EE559 Project Assignment

April 29, 2022

1 *Student Perfromance Dataset / Classification*

Imports

[ ]:

```python
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.decomposition import MiniBatchSparsePCA
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
```

[ ]:

```python
import warnings
warnings.filterwarnings('ignore')
```

Functions

[ ]:

```python
# 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('Cross Validation Best Score', clf.best_score_)
    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_)
    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)

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_)
    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)

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 Mission 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()
```

[ ]:

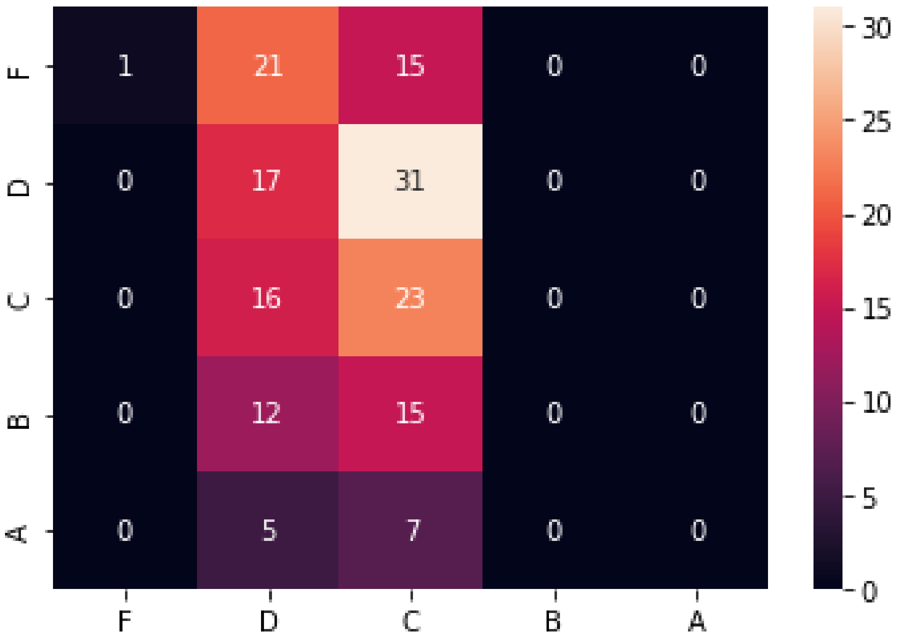
```
y_test = test_df.loc[:, test_df.columns.isin(['G1'])] #Rerun this cell to get␣
 ↪back orginal values of Y_test
Y_test = y_test['G1'].to_numpy()
y_grades_test_actual = list()
for i in range(len(Y_test)):
    y_grades_test_actual.append(get_grade(Y_test[i]))
Y_test_grades_actual = np.array(y_grades_test_actual)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

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 -  0.13843840370156163
The accuracy for the classifier is -  0.25153374233128833
```

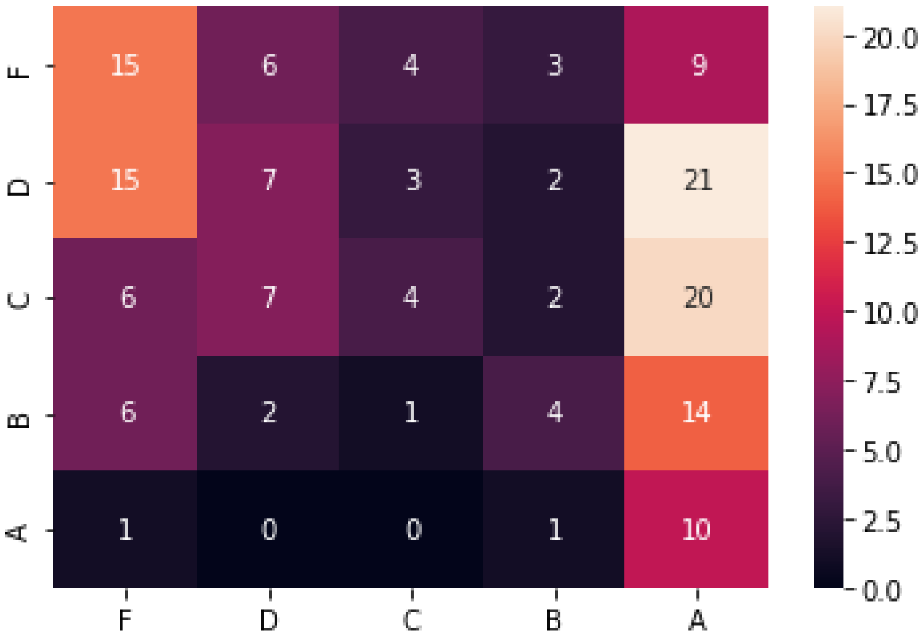


1.1.2 Reference System - Nearest Means

[ ]:

```
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

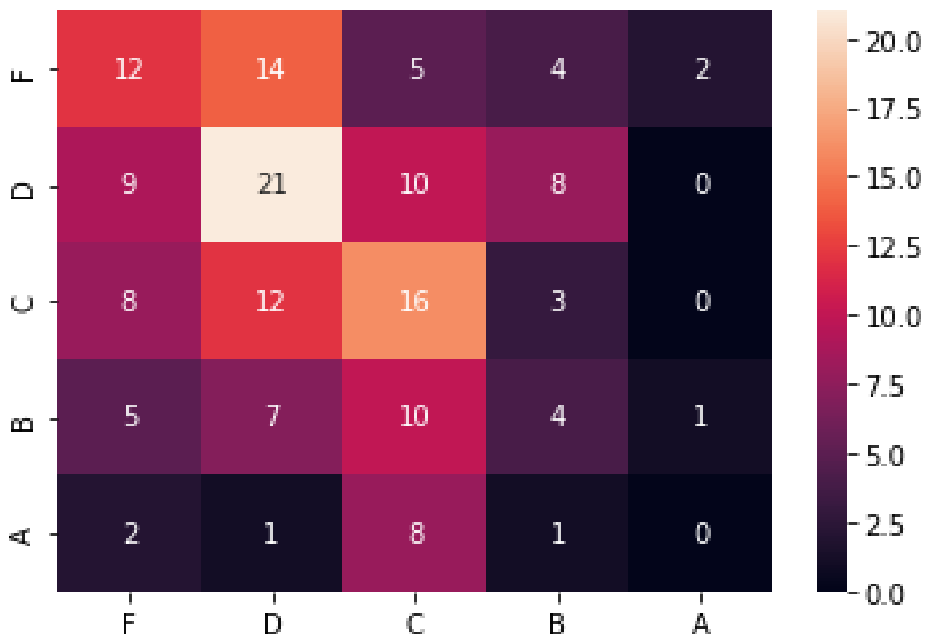
```
[ ]: selected_columns = train_df.loc[:, ~train_df.columns.isin(['G1', 'G2', 'G3'])]
     binary_vals = pd.get_dummies(selected_columns)
     X_train = binary_vals.to_numpy()
     pipe = Pipeline([('scale', StandardScaler())])
     X_train_ = pipe.fit_transform(X_train)
     pca = MiniBatchSparsePCA(n_components=25)
     X_train_scaled = pca.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()
     X_test_ = pipe.fit_transform(X_test)
     X_test_scaled = pca.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)
```

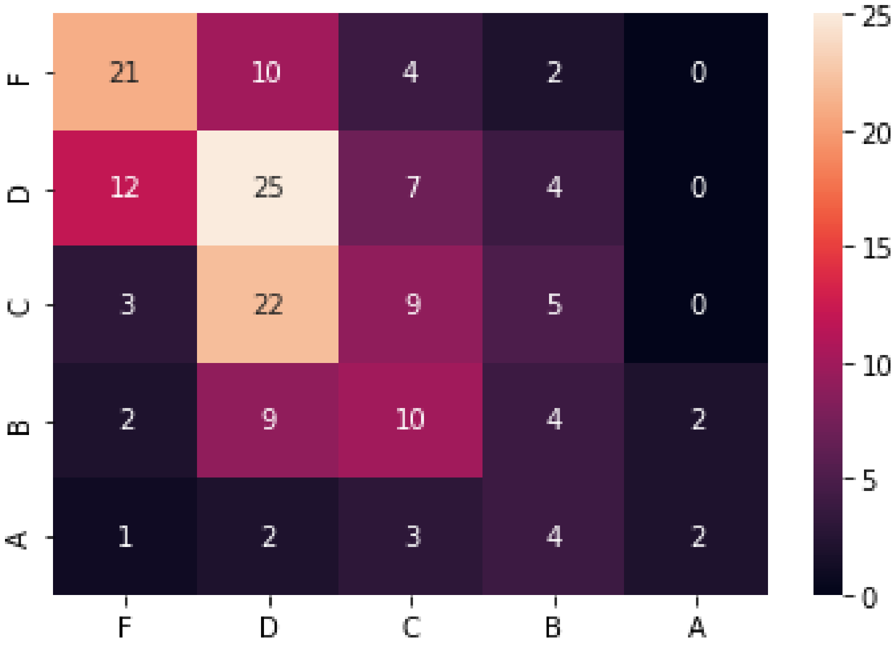
```
Best parameters from Cross Validation:  {'algorithm': 'ball_tree', 'leaf_size':
10, 'n_neighbors': 5, 'weights': 'uniform'}
Cross Validation Best Score 0.3579423521986114
The macro F1 score for the classifier is -  0.25407664863454876
The accuracy for the classifier is -  0.32515337423312884
```



1.1.4 Aproach 2 - Logistic Regression

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

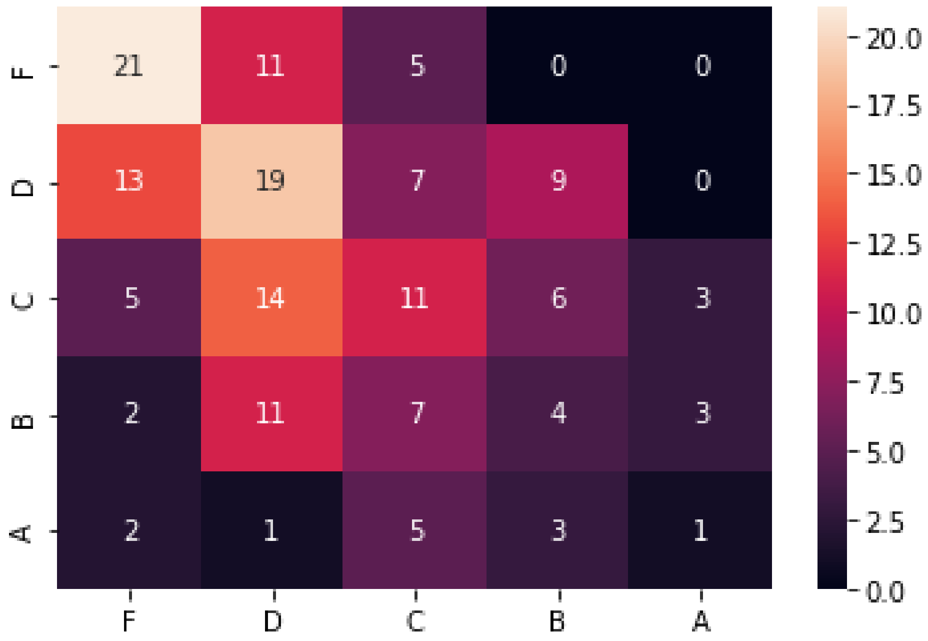
```
Best parameters from Cross Validation:  {'solver': 'newton-cg', 'tol': 1e-05}
Cross Validation Best Score 0.3415737428992215
The macro F1 score for the classifier is -  0.33151582103684996
The accuracy for the classifier is -  0.37423312883435583
```



1.1.5 Approach 3 - Kernel Support Vector Machine

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

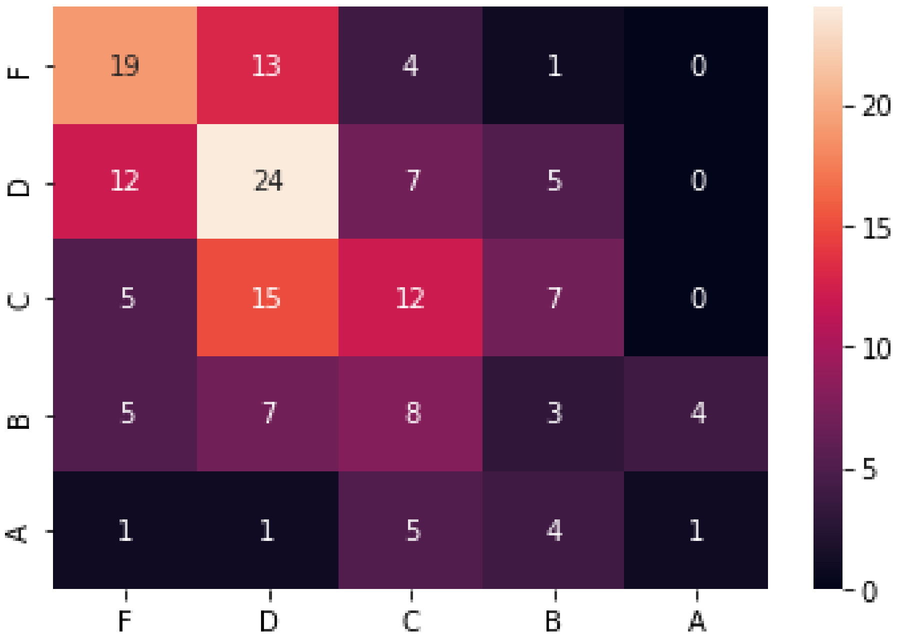
```
Best parameters from Cross Validation:  {'C': 1.0, 'class_weight': 'balanced',
'gamma': 'auto', 'kernel': 'rbf', 'tol': 1e-05}
Cross Validation Best Score 0.3723963812329055
The macro F1 score for the classifier is -  0.2912420753398197
The accuracy for the classifier is -  0.34355828220858897
```



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': 'tanh', 'alpha': 0.0001,
'learning_rate': 'constant', 'solver': 'sgd'}
Cross Validation Best Score 0.35394487691984006
The macro F1 score for the classifier is -  0.2981527471927814
The accuracy for the classifier is -  0.3619631901840491
```



1.2 Mission 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'])]
```

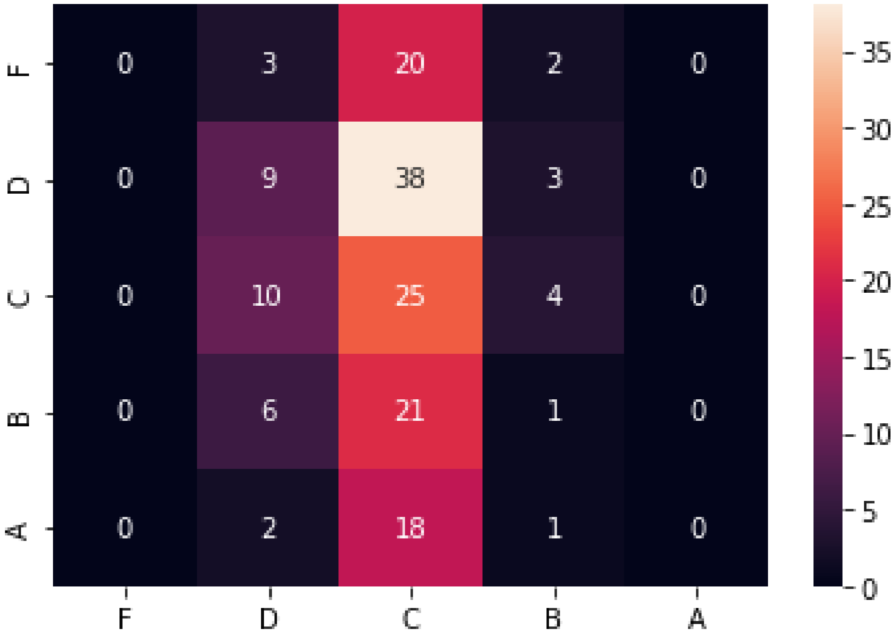
```
binary_vals = pd.get_dummies(selected_columns)
X_test = binary_vals.to_numpy() #Converting to numpy array for easier processing

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 -  0.11736821149864629
The accuracy for the classifier is -  0.2147239263803681
```

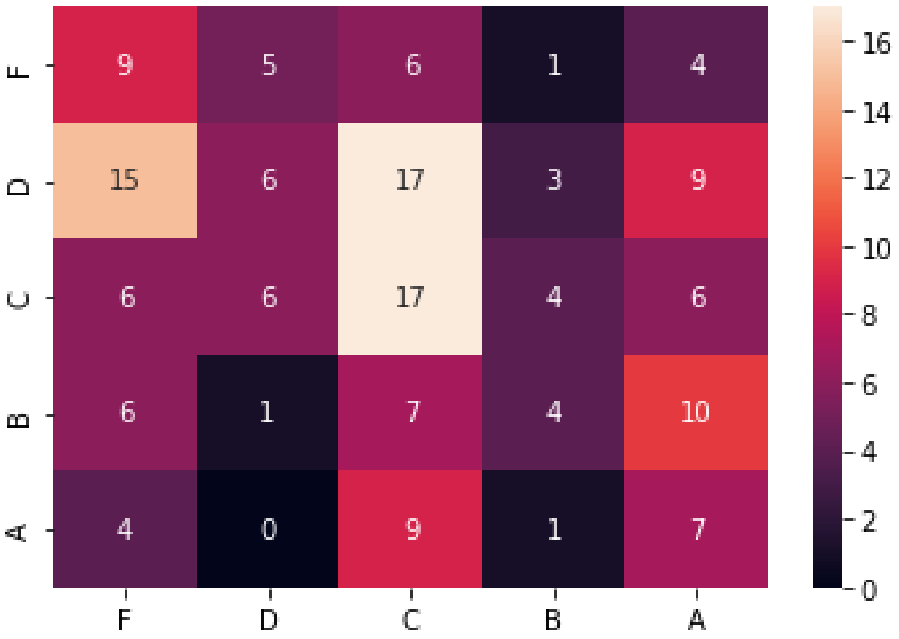


1.2.2 Reference System - Nearest Means

[ ]:

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

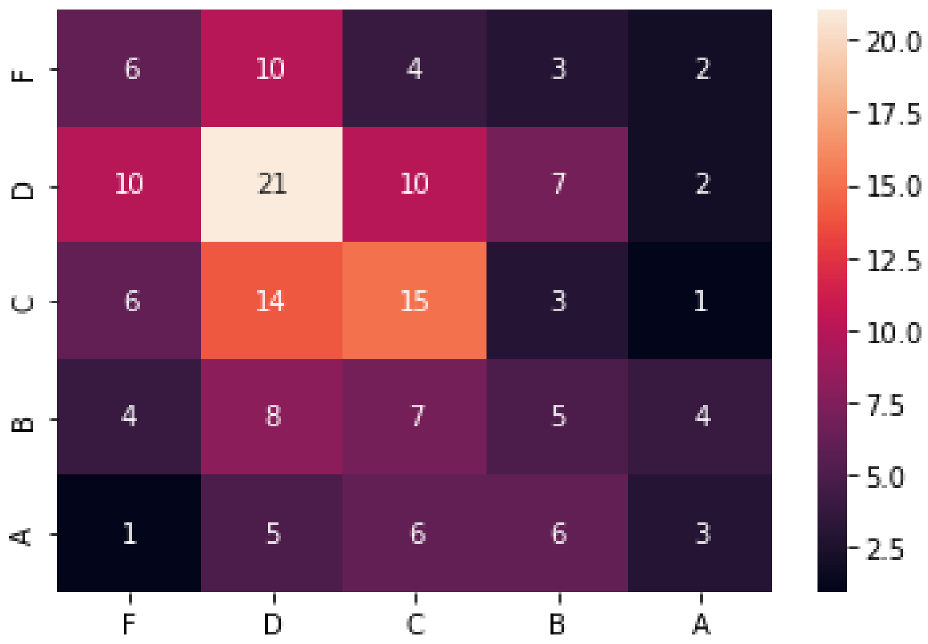
```
The macro F1 score for the classifier is -  0.25040487766154157
The accuracy for the classifier is -  0.26380368098159507
```



1.2.3 Approach 1: K Nearest Neighbors

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

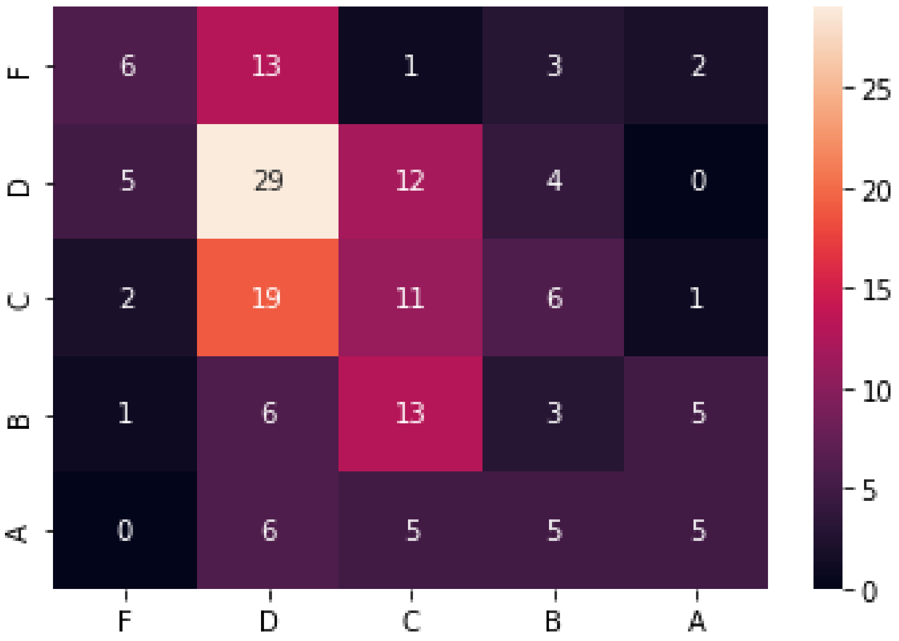
```
Best parameters from Cross Validation:  {'algorithm': 'ball_tree', 'leaf_size':
10, 'n_neighbors': 5, 'weights': 'uniform'}
Cross Validation Best Score 0.29633915421838836
The macro F1 score for the classifier is -  0.2728308728308728
The accuracy for the classifier is -  0.3067484662576687
```



1.2.4 Aproach 2 - Logistic Regression

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

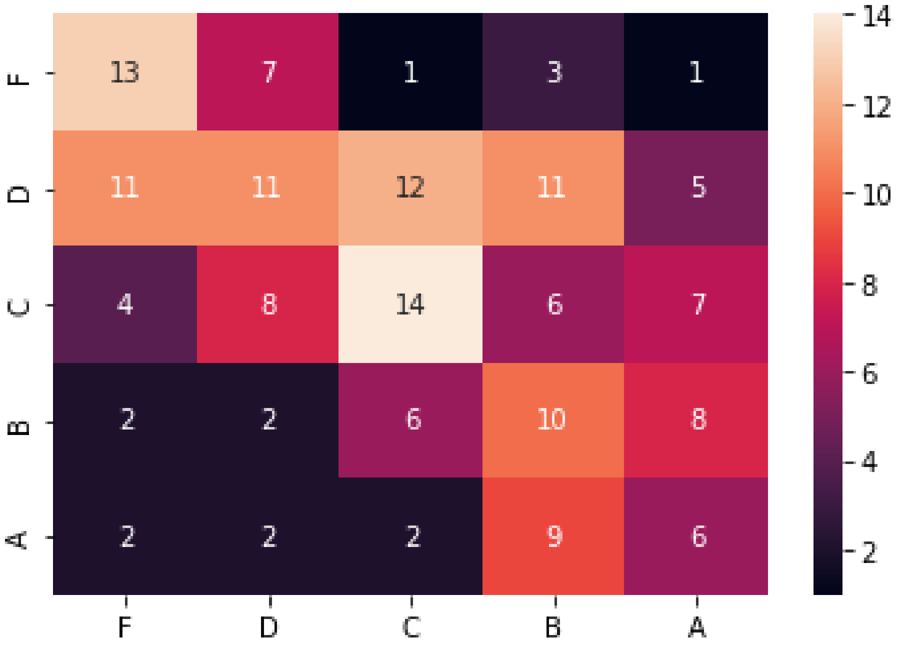
```
Best parameters from Cross Validation:  {'solver': 'newton-cg', 'tol': 1e-05}
Cross Validation Best Score 0.34963181148748157
The macro F1 score for the classifier is -  0.2934817176123454
The accuracy for the classifier is -  0.3312883435582822
```



1.2.5 Approach 3 - Kernel Support Vector Machine

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

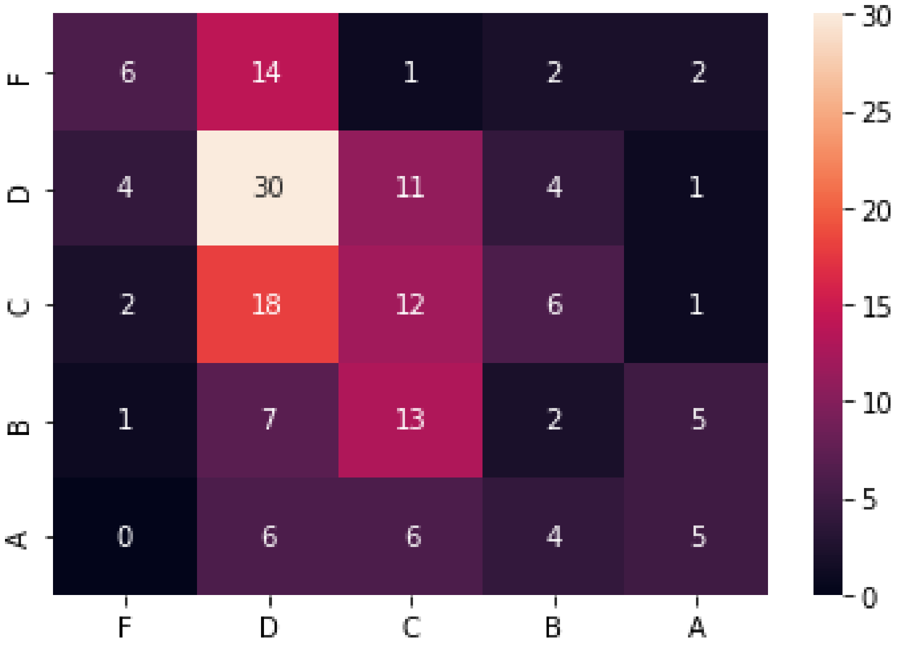
```
Best parameters from Cross Validation:  {'C': 0.8, 'class_weight': 'balanced',
'gamma': 'scale', 'kernel': 'rbf', 'tol': 1e-05}
Cross Validation Best Score 0.349737008205344
The macro F1 score for the classifier is -  0.3316052383884277
The accuracy for the classifier is -  0.3312883435582822
```



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': 'identity', 'alpha':
0.05, 'learning_rate': 'constant', 'solver': 'adam'}
Cross Validation Best Score 0.35169366715758466
The macro F1 score for the classifier is -  0.2922286415933789
The accuracy for the classifier is -  0.3374233128834356
```



1.3 Mission 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

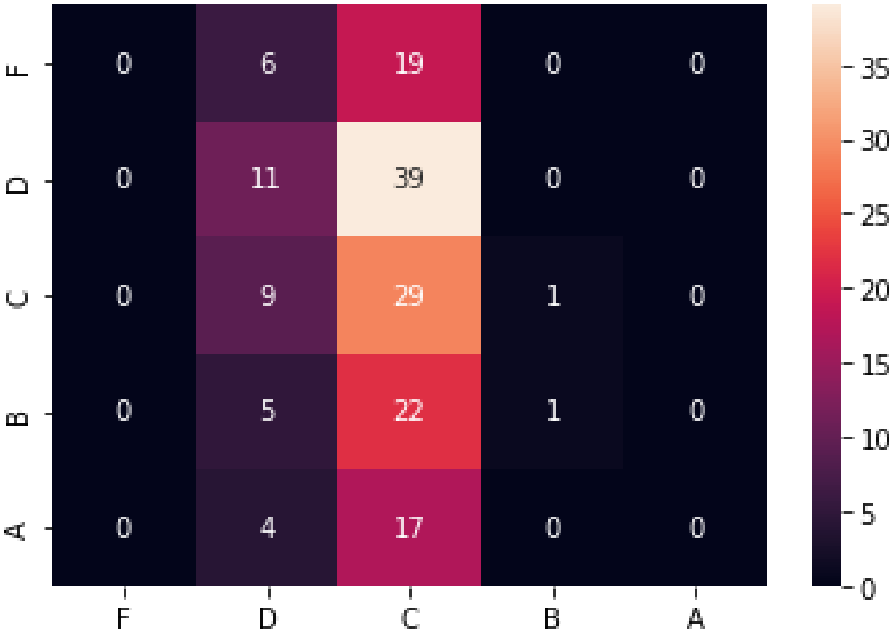
```
[ ]: test_df = pd.read_csv('data/student_performance_test.csv')
     selected_columns = test_df.loc[:, ~test_df.columns.isin(['Mjob', 'Fjob',␣
      ↪'reason', 'gaurdian', 'G3'])]
```

```
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)
```

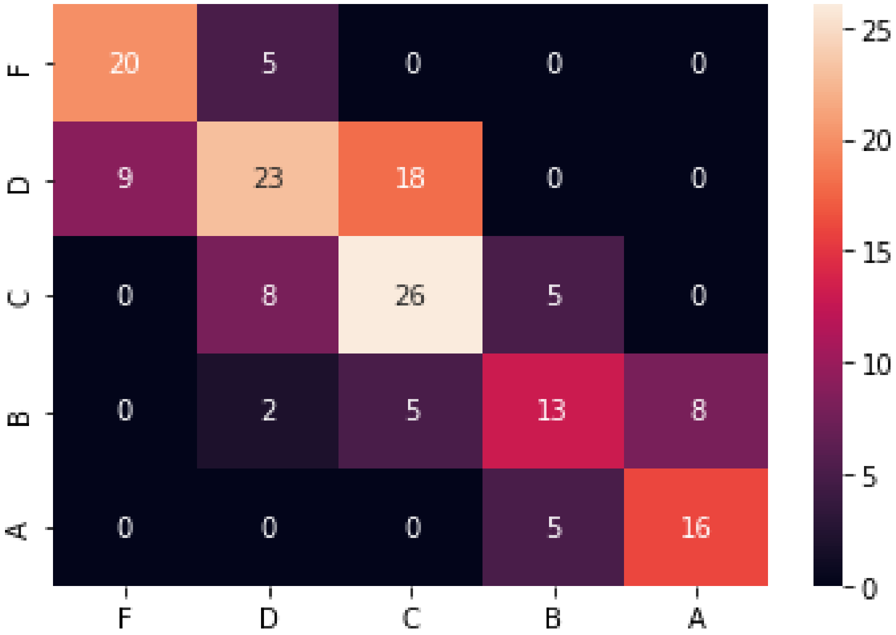
```
The macro F1 score for the classifier is -  0.13540106951871658
The accuracy for the classifier is -  0.25153374233128833
```



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

[ ]:
```
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_ = pipe.fit_transform(X_train)
pca = MiniBatchSparsePCA(n_components=25)
X_train_scaled = pca.fit_transform(X_train_)
```

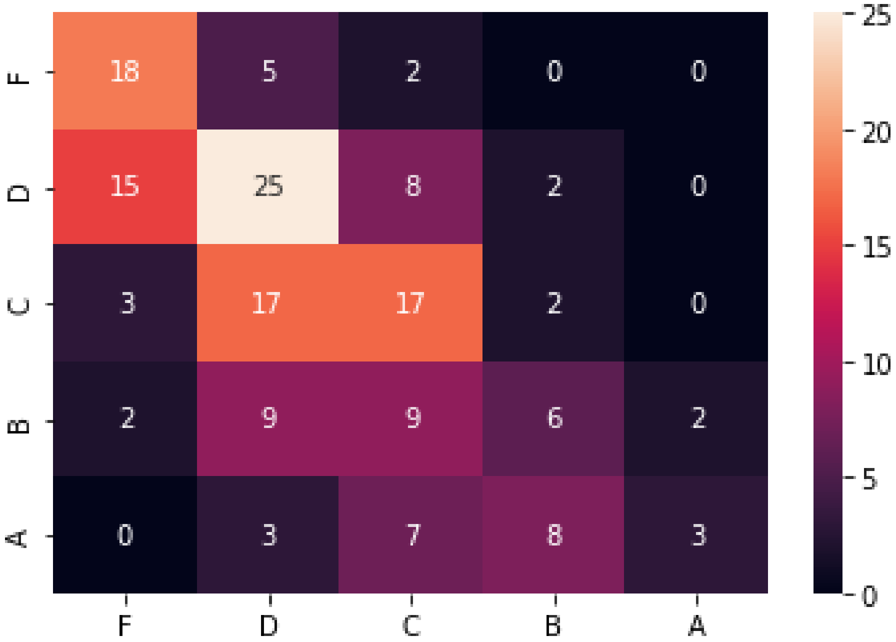
[ ]:
```
test_df = pd.read_csv('data/student_performance_test.csv')
selected_columns = test_df.loc[:, ~test_df.columns.isin(['G3'])]
binary_vals = pd.get_dummies(selected_columns)
X_test = binary_vals.to_numpy()
X_test_ = pipe.fit_transform(X_test)
X_test_scaled = pca.transform(X_test_)
```

1.3.3 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': 2, 'weights': 'uniform'}
```

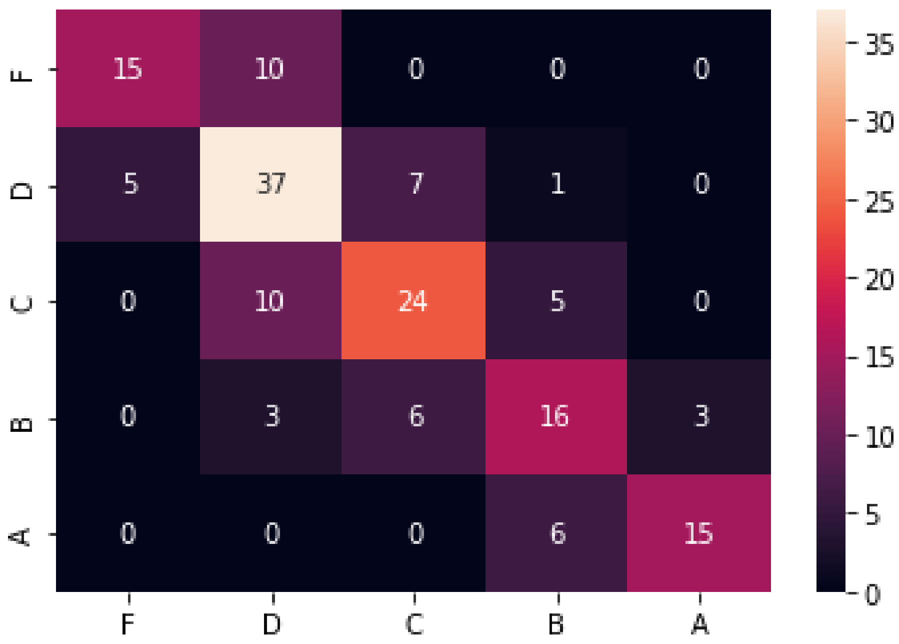
```
Cross Validation Best Score 0.3580685882600463
The macro F1 score for the classifier is -  0.3872834220173864
The accuracy for the classifier is -  0.4233128834355828
```



1.3.4 Aproach 2 - Logistic Regression

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

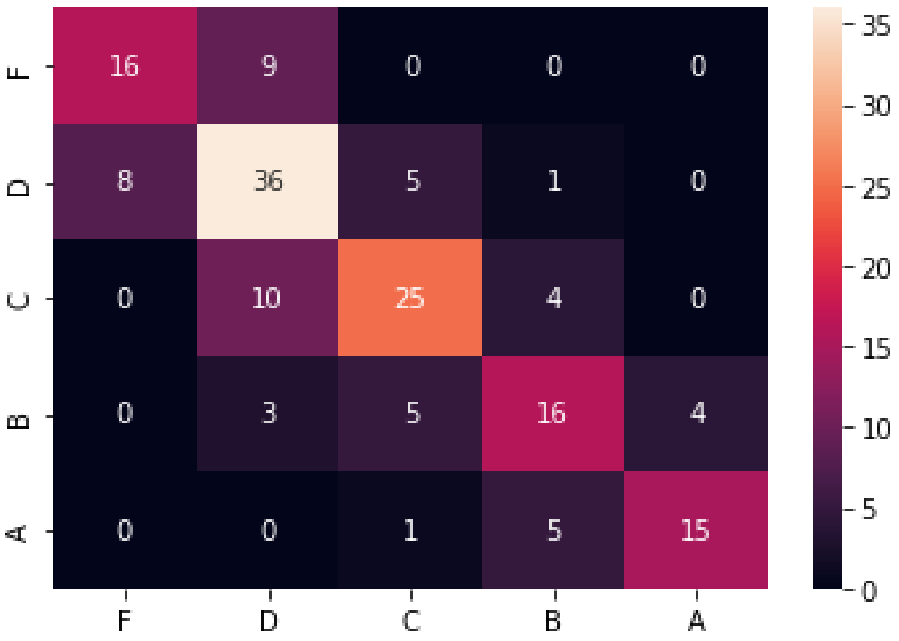
```
Best parameters from Cross Validation:  {'solver': 'newton-cg', 'tol': 1e-05}
Cross Validation Best Score 0.5862402693035977
The macro F1 score for the classifier is -  0.6623264454843402
The accuracy for the classifier is -  0.656441717791411
```



1.3.5 Approach 3 - Kernel Support Vector Machine

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

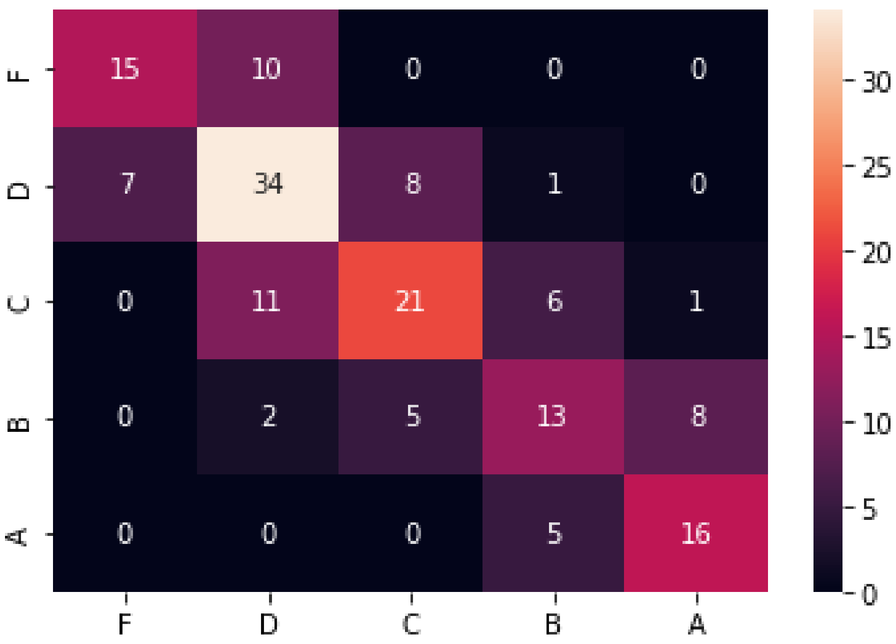
```
Best parameters from Cross Validation:  {'C': 0.9, 'class_weight': None,
'gamma': 'scale', 'kernel': 'linear', 'tol': 0.001}
Cross Validation Best Score 0.5801178203240058
The macro F1 score for the classifier is -  0.6657974300831444
The accuracy for the classifier is -  0.6625766871165644
```



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': 'logistic', 'alpha':
0.0001, 'learning_rate': 'constant', 'solver': 'adam'}
Cross Validation Best Score 0.5883231643172733
The macro F1 score for the classifier is -  0.6070745136868664
The accuracy for the classifier is -  0.6073619631901841
```


F
D
C
B
A
15
10
0
0
0
7
34
8
1
0
0
11
21
6
1
0
2
5
13
8
0
0
0
5
16
F
D
C
B
A
30
25
20
15
10
5
0