In [1]:

```
import warnings
warnings.filterwarnings("ignore")

import sqlite3
import pandas as pd
import numpy as np
import nltk
import string
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.feature_extraction.text import TfidfTransformer
from sklearn.feature_extraction.text import TfidfVectorizer

from sklearn.feature_extraction.text import CountVectorizer
from sklearn.metrics import confusion_matrix
from sklearn import metrics
from sklearn.metrics import roc_curve, auc
from nltk.stem.porter import PorterStemmer

import re
# Tutorial about Python regular expressions: https://pymotw.com/2/re/
import string
from nltk.corpus import stopwords
from nltk.stem import PorterStemmer
from nltk.stem.wordnet import WordNetLemmatizer

from gensim.models import Word2Vec
from gensim.models import KeyedVectors
import pickle

from tqdm import tqdm
import os

import plotly
import plotly.offline as offline
import plotly.graph_objs as go
offline.init_notebook_mode()
from collections import Counter
```

Reading the Data

In [2]:

```
# Tutorial about Python regular expressions: https://pymotw.com/2/re/
project_data = pd.read_csv('/home/shivam/Desktop/train_data.csv',nrows=20000)

resource_data = pd.read_csv('/home/shivam/Desktop/resources.csv')
```

In [3]:

```
project_data.head(5)
```

Out[3]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_submitted_datetime	project_grade_cate
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs.	IN	2016-12-05 13:43:57	Grades Pr
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr.	FL	2016-10-25 09:22:10	Grade
2	21895	p182444	3465aaf82da834c0582ebd0ef8040ca0	Ms.	AZ	2016-08-31 12:03:56	Grade
3	45	p246581	f3cb9bffbba169bef1a77b243e620b60	Mrs.	KY	2016-10-06 21:16:17	Grades Pr
4	172407	p104768	be1f7507a41f8479dc06f047086a39ec	Mrs.	TX	2016-07-11 01:10:09	Grades Pr

Preprocessing Categorical Features: project_grade_category

In [4]:

```
project_data['project_grade_category'].head(10)

project_data['project_grade_category'] = project_data['project_grade_category'].str.replace(' ','_')
project_data['project_grade_category'] = project_data['project_grade_category'].str.replace('-','_')
project_data['project_grade_category'] = project_data['project_grade_category'].str.lower()
project_data['project_grade_category'].value_counts()
```

Out[4]:

```
grades_prek_2    8171
grades_3_5       6785
grades_6_8       3079
grades_9_12      1965
Name: project_grade_category, dtype: int64
```

Preprocessing Categorical Features: project_subject_categories

In [5]:

```
#
project_data['project_subject_categories'] = project_data['project_subject_categories'].str.replace(' The ','')
project_data['project_subject_categories'] = project_data['project_subject_categories'].str.replace(' ','')
project_data['project_subject_categories'] = project_data['project_subject_categories'].str.replace('&','_')
project_data['project_subject_categories'] = project_data['project_subject_categories'].str.replace(',','_')
project_data['project_subject_categories'] = project_data['project_subject_categories'].str.lower()
project_data['project_subject_categories'].value_counts()
```

Out[5]:

```
literacy_language                        4403
math_science                             3039
literacy_language_math_science           2707
health_sports                            1896
music_arts                                929
specialneeds                              742
literacy_language_specialneeds            742
appliedlearning                           694
math_science_literacy_language            435
appliedlearning_literacy_language         404
math_science_specialneeds                 358
history_civics                            331
literacy_language_music_arts              302
appliedlearning_specialneeds              300
math_science_music_arts                   286
history_civics_literacy_language          257
warmth_care_hunger                        245
health_sports_specialneeds                240
math_science_appliedlearning              217
appliedlearning_math_science              189
appliedlearning_music_arts                157
health_sports_literacy_language           140
literacy_language_history_civics          138
appliedlearning_health_sports             110
math_science_history_civics               109
literacy_language_appliedlearning         102
math_science_health_sports                 71
history_civics_math_science                69
health_sports_math_science                 50
history_civics_music_arts                  49
health_sports_appliedlearning              44
specialneeds_music_arts                    44
history_civics_specialneeds                39
appliedlearning_history_civics             37
health_sports_music_arts                   26
music_arts_specialneeds                    26
literacy_language_health_sports            12
history_civics_appliedlearning             12
health_sports_history_civics               11
specialneeds_health_sports                 10
health_sports_warmth_care_hunger            5
math_science_warmth_care_hunger             4
appliedlearning_warmth_care_hunger          4
music_arts_history_civics                   3
music_arts_health_sports                    3
specialneeds_warmth_care_hunger             3
history_civics_health_sports                2
literacy_language_warmth_care_hunger        2
music_arts_warmth_care_hunger               1
music_arts_appliedlearning                  1
Name: project_subject_categories, dtype: int64
```

Preprocessing Categorical Features: teacher_prefix

In [6]:

```
#
project_data['teacher_prefix'] = project_data['teacher_prefix'].str.replace('.','')
project_data['teacher_prefix'] = project_data['teacher_prefix'].str.lower()
project_data['teacher_prefix'].value_counts()
```

Out[6]:

```
mrs        10420
ms          7222
mr          1908
teacher      449
Name: teacher_prefix, dtype: int64
```

Preprocessing Categorical Features: project_subject_subcategories

In [7]:

```
#
project_data['project_subject_subcategories'] = project_data['project_subject_subcategories'].str.replace(' The '
,'')
project_data['project_subject_subcategories'] = project_data['project_subject_subcategories'].str.replace(' ','')
project_data['project_subject_subcategories'] = project_data['project_subject_subcategories'].str.replace('&','_'
)
project_data['project_subject_subcategories'] = project_data['project_subject_subcategories'].str.replace(',','_'
)
project_data['project_subject_subcategories'] = project_data['project_subject_subcategories'].str.lower()
project_data['project_subject_subcategories'].value_counts()
```

Out[7]:

```
literacy                                1822
literacy_mathematics                    1519
literature_writing_mathematics          1124
literacy_literature_writing             1023
mathematics                              955
                                        ...
economics_other                            1
environmentalscience_other                 1
parentinvolvement_performingarts           1
civics_government_college_careerprep       1
communityservice_nutritioneducation        1
Name: project_subject_subcategories, Length: 339, dtype: int64
```

Preprocessing Categorical Features: school_state

In [8]:

```
#
project_data['school_state'] = project_data['school_state'].str.lower()
project_data['school_state'].value_counts()
```

Out[8]:

```
ca    2808
ny    1320
tx    1316
fl    1093
nc     967
il     769
sc     737
ga     725
mi     612
pa     575
oh     481
in     479
mo     475
la     458
wa     440
ok     430
ma     414
az     412
nj     399
va     352
ct     327
wi     322
tn     320
ut     318
al     300
nv     264
md     255
or     244
ky     231
co     228
ms     224
mn     212
ar     174
ks     129
id     124
ia     123
dc     100
me     100
hi      99
wv      99
nm      93
ak      66
sd      63
ne      59
de      55
ri      55
nh      51
mt      41
nd      26
wy      25
vt      11
Name: school_state, dtype: int64
```

In [9]:

```python
def decontracted(phrase):
    # specific
    phrase = re.sub(r"won't", "will not", phrase)
    phrase = re.sub(r"can\'t", "can not", phrase)

    # general
    phrase = re.sub(r"n\'t", " not", phrase)
    phrase = re.sub(r"\'re", " are", phrase)
    phrase = re.sub(r"\'s", " is", phrase)
    phrase = re.sub(r"\'d", " would", phrase)
    phrase = re.sub(r"\'ll", " will", phrase)
    phrase = re.sub(r"\'t", " not", phrase)
    phrase = re.sub(r"\'ve", " have", phrase)
    phrase = re.sub(r"\'m", " am", phrase)
    return phrase
```

In [10]:

```
stopwords= ['i', 'me', 'my', 'myself', 'we', 'our', 'ours', 'ourselves', 'you', "you're", "you've",\
            "you'll", "you'd", 'your', 'yours', 'yourself', 'yourselves', 'he', 'him', 'his', 'himself', \
            'she', "she's", 'her', 'hers', 'herself', 'it', "it's", 'its', 'itself', 'they', 'them', 'their',\
            'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'that', "that'll", 'these', 'those',
\
            'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'has', 'had', 'having', 'do', 'does'
, \
            'did', 'doing', 'a', 'an', 'the', 'and', 'but', 'if', 'or', 'because', 'as', 'until', 'while', 'of',
\
            'at', 'by', 'for', 'with', 'about', 'against', 'between', 'into', 'through', 'during', 'before', 'aft
er',\
            'above', 'below', 'to', 'from', 'up', 'down', 'in', 'out', 'on', 'off', 'over', 'under', 'again', 'fu
rther',\
            'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'all', 'any', 'both', 'each', 'few',
'more',\
            'most', 'other', 'some', 'such', 'only', 'own', 'same', 'so', 'than', 'too', 'very', \
            's', 't', 'can', 'will', 'just', 'don', "don't", 'should', "should've", 'now', 'd', 'll', 'm', 'o', '
re', \
            've', 'y', 'ain', 'aren', "aren't", 'couldn', "couldn't", 'didn', "didn't", 'doesn', "doesn't", 'hadn
',\
            "hadn't", 'hasn', "hasn't", 'haven', "haven't", 'isn', "isn't", 'ma', 'mightn', "mightn't", 'mustn',\
            "mustn't", 'needn', "needn't", 'shan', "shan't", 'shouldn', "shouldn't", 'wasn', "wasn't", 'weren', "
weren't", \
            'won', "won't", 'wouldn', "wouldn't"]
```

Preprocessing Text Features: project_title

In [11]:

```
from tqdm import tqdm
def preprocess_text(text_data):
    preprocessed_text = []
    # tqdm is for printing the status bar
    for sentance in tqdm(text_data):
        sent = decontracted(sentance)
        sent = sent.replace('\\r', ' ')
        sent = sent.replace('\\n', ' ')
        sent = sent.replace('\\"', ' ')
        sent = re.sub('[^A-Za-z0-9]+', ' ', sent)
        # https://gist.github.com/sebleier/554280
        sent = ' '.join(e for e in sent.split() if e.lower() not in stopwords)
        preprocessed_text.append(sent.lower().strip())
    return preprocessed_text
preprocessed_titles = preprocess_text(project_data['project_title'].values)


project_data['project_title']=preprocessed_titles
```

```
100%|██████████| 20000/20000 [00:01<00:00, 12331.01it/s]
```

Adding all essay and save in new column "essay"

In [12]:

```
project_data["essay"] = project_data["project_essay_1"].map(str) +\
                        project_data["project_essay_2"].map(str) + \
                        project_data["project_essay_3"].map(str) + \
                        project_data["project_essay_4"].map(str)


preprocessed_essays = preprocess_text(project_data['essay'].values)

project_data['essay']=preprocessed_essays
```

```
100%|██████████| 20000/20000 [00:36<00:00, 551.86it/s]
```

Merge column (price,quantity) from resource_data into project_data

In [13]:

```
price_data = resource_data.groupby('id').agg({'price':'sum', 'quantity':'sum'}).reset_index()
project_data = pd.merge(project_data, price_data, on='id', how='left')

project_data['price'].head()
```

Out[13]:

```
0    154.60
1    299.00
2    516.85
3    232.90
4     67.98
Name: price, dtype: float64
```

Drop all unwanted columns and save data in X, y variables

In [14]:

```
project_data.columns
data = project_data.drop(['project_is_approved','Unnamed: 0','project_essay_1', 'project_essay_2',
       'project_essay_3', 'project_essay_4','teacher_id','project_submitted_datetime'], axis=1)

y = project_data['project_is_approved'].values
X = data
```

In [15]:

```
X.head()
```

Out[15]:

	id	teacher_prefix	school_state	project_grade_category	project_subject_categories	project_subject_subcategories	pro
0	p253737	mrs	in	grades_prek_2	literacy_language	esl_literacy	ed suppo learn
1	p258326	mr	fl	grades_6_8	history_civics_health_sports	civics_government_teamsports	hungry
2	p182444	ms	az	grades_6_8	health_sports	health_wellness_teamsports	e a midd
3	p246581	mrs	ky	grades_prek_2	literacy_language_math_science	literacy_mathematics	kinder
4	p104768	mrs	tx	grades_prek_2	math_science	mathematics	interac

Break data into Train, CV and Test

In [16]:

```
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, stratify=y)
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train, test_size=0.2, stratify=y_train)
```

In [17]:

```
print(X_train.shape, y_train.shape)
print(X_cv.shape, y_cv.shape)
print(X_test.shape, y_test.shape)
```

```
(12800, 12) (12800,)
(3200, 12) (3200,)
(4000, 12) (4000,)
```

Checking percentage of unique class

In [89]:

```
(classes, counts) = np.unique(y_train, return_counts=True)
print(50*'*','Training lables',50*'*')
print('class 0','{0:.2f}'.format(counts[0]/(counts[0]+counts[1])*100))
print('class 1','{0:.2f}'.format(counts[1]/(counts[0]+counts[1])*100))


print(50*'*','CV lables',50*'*')
(classes, counts) = np.unique(y_cv, return_counts=True)
print('class 0','{0:.2f}'.format(counts[0]/(counts[0]+counts[1])*100))
print('class 1','{0:.2f}'.format(counts[1]/(counts[0]+counts[1])*100))


print(50*'*','Test lables',50*'*')
(classes, counts) = np.unique(y_test, return_counts=True)
print('class 0','{0:.2f}'.format(counts[0]/(counts[0]+counts[1])*100))
print('class 1','{0:.2f}'.format(counts[1]/(counts[0]+counts[1])*100))
```

```
************************************************** Training lables **********************************
**********
class 0 15.24
class 1 84.76
************************************************** CV lables ****************************************
**********
class 0 15.25
class 1 84.75
************************************************** Test lables **************************************
**********
class 0 15.25
class 1 84.75
```

encoding categorical features: School State

In [90]:

```
vectorizer = CountVectorizer()
vectorizer.fit(X_train['school_state'].values)
```

Out[90]:

```
CountVectorizer(analyzer='word', binary=False, decode_error='strict',
                dtype=<class 'numpy.int64'>, encoding='utf-8', input='content',
                lowercase=True, max_df=1.0, max_features=None, min_df=1,
                ngram_range=(1, 1), preprocessor=None, stop_words=None,
                strip_accents=None, token_pattern='(?u)\\b\\w\\w+\\b',
                tokenizer=None, vocabulary=None)
```

In [91]:

```
# we use the fitted CountVectorizer to convert the text to vector
X_train_state_ohe = vectorizer.transform(X_train['school_state'].values)
X_cv_state_ohe = vectorizer.transform(X_cv['school_state'].values)
X_test_state_ohe = vectorizer.transform(X_test['school_state'].values)
```

In [92]:

```
print("After vectorizations")
print(X_train_state_ohe.shape, y_train.shape)
print(X_cv_state_ohe.shape, y_cv.shape)
print(X_test_state_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
After vectorizations
(12800, 51) (12800,)
(3200, 51) (3200,)
(4000, 51) (4000,)
['ak', 'al', 'ar', 'az', 'ca', 'co', 'ct', 'dc', 'de', 'fl', 'ga', 'hi', 'ia', 'id', 'il', 'in', 'ks
', 'ky', 'la', 'ma', 'md', 'me', 'mi', 'mn', 'mo', 'ms', 'mt', 'nc', 'nd', 'ne', 'nh', 'nj', 'nm', '
nv', 'ny', 'oh', 'ok', 'or', 'pa', 'ri', 'sc', 'sd', 'tn', 'tx', 'ut', 'va', 'vt', 'wa', 'wi', 'wv',
'wy']
====================================================================================================
```

#encoding categorical features: teacher_prefix

In [93]:

```
X_train['teacher_prefix']=X_train['teacher_prefix'].fillna('Mrs.')
X_cv['teacher_prefix']=X_cv['teacher_prefix'].fillna('Mrs.')
X_test['tearcher_prefix']=X_test['teacher_prefix'].fillna('Mrs.')
vectorizer = CountVectorizer()
vectorizer.fit(X_train['teacher_prefix'].values)
```

Out[93]:

```
CountVectorizer(analyzer='word', binary=False, decode_error='strict',
                dtype=<class 'numpy.int64'>, encoding='utf-8', input='content',
                lowercase=True, max_df=1.0, max_features=None, min_df=1,
                ngram_range=(1, 1), preprocessor=None, stop_words=None,
                strip_accents=None, token_pattern='(?u)\\b\\w\\w+\\b',
                tokenizer=None, vocabulary=None)
```

In [94]:

```
# we use the fitted CountVectorizer to convert the text to vector
X_train_teacher_ohe = vectorizer.transform(X_train['teacher_prefix'].values)
X_cv_teacher_ohe = vectorizer.transform(X_cv['teacher_prefix'].values)
X_test_teacher_ohe = vectorizer.transform(X_test['teacher_prefix'].values)
```

In [95]:

```
print("After vectorizations")
print(X_train_teacher_ohe.shape, y_train.shape)
print(X_cv_teacher_ohe.shape, y_cv.shape)
print(X_test_teacher_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
After vectorizations
(12800, 4) (12800,)
(3200, 4) (3200,)
(4000, 4) (4000,)
['mr', 'mrs', 'ms', 'teacher']
====================================================================================================
```

encoding categorical features: project_grade_category

In [96]:

```
vectorizer = CountVectorizer()
vectorizer.fit(X_train['project_grade_category'].values) # fit has to happen only on train data
```

Out[96]:

```
CountVectorizer(analyzer='word', binary=False, decode_error='strict',
                dtype=<class 'numpy.int64'>, encoding='utf-8', input='content',
                lowercase=True, max_df=1.0, max_features=None, min_df=1,
                ngram_range=(1, 1), preprocessor=None, stop_words=None,
                strip_accents=None, token_pattern='(?u)\\b\\w\\w+\\b',
                tokenizer=None, vocabulary=None)
```

In [97]:

```
# we use the fitted CountVectorizer to convert the text to vector
X_train_grade_ohe = vectorizer.transform(X_train['project_grade_category'].values)
X_cv_grade_ohe = vectorizer.transform(X_cv['project_grade_category'].values)
X_test_grade_ohe = vectorizer.transform(X_test['project_grade_category'].values)
```

In [98]:

```
print("After vectorizations")
print(X_train_grade_ohe.shape, y_train.shape)
print(X_cv_grade_ohe.shape, y_cv.shape)
print(X_test_grade_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
After vectorizations
(12800, 4) (12800,)
(3200, 4) (3200,)
(4000, 4) (4000,)
['grades_3_5', 'grades_6_8', 'grades_9_12', 'grades_prek_2']
====================================================================================================
```

Normalize feature: Price

In [99]:

```
from sklearn.preprocessing import Normalizer
normalizer = Normalizer()
# normalizer.fit(X_train['price'].values)
# this will rise an error Expected 2D array, got 1D array instead:
# array=[105.22 215.96  96.01 ... 368.98  80.53 709.67].
# Reshape your data either using
# array.reshape(-1, 1) if your data has a single feature
# array.reshape(1, -1)  if it contains a single sample.
normalizer.fit(X_train['price'].values.reshape(-1,1))

X_train_price_norm = normalizer.transform(X_train['price'].values.reshape(-1,1))
X_cv_price_norm = normalizer.transform(X_cv['price'].values.reshape(-1,1))
X_test_price_norm = normalizer.transform(X_test['price'].values.reshape(-1,1))
```

In [100]:

```
print("After vectorizations")
print(X_train_price_norm.shape, y_train.shape)
print(X_cv_price_norm.shape, y_cv.shape)
print(X_test_price_norm.shape, y_test.shape)
print("="*100)
```

```
After vectorizations
(12800, 1) (12800,)
(3200, 1) (3200,)
(4000, 1) (4000,)
====================================================================================================
```

In [101]:

```
project_data.head()
```

Out[101]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_submitted_datetime	project_grade_cate
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	mrs	in	2016-12-05 13:43:57	grades_pr
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	mr	fl	2016-10-25 09:22:10	grades
2	21895	p182444	3465aaf82da834c0582ebd0ef8040ca0	ms	az	2016-08-31 12:03:56	grades
3	45	p246581	f3cb9bffbba169bef1a77b243e620b60	mrs	ky	2016-10-06 21:16:17	grades_pr
4	172407	p104768	be1f7507a41f8479dc06f047086a39ec	mrs	tx	2016-07-11 01:10:09	grades_pr

Tfidf featurization:essay

In [102]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
vectorizer_tfidf = TfidfVectorizer(min_df=10,ngram_range=(1,2))
vectorizer_tfidf.fit(X_train['essay'].values)
X_train_essay_tfidf = vectorizer_tfidf.transform(X_train['essay'].values)
X_cv_essay_tfidf = vectorizer_tfidf.transform(X_cv['essay'].values)
X_test_essay_tfidf = vectorizer_tfidf.transform(X_test['essay'].values)
```

In [103]:

```
print("After vectorizations")
print(X_train_essay_tfidf.shape, y_train.shape)
print(X_cv_essay_tfidf.shape, y_cv.shape)
print(X_test_essay_tfidf.shape, y_test.shape)
print("="*100)
```

```
After vectorizations
(12800, 27931) (12800,)
(3200, 27931) (3200,)
(4000, 27931) (4000,)
====================================================================================================
```

Tfidf featurization:project title

In [104]:

```
vectorizer_tfidf = TfidfVectorizer(min_df=10,ngram_range=(1,2))
vectorizer_tfidf.fit(X_train['project_title'].values)
X_train_project_title_tfidf = vectorizer_tfidf.transform(X_train['project_title'].values)
X_cv_project_title_tfidf = vectorizer_tfidf.transform(X_cv['project_title'].values)
X_test_project_title_tfidf = vectorizer_tfidf.transform(X_test['project_title'].values)
```

In [105]:

```
print("After vectorizations")
print(X_train_project_title_tfidf.shape, y_train.shape)
print(X_cv_project_title_tfidf.shape, y_cv.shape)
print(X_test_project_title_tfidf.shape, y_test.shape)
print("="*100)
```

```
After vectorizations
(12800, 956) (12800,)
(3200, 956) (3200,)
(4000, 956) (4000,)
====================================================================================================
```

Combine all encoding, tfidf feature in sparse matrix

In [106]:

```
from scipy.sparse import hstack
X_tr = hstack((X_train_essay_tfidf,X_train_project_title_tfidf, X_train_state_ohe, X_train_teacher_ohe, X_train_grade_ohe,X_train_price_norm)).tocsr()
X_cr = hstack((X_cv_essay_tfidf,X_cv_project_title_tfidf, X_cv_state_ohe, X_cv_teacher_ohe, X_cv_grade_ohe, X_cv_price_norm)).tocsr()
X_te = hstack((X_test_essay_tfidf,X_test_project_title_tfidf, X_test_state_ohe, X_test_teacher_ohe, X_test_grade_ohe, X_test_price_norm)).tocsr()

print("Final Data matrix")
print(X_tr.shape, y_train.shape)
print(X_cr.shape, y_cv.shape)
print(X_te.shape, y_test.shape)
print("="*100)
```

```
Final Data matrix
(12800, 28947) (12800,)
(3200, 28947) (3200,)
(4000, 28947) (4000,)
====================================================================================================
```

Randomized Search

In [107]:

```
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import RandomizedSearchCV
param_dist = {"max_depth": [1,5,10,50],
              "min_samples_leaf": [5,10,100,500],
              "criterion": ["gini", "entropy"]}

tree=DecisionTreeClassifier(class_weight = 'balanced')


clf = RandomizedSearchCV(tree, param_dist, cv=3, scoring='roc_auc',return_train_score=True)

clf.fit(X_tr, y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results.columns
```

Out[107]:

```
Index(['mean_fit_time', 'std_fit_time', 'mean_score_time', 'std_score_time',
       'param_min_samples_leaf', 'param_max_depth', 'param_criterion',
       'params', 'split0_test_score', 'split1_test_score', 'split2_test_score',
       'mean_test_score', 'std_test_score', 'rank_test_score',
       'split0_train_score', 'split1_train_score', 'split2_train_score',
       'mean_train_score', 'std_train_score'],
      dtype='object')
```

Ploting 3d Graph (min_sample_leaf,max_depth,score)

In [108]:

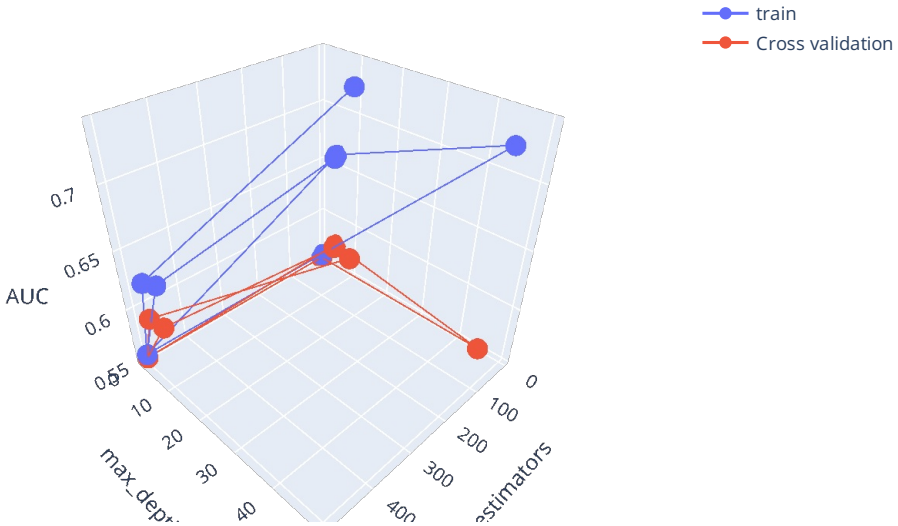
```
import plotly.offline as offline
import plotly.graph_objs as go
offline.init_notebook_mode()
import numpy as np
```

In [109]:

```
x1=results.param_min_samples_leaf
y1=results.param_max_depth
z1=results.mean_train_score
x2=results.param_min_samples_leaf
y2=results.param_max_depth
z2=results.mean_test_score
```

In [110]:

```
trace1 = go.Scatter3d(x=x1,y=y1,z=z1, name = 'train')
trace2 = go.Scatter3d(x=x2,y=y2,z=z2, name = 'Cross validation')
data = [trace1,trace2]

layout = go.Layout(scene = dict(
        xaxis = dict(title='n_estimators'),
        yaxis = dict(title='max_depth'),
        zaxis = dict(title='AUC'),))

fig = go.Figure(data=data, layout=layout)
offline.iplot(fig, filename='3d-scatter-colorscale')
```



Grid Search CV

In [111]:

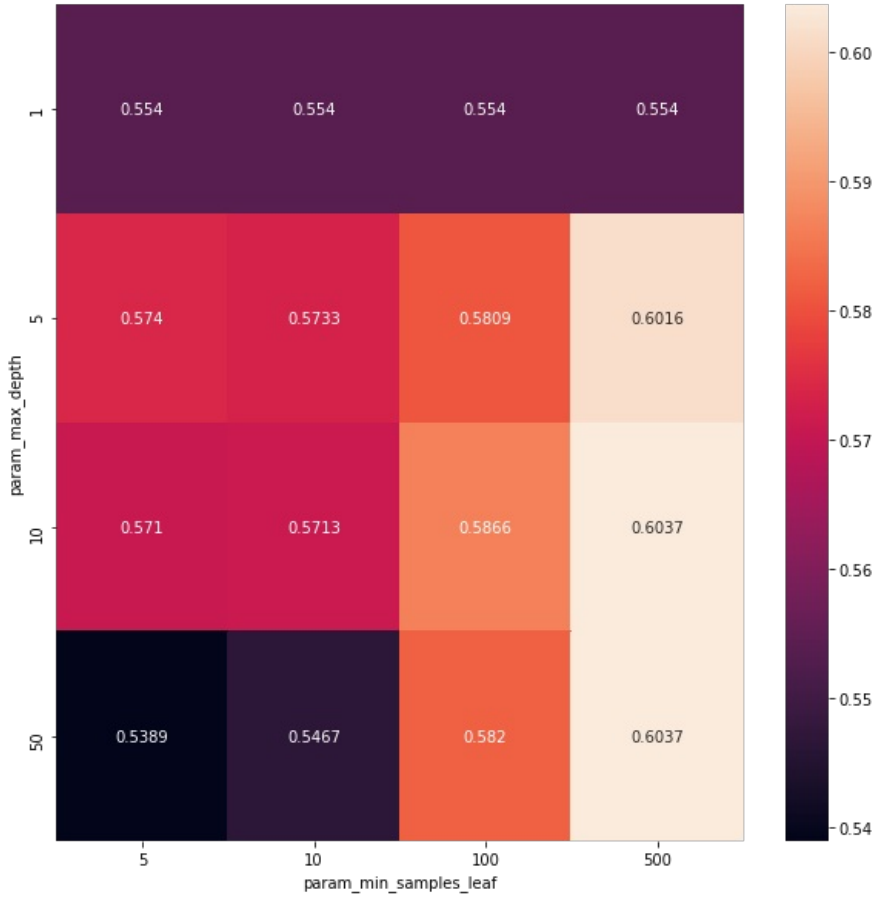
```
from sklearn.model_selection import GridSearchCV

from sklearn.tree import DecisionTreeClassifier
param_grid = {"max_depth": [1,5,10,50],
              "min_samples_leaf": [5,10,100,500],
              "criterion": ["gini", "entropy"]}
tree=DecisionTreeClassifier(class_weight = 'balanced')

clf=GridSearchCV(tree,param_grid,cv=3,scoring='roc_auc')

clf.fit(X_tr, y_train)

print("Best cross-validation score: {:.2f}".format(clf.best_score_))
print("Best parameters: ", clf.best_params_)

results = pd.DataFrame.from_dict(clf.cv_results_)
results.columns
import pandas as pd
pvt = pd.pivot_table(pd.DataFrame(clf.cv_results_),
    values='mean_test_score', index='param_max_depth', columns='param_min_samples_leaf')
```

```
Best cross-validation score: 0.60
Best parameters:  {'criterion': 'entropy', 'max_depth': 10, 'min_samples_leaf': 500}
```

Heat map of training

In [112]:

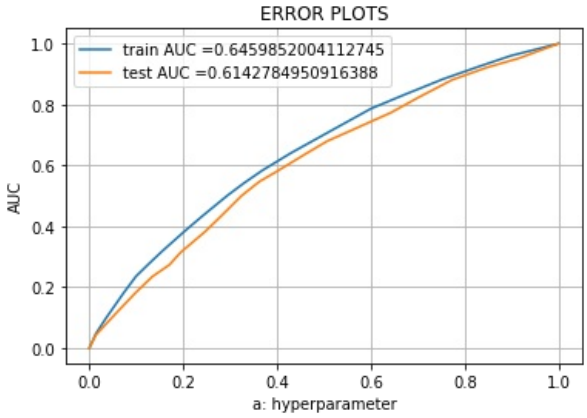
```
fig, ax = plt.subplots(figsize=(10,10))
ax = sns.heatmap(pvt,annot=True,fmt='.4g')
```



ROC of train data and test data

In [117]:

```
tree=DecisionTreeClassifier(max_depth=10,min_samples_leaf= 500)
from sklearn.metrics import roc_curve, auc


tree.fit(X_tr, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive class
# not the predicted outputs

y_train_pred = tree.predict_proba(X_tr)[:,1]
y_test_pred = tree.predict_proba(X_te)[:,1]


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred)

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("a: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.grid()
plt.show()
test_auc_tfidf=auc(test_fpr, test_tpr)
print('{0:.2f}'.format(test_auc_tfidf*100))
```



61.43

Confusion Matrix

In [118]:

```
def find_best_threshold(threshould, fpr, tpr):
    t = threshould[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for threshold", np.round(t,3))
    return t
```

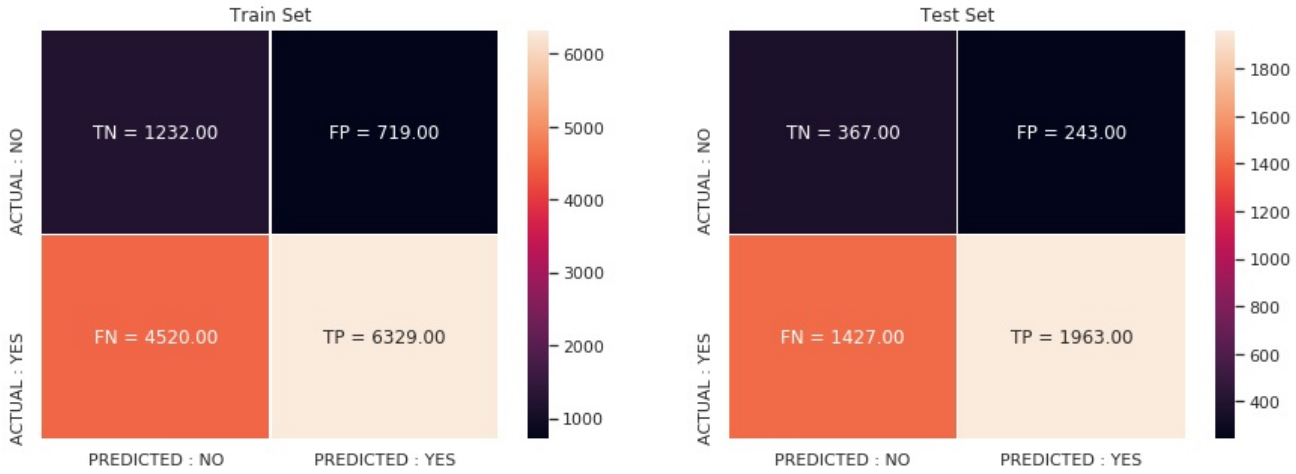
In [119]:

```
def predict_with_best_t(proba, threshould):
    predictions = []
    for i in proba:
        if i>=threshould:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

In [120]:

```
import seaborn as sns; sns.set()
from sklearn.metrics import confusion_matrix

best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)

con_m_train = confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t))
con_m_test = (confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))

key = (np.asarray([['TN','FP'], ['FN', 'TP']]))
fig, ax = plt.subplots(1,2, figsize=(15,5))
labels_train = (np.asarray(["{0} = {1:.2f}" .format(key, value) for key, value in zip(key.flatten(), con_m_train.
flatten())])).reshape(2,2)
labels_test = (np.asarray(["{0} = {1:.2f}" .format(key, value) for key, value in zip(key.flatten(),con_m_test.fla
tten())])).reshape(2,2)

sns.heatmap(con_m_train, linewidths=.5, xticklabels=['PREDICTED : NO', 'PREDICTED : YES'],yticklabels=['ACTUAL :
NO', 'ACTUAL : YES'], annot = labels_train, fmt = '', ax=ax[0])
sns.heatmap(con_m_test, linewidths=.5, xticklabels=['PREDICTED : NO', 'PREDICTED : YES'],yticklabels=['ACTUAL : N
O', 'ACTUAL : YES'], annot = labels_test, fmt = '', ax=ax[1])
ax[0].set_title('Train Set')
ax[1].set_title('Test Set')
plt.show()
```

```
the maximum value of tpr*(1-fpr) 0.3683823592288891 for threshold 0.856
```



Plot wordcloud of essay text of these `false positive data points`

In [121]:

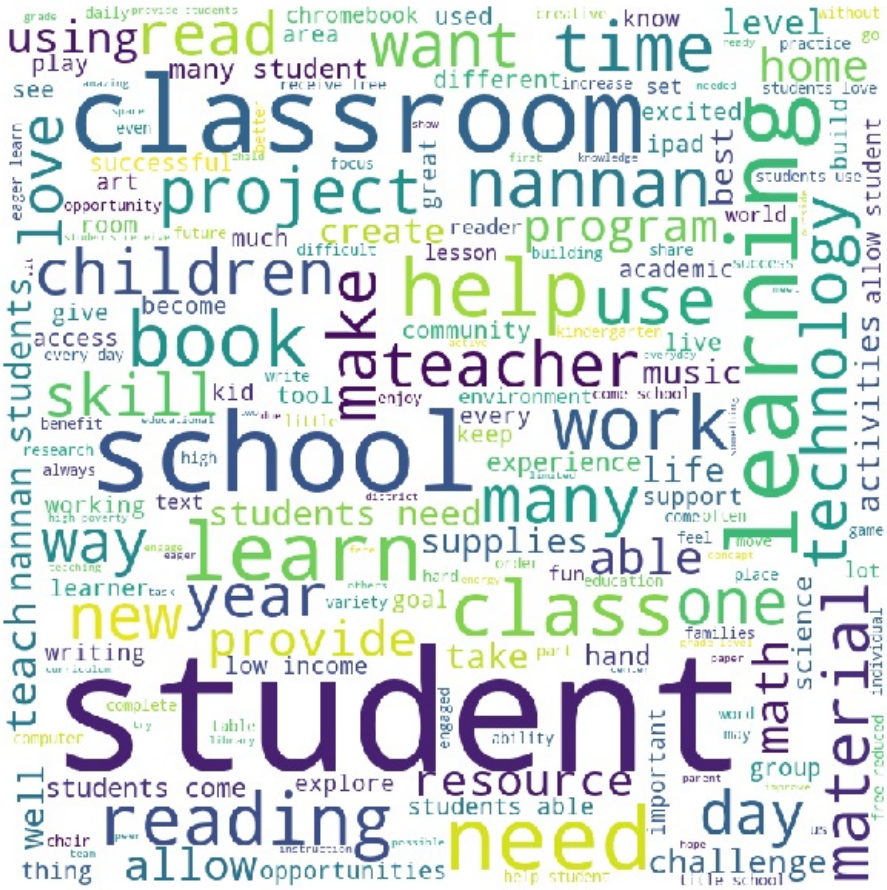
```
p=predict_with_best_t(y_test_pred, best_t)
```

In [122]:

```
text=[]
for i in range(len(p)):
    if (p[i]==1 and y_test[i]==0):
        text.append(project_data['essay'][i])
```

In [123]:

```
from wordcloud import WordCloud, STOPWORDS
import matplotlib.pyplot as plt
import pandas as pd

comment_words = ' '
stopwords = set(STOPWORDS)


for val in text:

    # typecaste each val to string
    val = str(val)

    # split the value
    tokens = val.split()

    # Converts each token into lowercase
    for i in range(len(tokens)):
        tokens[i] = tokens[i].lower()

    for words in tokens:
        comment_words = comment_words + words+' '


wordcloud = WordCloud(width = 800, height = 800,
                background_color ='white',
                stopwords = stopwords,
                min_font_size = 10).generate(comment_words)

# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```



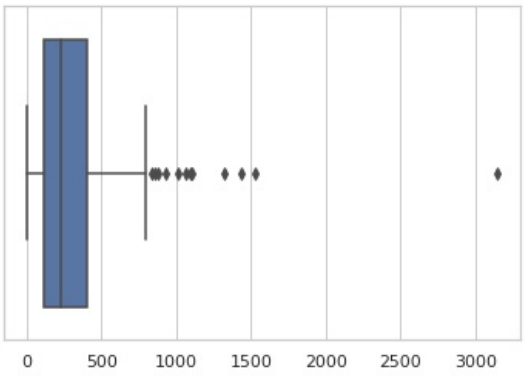
Box Plot with the `price` of these `false positive data points`

In [124]:

```
price=[]
for i in range(len(p)):
    if (p[i]==1 and y_test[i]==0):
        price.append(project_data['price'][i])
```

In [125]:

```
import seaborn as sns
sns.set(style="whitegrid")

ax = sns.boxplot(x=price)
```



Plot the pdf with the `teacher_number_of_previously_posted_projects` of these `false positive data points`

In [126]:

```
previously_posted_projects=[]
for i in range(len(p)):
    if (p[i]==1 and y_test[i]==0):
        previously_posted_projects.append(project_data['teacher_number_of_previously_posted_projects'][i])
```

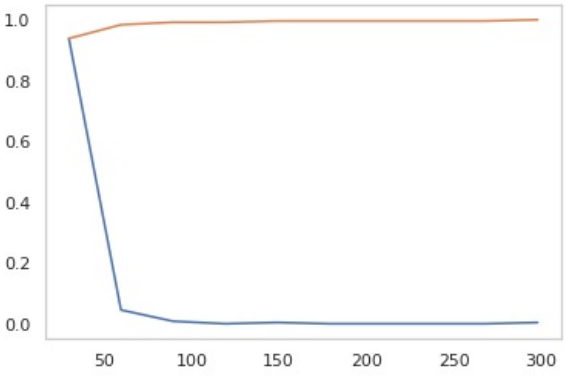
In [127]:

```
counts, bin_edges = np.histogram(previously_posted_projects, bins=10, density = True)
pdf = counts/(sum(counts))
print(pdf)
plt.grid()

cdf = np.cumsum(pdf)
plt.plot(bin_edges[1:],pdf)
plt.plot(bin_edges[1:], cdf)
```

```
[0.9382716  0.04526749 0.00823045 0.         0.00411523 0.
 0.         0.         0.         0.00411523]
```

Out[127]:

```
[<matplotlib.lines.Line2D at 0x7fc238700d68>]
```



Avg word2vec

In [128]:

```
def loadGloveModel(gloveFile):

    print ("Loading Glove Model")

    f = open(gloveFile,'r', encoding = 'utf8')

    model = {}

    for line in tqdm(f):
        splitLine = line.split()
        word = splitLine[0]
        embedding = np.array([float(val) for val in splitLine[1:]])
        model[word] = embedding

    print ("Done.",len(model)," words loaded!")

    return model
```

In [129]:

```
model = loadGloveModel('/home/shivam/Desktop/assignment 11/glove.6B.50d.txt')
```

```
1241it [00:00, 12404.63it/s]

Loading Glove Model

400000it [00:23, 16677.08it/s]

Done. 400000  words loaded!
```

In [130]:

```
glove_words = set(model.keys())
```

In [131]:

```
# average Word2Vec
# compute average word2vec for each review.
def func(wordlist):

  train_avg_w2v_vectors = []; # the avg-w2v for each sentence/review is stored in this list
  for sentence in tqdm(wordlist): # for each review/sentence
    vector = np.zeros(50) # as word vectors are of zero length # we are taking the 300dimensions very large
    cnt_words =0; # num of words with a valid vector in the sentence/review
    for word in sentence.split(): # for each word in a review/sentence
        if word in glove_words:
            vector += model[word]
            cnt_words += 1
    if cnt_words != 0:
        vector /= cnt_words
    train_avg_w2v_vectors.append(vector)

  print(len(train_avg_w2v_vectors))
  print(len(train_avg_w2v_vectors[0]))
  return train_avg_w2v_vectors
```

In [132]:

```
train_avg_w2v_vectors_essay=func(X_train['essay'])
test_avg_w2v_vectors_essay=func(X_test['essay'])
cv_avg_w2v_vectors_essay=func(X_cv['essay'])
```

```
100%|██████████| 12800/12800 [00:07<00:00, 1664.77it/s]
  5%|▍         | 188/4000 [00:00<00:02, 1871.83it/s]

12800
50

100%|██████████| 4000/4000 [00:02<00:00, 1842.67it/s]
  5%|▍         | 170/3200 [00:00<00:01, 1694.69it/s]

4000
50

100%|██████████| 3200/3200 [00:01<00:00, 1795.71it/s]

3200
50
```

In [133]:

```
#for titles
cv_avg_w2v_vectors_project_title=func(X_cv['project_title'])
test_avg_w2v_vectors_project_title=func(X_test['project_title'])
train_avg_w2v_vectors_project_title=func(X_train['project_title'])
```

```
100%|██████████| 3200/3200 [00:00<00:00, 28190.19it/s]
100%|██████████| 4000/4000 [00:00<00:00, 28755.63it/s]
  0%|          | 0/12800 [00:00<?, ?it/s]

3200
50
4000
50

100%|██████████| 12800/12800 [00:00<00:00, 31744.93it/s]

12800
50
```

Merging....

In [134]:

```
from scipy.sparse import hstack
X_tr_w2v = hstack((train_avg_w2v_vectors_essay,train_avg_w2v_vectors_project_title, X_train_state_ohe, X_train_te
acher_ohe, X_train_grade_ohe,X_train_price_norm)).tocsr()
X_cr_w2v = hstack((cv_avg_w2v_vectors_essay,cv_avg_w2v_vectors_project_title, X_cv_state_ohe, X_cv_teacher_ohe, X
_cv_grade_ohe, X_cv_price_norm)).tocsr()
X_te_w2v = hstack((test_avg_w2v_vectors_essay,test_avg_w2v_vectors_project_title, X_test_state_ohe, X_test_teache
r_ohe, X_test_grade_ohe, X_test_price_norm)).tocsr()

print("Final Data matrix")
print(X_tr_w2v.shape, y_train.shape)
print(X_cr_w2v.shape, y_cv.shape)
print(X_te_w2v.shape, y_test.shape)
print("="*100)
```

```
Final Data matrix
(12800, 160) (12800,)
(3200, 160) (3200,)
(4000, 160) (4000,)
====================================================================================================
```

Grid Search for w2v

In [60]:

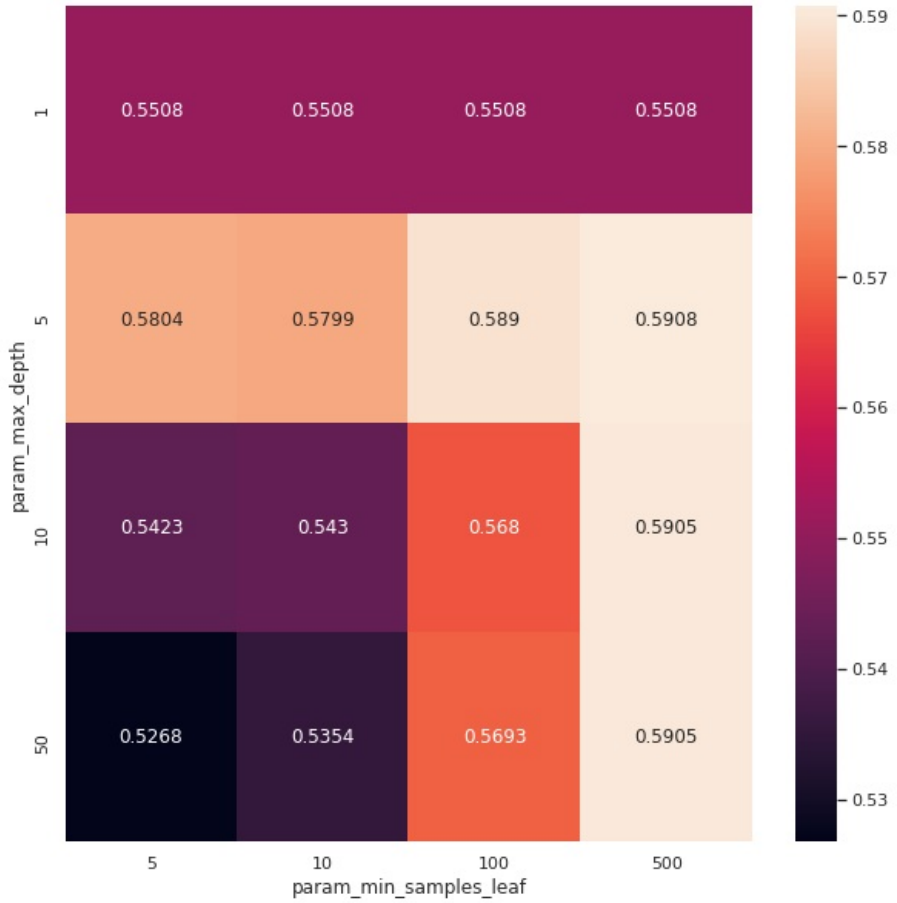
```
from sklearn.model_selection import GridSearchCV

from sklearn.tree import DecisionTreeClassifier
param_grid = {"max_depth": [1,5,10,50],
              "min_samples_leaf": [5,10,100,500],
              "criterion": ["gini", "entropy"]}
tree=DecisionTreeClassifier(class_weight = 'balanced')

clf=GridSearchCV(tree,param_grid,cv=3,scoring='roc_auc')

clf.fit(X_tr_w2v, y_train)

print("Best cross-validation score: {:.2f}".format(clf.best_score_))
print("Best parameters: ", clf.best_params_)

results = pd.DataFrame.from_dict(clf.cv_results_)
results.columns
import pandas as pd
pvt = pd.pivot_table(pd.DataFrame(clf.cv_results_),
    values='mean_test_score', index='param_max_depth', columns='param_min_samples_leaf')
```

```
Best cross-validation score: 0.59
Best parameters:  {'criterion': 'entropy', 'max_depth': 5, 'min_samples_leaf': 100}
```

Heat map

In [61]:

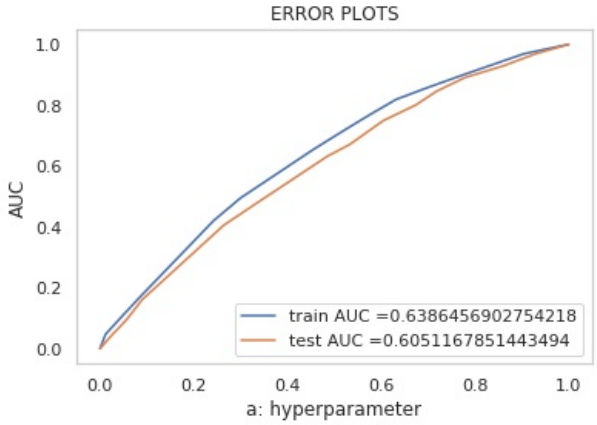
```
fig, ax = plt.subplots(figsize=(10,10))
ax = sns.heatmap(pvt,annot=True,fmt='.4g')
```



ROC

In [137]:

```
tree=DecisionTreeClassifier(max_depth=5,min_samples_leaf= 500)
from sklearn.metrics import roc_curve, auc


tree.fit(X_tr_w2v, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive class
# not the predicted outputs

y_train_pred = tree.predict_proba(X_tr_w2v)[:,1]
y_test_pred = tree.predict_proba(X_te_w2v)[:,1]


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred)

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("a: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.grid()
plt.show()
test_auc_avg_w2v=auc(test_fpr, test_tpr)
print('{0:.2f}'.format(test_auc_avg_w2v*100))
```



60.51

confusion matrix

In [138]:

```
def find_best_threshold(threshould, fpr, tpr):
    t = threshould[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for threshold", np.round(t,3))
    return t
```

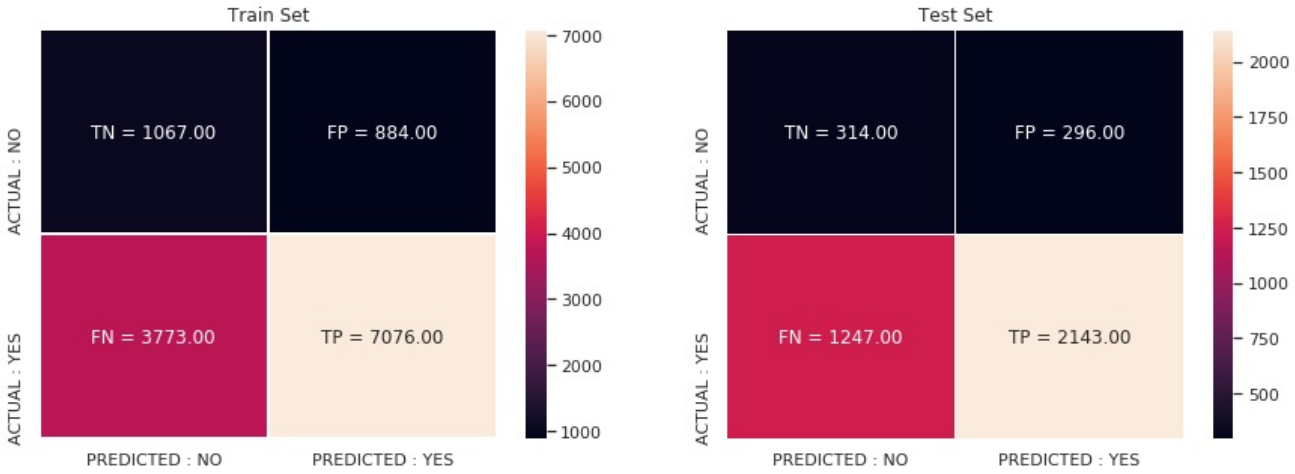
In [139]:

```
def predict_with_best_t(proba, threshould):
    predictions = []
    for i in proba:
        if i>=threshould:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

In [140]:

```
import seaborn as sns; sns.set()
from sklearn.metrics import confusion_matrix

best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)

con_m_train = confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t))
con_m_test = (confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))

key = (np.asarray([['TN','FP'], ['FN', 'TP']]))
fig, ax = plt.subplots(1,2, figsize=(15,5))
labels_train = (np.asarray(["{0} = {1:.2f}" .format(key, value) for key, value in zip(key.flatten(), con_m_train.
flatten())])).reshape(2,2)
labels_test = (np.asarray(["{0} = {1:.2f}" .format(key, value) for key, value in zip(key.flatten(),con_m_test.fla
tten())])).reshape(2,2)

sns.heatmap(con_m_train, linewidths=.9, xticklabels=['PREDICTED : NO', 'PREDICTED : YES'],yticklabels=['ACTUAL :
NO', 'ACTUAL : YES'], annot = labels_train, fmt = '', ax=ax[0])
sns.heatmap(con_m_test, linewidths=.5, xticklabels=['PREDICTED : NO', 'PREDICTED : YES'],yticklabels=['ACTUAL : N
O', 'ACTUAL : YES'], annot = labels_test, fmt = '', ax=ax[1])
ax[0].set_title('Train Set')
ax[1].set_title('Test Set')
plt.show()
```

```
the maximum value of tpr*(1-fpr) 0.35670177057514596 for threshold 0.851
```



Tfidf_W2V Using Golve

In [141]:

```
#For essay
tfidf_model_essay = TfidfVectorizer()
tfidf_model_essay.fit(X_train['essay'])
# we are converting a dictionary with word as a key, and the idf as a value
dictionary = dict(zip(tfidf_model_essay.get_feature_names(), list(tfidf_model_essay.idf_)))
tfidf_words_essay = set(tfidf_model_essay.get_feature_names())
```

In [142]:

```
def tf_idf_w2v(sent_list):
    train_title_tfidf_w2v_vectors = []; # the avg-w2v for each sentence/review is stored in this list
    for sentence in tqdm(sent_list): # for each review/sentence
        vector = np.zeros(50) # as word vectors are of zero length
        tf_idf_weight =0; # num of words with a valid vector in the sentence/review
        for word in sentence.split():#.split(): # for each word in a review/sentence
            if (word in glove_words) and (word in tfidf_words_essay):
              #vec = model.wv[word]
                vec = model[word] # getting the vector for each word
# here we are multiplying idf value(dictionary[word]) and the tf value((sentence.count(word)/len(sentence.split()
)))
                tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split()))
                vector += (vec * tf_idf) # calculating tfidf weighted w2v
                tf_idf_weight += tf_idf
        if tf_idf_weight != 0:
            vector /= tf_idf_weight
        train_title_tfidf_w2v_vectors.append(vector)
    print(len(train_title_tfidf_w2v_vectors))
    print(len(train_title_tfidf_w2v_vectors[0]))
    return train_title_tfidf_w2v_vectors
```

In [143]:

```
#For essay
X_train_tfidf_w2v_essay=tf_idf_w2v(X_train['essay'])
X_test_tfidf_w2v_essay=tf_idf_w2v(X_test['essay'])
X_cv_tfidf_w2v_essay=tf_idf_w2v(X_cv['essay'])
```

```
100%|██████████| 12800/12800 [00:56<00:00, 225.83it/s]
  0%|          | 19/4000 [00:00<00:21, 181.35it/s]

12800
50

100%|██████████| 4000/4000 [00:17<00:00, 229.68it/s]
  1%|          | 23/3200 [00:00<00:13, 227.91it/s]

4000
50

100%|██████████| 3200/3200 [00:13<00:00, 230.26it/s]

3200
50
```

In [144]:

```
#for titles
tfidf_model_project_title = TfidfVectorizer()
tfidf_model_project_title.fit(X_train['project_title'])
# we are converting a dictionary with word as a key, and the idf as a value
dictionary = dict(zip(tfidf_model_project_title.get_feature_names(), list(tfidf_model_project_title.idf_)))
tfidf_words_project_title = set(tfidf_model_project_title.get_feature_names())
```

In [145]:

```
def tf_idf_w2v(sent_list):
    train_title_tfidf_w2v_vectors = []; # the avg-w2v for each sentence/review is stored in this list
    for sentence in tqdm(sent_list): # for each review/sentence
        vector = np.zeros(50) # as word vectors are of zero length
        tf_idf_weight =0; # num of words with a valid vector in the sentence/review
        for word in sentence.split():#.split(): # for each word in a review/sentence
            if (word in glove_words) and (word in tfidf_words_project_title):
              #vec = model.wv[word]
              vec = model[word] # getting the vector for each word
# here we are multiplying idf value(dictionary[word]) and the tf value((sentence.count(word)/len(sentence.split()
)))
              tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split()))
              vector += (vec * tf_idf) # calculating tfidf weighted w2v
              tf_idf_weight += tf_idf
        if tf_idf_weight != 0:
            vector /= tf_idf_weight
        train_title_tfidf_w2v_vectors.append(vector)
    print(len(train_title_tfidf_w2v_vectors))
    print(len(train_title_tfidf_w2v_vectors[0]))
    return train_title_tfidf_w2v_vectors
```

In [146]:

```
X_train_tfidf_w2v_project=tf_idf_w2v(X_train['project_title'])
X_test_tfidf_w2v_project=tf_idf_w2v(X_test['project_title'])
X_cv_tfidf_w2v_project=tf_idf_w2v(X_cv['project_title'])
```

```
100%|██████████| 12800/12800 [00:00<00:00, 15404.66it/s]
 37%|███▋      | 1488/4000 [00:00<00:00, 14875.23it/s]

12800
50

100%|██████████| 4000/4000 [00:00<00:00, 16494.87it/s]
 44%|████▍     | 1416/3200 [00:00<00:00, 14157.79it/s]

4000
50

100%|██████████| 3200/3200 [00:00<00:00, 14587.44it/s]

3200
50
```

Merging...

In [147]:

```
from scipy.sparse import hstack
X_tr_tfidf_w2v = hstack((X_train_tfidf_w2v_essay,X_train_tfidf_w2v_project, X_train_state_ohe, X_train_teacher_oh
e, X_train_grade_ohe,X_train_price_norm)).tocsr()
X_cr_tfidf_w2v = hstack((X_cv_tfidf_w2v_essay,X_cv_tfidf_w2v_project, X_cv_state_ohe, X_cv_teacher_ohe, X_cv_grad
e_ohe, X_cv_price_norm)).tocsr()
X_te_tfidf_w2v = hstack((X_test_tfidf_w2v_essay,X_test_tfidf_w2v_project, X_test_state_ohe, X_test_teacher_ohe, X
_test_grade_ohe, X_test_price_norm)).tocsr()

print("Final Data matrix")
print(X_tr_tfidf_w2v.shape, y_train.shape)
print(X_cr_tfidf_w2v.shape, y_cv.shape)
print(X_te_tfidf_w2v.shape, y_test.shape)
print("="*100)
```

```
Final Data matrix
(12800, 160) (12800,)
(3200, 160) (3200,)
(4000, 160) (4000,)
====================================================================================================
```

Grid Search for tfidf_w2v

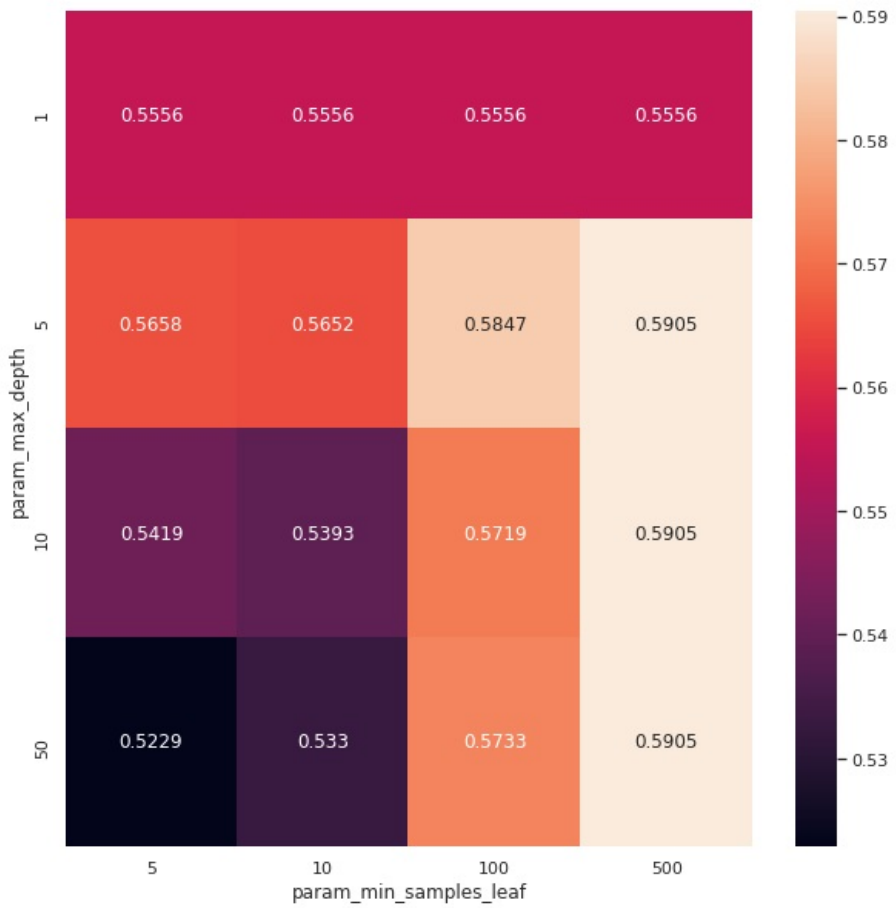
In [73]:

```
from sklearn.model_selection import GridSearchCV

from sklearn.tree import DecisionTreeClassifier
param_grid = {"max_depth": [1,5,10,50],
              "min_samples_leaf": [5,10,100,500],
              "criterion": ["gini", "entropy"]}
tree=DecisionTreeClassifier(class_weight = 'balanced')

clf=GridSearchCV(tree,param_grid,cv=3,scoring='roc_auc')

clf.fit(X_tr_tfidf_w2v, y_train)

print("Best cross-validation score: {:.2f}".format(clf.best_score_))
print("Best parameters: ", clf.best_params_)

results = pd.DataFrame.from_dict(clf.cv_results_)
results.columns
import pandas as pd
pvt = pd.pivot_table(pd.DataFrame(clf.cv_results_),
    values='mean_test_score', index='param_max_depth', columns='param_min_samples_leaf')
```

```
Best cross-validation score: 0.61
Best parameters:  {'criterion': 'entropy', 'max_depth': 5, 'min_samples_leaf': 500}
```

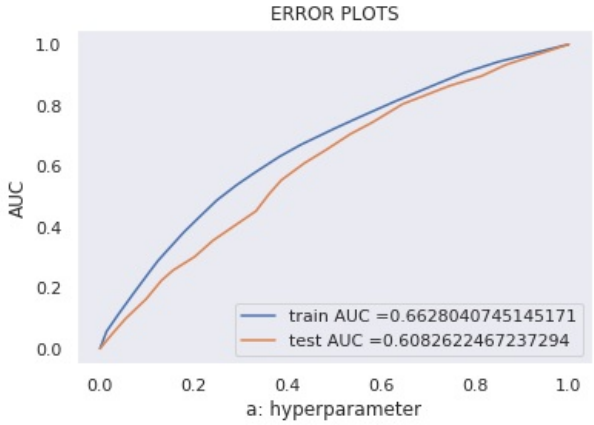
In [119]:

```
fig, ax = plt.subplots(figsize=(10,10))
ax = sns.heatmap(pvt,annot=True,fmt='.4g')
```



In [149]:

```
tree=DecisionTreeClassifier(max_depth=10,min_samples_leaf= 500)
from sklearn.metrics import roc_curve, auc


tree.fit(X_tr_tfidf_w2v, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive class
# not the predicted outputs

y_train_pred = tree.predict_proba(X_tr_tfidf_w2v)[:,1]
y_test_pred = tree.predict_proba(X_te_tfidf_w2v)[:,1]


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred)

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("a: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.grid()
plt.show()
test_auc_tfidf_w2v=auc(test_fpr, test_tpr)
print('{0:.2f}'.format(test_auc_tfidf_w2v*100))
```




```
60.83
```

In [150]:

```
def find_best_threshold(threshould, fpr, tpr):
    t = threshould[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for threshold", np.round(t,3))
    return t
```

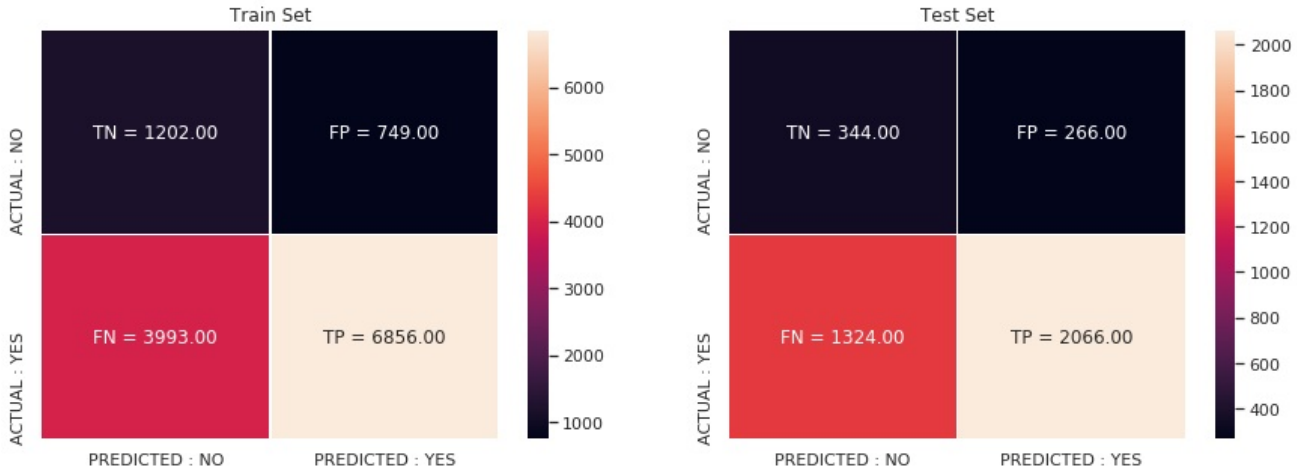
In [151]:

```
def predict_with_best_t(proba, threshould):
    predictions = []
    for i in proba:
        if i>=threshould:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

In [152]:

```
import seaborn as sns; sns.set()
from sklearn.metrics import confusion_matrix

best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)

con_m_train = confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t))
con_m_test = (confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))

key = (np.asarray([['TN','FP'], ['FN', 'TP']]))
fig, ax = plt.subplots(1,2, figsize=(15,5))
labels_train = (np.asarray(["{0} = {1:.2f}" .format(key, value) for key, value in zip(key.flatten(), con_m_train.
flatten())])).reshape(2,2)
labels_test = (np.asarray(["{0} = {1:.2f}" .format(key, value) for key, value in zip(key.flatten(),con_m_test.fla
tten())])).reshape(2,2)

sns.heatmap(con_m_train, linewidths=.5, xticklabels=['PREDICTED : NO', 'PREDICTED : YES'],yticklabels=['ACTUAL :
NO', 'ACTUAL : YES'], annot = labels_train, fmt = '', ax=ax[0])
sns.heatmap(con_m_test, linewidths=.5, xticklabels=['PREDICTED : NO', 'PREDICTED : YES'],yticklabels=['ACTUAL : N
O', 'ACTUAL : YES'], annot = labels_test, fmt = '', ax=ax[1])
ax[0].set_title('Train Set')
ax[1].set_title('Test Set')
plt.show()
```

```
the maximum value of tpr*(1-fpr) 0.3893393486534956 for threshold 0.847
```



Task 2 ----With feature importance

In [153]:

```
from scipy.sparse import hstack
X_tr = hstack((X_train_essay_tfidf,X_train_project_title_tfidf, X_train_state_ohe, X_train_teacher_ohe, X_train_g
rade_ohe,X_train_price_norm)).tocsr()
X_cr = hstack((X_cv_essay_tfidf,X_cv_project_title_tfidf, X_cv_state_ohe, X_cv_teacher_ohe, X_cv_grade_ohe, X_cv_
price_norm)).tocsr()
X_te = hstack((X_test_essay_tfidf,X_test_project_title_tfidf, X_test_state_ohe, X_test_teacher_ohe, X_test_grade_
ohe, X_test_price_norm)).tocsr()

print("Final Data matrix")
print(X_tr.shape, y_train.shape)
print(X_cr.shape, y_cv.shape)
print(X_te.shape, y_test.shape)
print("="*100)
```

```
Final Data matrix
(12800, 28947) (12800,)
(3200, 28947) (3200,)
(4000, 28947) (4000,)
====================================================================================================
```

In [154]:

```
from sklearn.model_selection import GridSearchCV
param_grid = {"max_depth": [1,5,10,50],
              "min_samples_leaf": [5,10,100,500],
              "criterion": ["gini", "entropy"]}

clf=GridSearchCV(tree,param_grid,cv=3,scoring='roc_auc')

clf.fit(X_tr, y_train)

print("Best cross-validation score: {:.2f}".format(clf.best_score_))
print("Best parameters: ", clf.best_params_)

results = pd.DataFrame.from_dict(clf.cv_results_)
results.columns
import pandas as pd
pvt = pd.pivot_table(pd.DataFrame(clf.cv_results_),
    values='mean_test_score', index='param_max_depth', columns='param_min_samples_leaf')
```

```
Best cross-validation score: 0.61
Best parameters:  {'criterion': 'entropy', 'max_depth': 10, 'min_samples_leaf': 500}
```

In [155]:

```
from sklearn.tree import DecisionTreeClassifier
tree=DecisionTreeClassifier(max_depth=5,min_samples_leaf= 500,class_weight='balanced')
from sklearn.metrics import roc_curve, auc


tree.fit(X_tr, y_train)
```

Out[155]:

```
DecisionTreeClassifier(ccp_alpha=0.0, class_weight='balanced', criterion='gini',
                       max_depth=5, max_features=None, max_leaf_nodes=None,
                       min_impurity_decrease=0.0, min_impurity_split=None,
                       min_samples_leaf=500, min_samples_split=2,
                       min_weight_fraction_leaf=0.0, presort='deprecated',
                       random_state=None, splitter='best')
```

In [156]:

```
feature_impce = tree.feature_importances_
relevant_features = []
cols = []

for i, val in enumerate(feature_impce):     #dtc2 is optimal decision tree model for set 2.
    if val > 0:
        relevant_features.append(feature_impce[i])
        cols.append(i)
```

In [158]:

```
X_tr_new = X_tr.todense()[:, cols]
X_test_new = X_te.todense()[:, cols]
```

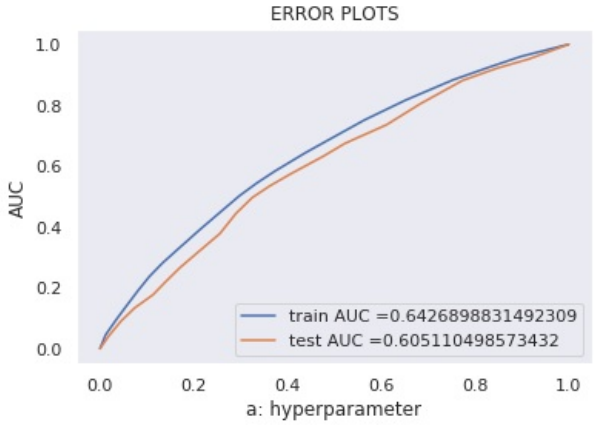
In [159]:

```
from sklearn.model_selection import GridSearchCV
param_grid = {"max_depth": [1,5,10,50],
              "min_samples_leaf": [5,10,100,500],
              "criterion": ["gini", "entropy"]}

clf=GridSearchCV(tree,param_grid,cv=3,scoring='roc_auc')

clf.fit(X_tr_new, y_train)

print("Best cross-validation score: {:.2f}".format(clf.best_score_))
print("Best parameters: ", clf.best_params_)

results = pd.DataFrame.from_dict(clf.cv_results_)
results.columns
import pandas as pd
pvt = pd.pivot_table(pd.DataFrame(clf.cv_results_),
    values='mean_test_score', index='param_max_depth', columns='param_min_samples_leaf')
```

```
Best cross-validation score: 0.61
Best parameters:  {'criterion': 'gini', 'max_depth': 10, 'min_samples_leaf': 500}
```

In [160]:

```
tree=DecisionTreeClassifier(max_depth=10,min_samples_leaf= 500)
from sklearn.metrics import roc_curve, auc


tree.fit(X_tr_new, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive class
# not the predicted outputs

y_train_pred = tree.predict_proba(X_tr_new)[:,1]
y_test_pred = tree.predict_proba(X_test_new)[:,1]


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred)

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("a: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.grid()
plt.show()
test_auc_feature_imp=auc(test_fpr, test_tpr)
print('{0:.2f}'.format(test_auc_feature_imp*100))
```



60.51

In [167]:

```
def find_best_threshold(threshould, fpr, tpr):
    t = threshould[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for threshold", np.round(t,3))
    return t
```

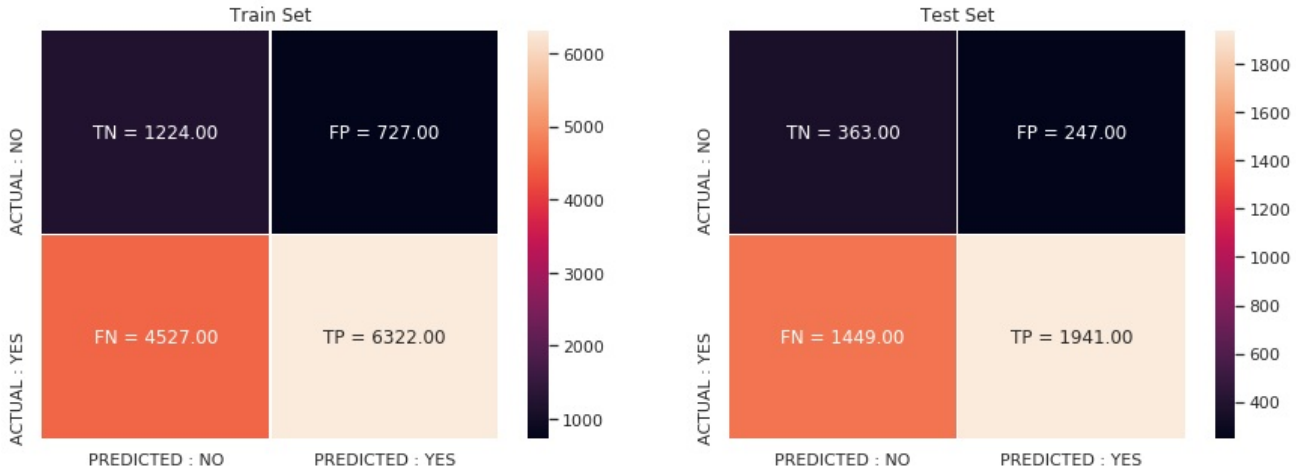
In [168]:

```
def predict_with_best_t(proba, threshould):
    predictions = []
    for i in proba:
        if i>=threshould:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

In [169]:

```
import seaborn as sns; sns.set()
from sklearn.metrics import confusion_matrix

best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)

con_m_train = confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t))
con_m_test = (confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))

key = (np.asarray([['TN','FP'], ['FN', 'TP']]))
fig, ax = plt.subplots(1,2, figsize=(15,5))
labels_train = (np.asarray(["{0} = {1:.2f}" .format(key, value) for key, value in zip(key.flatten(), con_m_train.
flatten())])).reshape(2,2)
labels_test = (np.asarray(["{0} = {1:.2f}" .format(key, value) for key, value in zip(key.flatten(),con_m_test.fla
tten())])).reshape(2,2)

sns.heatmap(con_m_train, linewidths=.5, xticklabels=['PREDICTED : NO', 'PREDICTED : YES'],yticklabels=['ACTUAL :
NO', 'ACTUAL : YES'], annot = labels_train, fmt = '', ax=ax[0])
sns.heatmap(con_m_test, linewidths=.5, xticklabels=['PREDICTED : NO', 'PREDICTED : YES'],yticklabels=['ACTUAL : N
O', 'ACTUAL : YES'], annot = labels_test, fmt = '', ax=ax[1])
ax[0].set_title('Train Set')
ax[1].set_title('Test Set')
plt.show()
```

```
the maximum value of tpr*(1-fpr) 0.365585473466696 for threshold 0.85
```

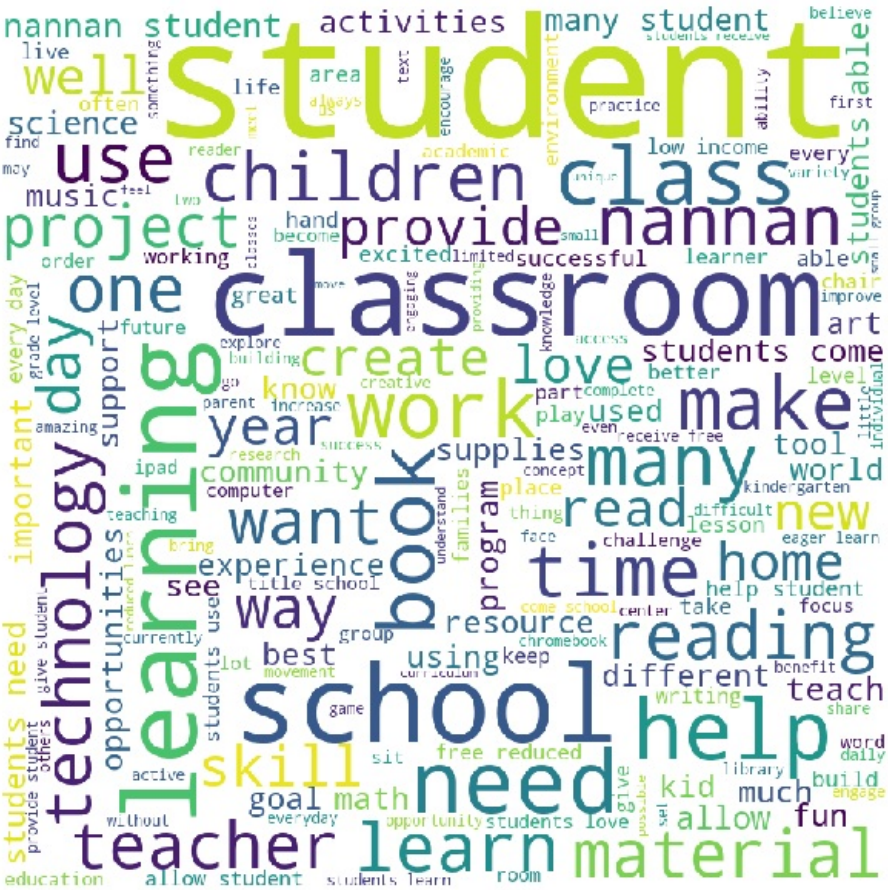


In [174]:

```
p=predict_with_best_t(y_test_pred, best_t)


text=[]
for i in range(len(p)):
    if (p[i]==1 and y_test[i]==0):
        text.append(project_data['essay'][i])
```

In [175]:

```
from wordcloud import WordCloud, STOPWORDS
import matplotlib.pyplot as plt
import pandas as pd

comment_words = ' '
stopwords = set(STOPWORDS)


for val in text:

    # typecaste each val to string
    val = str(val)

    # split the value
    tokens = val.split()

    # Converts each token into lowercase
    for i in range(len(tokens)):
        tokens[i] = tokens[i].lower()

    for words in tokens:
        comment_words = comment_words + words+' '


wordcloud = WordCloud(width = 800, height = 800,
                background_color ='white',
                stopwords = stopwords,
                min_font_size = 10).generate(comment_words)

# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```



Conclusion

In [166]:

```
from prettytable import PrettyTable

table = PrettyTable()
table.field_names = ["Vectorizer", "Hyper Parameter", "AUC"]
optimal=[10,500]
table.add_row(["TFIDF", optimal, test_auc_tfidf])
table.add_row(["AVG_W2V", optimal, test_auc_avg_w2v])
table.add_row(["TFIDF_W2V", optimal, test_auc_tfidf_w2v])
table.add_row(["TFIDF FEATURE_IMP", optimal, test_auc_feature_imp])
print(table)
```

```
+------------------+-----------------+--------------------+
|    Vectorizer    | Hyper Parameter |        AUC         |
+------------------+-----------------+--------------------+
|       TFIDF      |    [10, 500]    | 0.6142784950916388 |
|      AVG_W2V     |    [10, 500]    | 0.6051167851443494 |
|    TFIDF_W2V     |    [10, 500]    | 0.6082622467237294 |
| TFIDF FEATURE_IMP |    [10, 500]    | 0.605110498573432  |
+------------------+-----------------+--------------------+
```