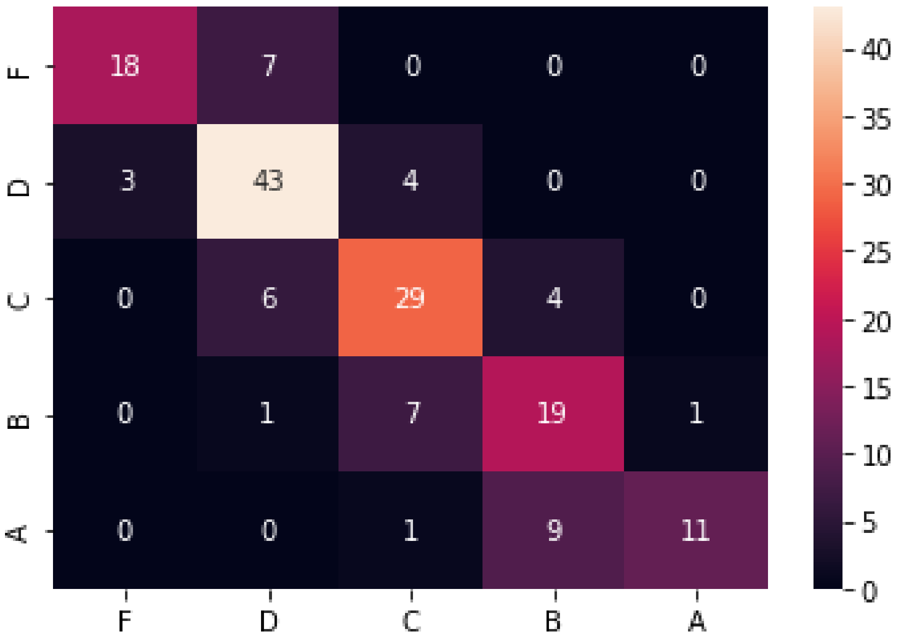
```
The macro F1 score for the classifier is -  0.3943313305498517
The accuracy for the classifier is -  0.4049079754601227
```



1.3.4 Aproach 2 - Logistic Regression

```
[ ]: LogitClassifier(X_train_scaled, y_grades_train, X_test_scaled,␣
      ↪y_grades_test_actual)
```

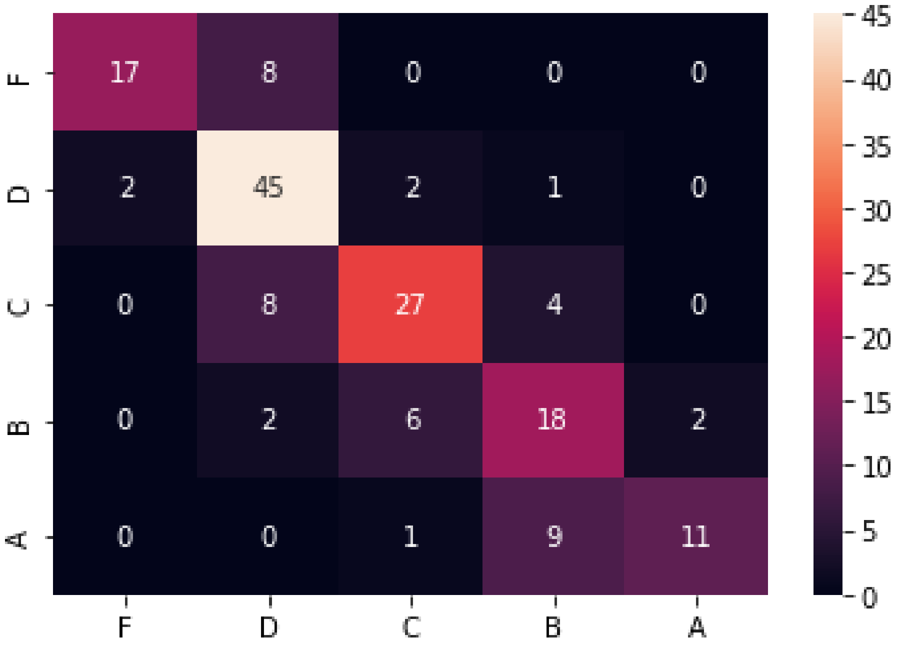
```
Best parameters from Cross Validation:  {'solver': 'newton-cg', 'tol': 1e-05}
Cross Validation Best Score 0.8045267489711934
The macro F1 score for the classifier is -  0.7222694026818367
The accuracy for the classifier is -  0.7361963190184049
```



1.3.5 Approach 3 - Kernel Support Vector Machine

```
[ ]: KernelSVMClassifier(X_train_scaled, y_grades_train, X_test_scaled, y_grades_test_actual)
```

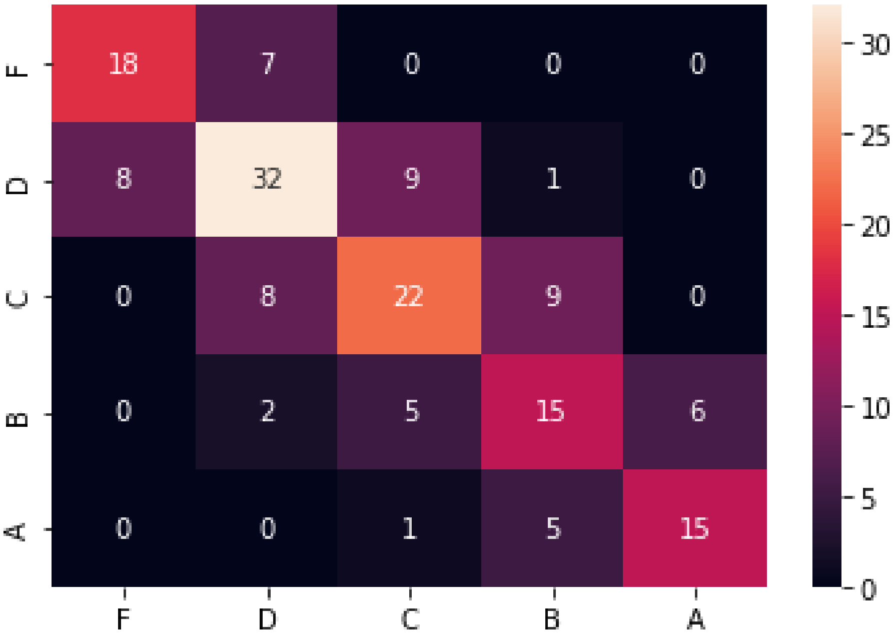
```
Best parameters from Cross Validation:  {'C': 1.2, 'class_weight': None,
'gamma': 'scale', 'kernel': 'linear', 'tol': 1e-05}
Cross Validation Best Score 0.8559670781893005
The macro F1 score for the classifier is -  0.707249254649567
The accuracy for the classifier is -  0.7239263803680982
```



1.3.6 Approach 4 - Multi Layer Perceptron

```
[ ]: MLPerceptromClassifier(X_train_scaled, y_grades_train, X_test_scaled, y_grades_test_actual)
```

```
Best parameters from Cross Validation:  {'activation': 'relu', 'alpha': 0.0001,
'learning_rate': 'constant', 'solver': 'lbfgs'}
Cross Validation Best Score 0.615190406059331
The macro F1 score for the classifier is -  0.6325642922845869
The accuracy for the classifier is -  0.6257668711656442
```



	F	D	C	B	A
F	18	7	0	0	0
D	8	32	9	1	0
C	0	8	22	9	0
B	0	2	5	15	6
A	0	0	1	5	15