DonorsChoose

DonorsChoose.org receives hundreds of thousands of project proposals each year for classroom projects in need of funding. Right now, a large number of volunteers is needed to manually screen each submission before it's approved to be posted on the DonorsChoose.org website.

Next year, DonorsChoose.org expects to receive close to 500,000 project proposals. As a result, there are three main problems they need to solve:

- How to scale current manual processes and resources to screen 500,000 projects so that they can be posted as quickly and as efficiently as possible
- How to increase the consistency of project vetting across different volunteers to improve the experience for teachers
- How to focus volunteer time on the applications that need the most assistance

The goal of the competition is to predict whether or not a DonorsChoose.org project proposal submitted by a teacher will be approved, using the text of project descriptions as well as additional metadata about the project, teacher, and school. DonorsChoose.org can then use this information to identify projects most likely to need further review before approval.

About the DonorsChoose Data Set

The `train.csv` data set provided by DonorsChoose contains the following features:

Feature	D
`project_id`	A unique identifier for the proposed project. **Example**
`project_title`	Title of the project. • `Art Will Make Yo` • `First G`
`project_grade_category`	Grade level of students for which the project is targeted. One of t enumera • `Grade` • `Gr` • `Gr` • `Gra`

Feature	I
`project_subject_categories`	One or more (comma-separated) subject categories for the proj following enumerated lis • `Applied` • `Care` • `Health` • `History` • `Literacy &` • `Math &` • `Music &` • `Speci` • • `Music &` • `Literacy & Language, Math &`
`school_state`	State where school is located (Two-letter U.S. (https://en.wikipedia.org/wiki/List_of_U.S._state_abbreviations#Pos **Ex**
`project_subject_subcategories`	One or more (comma-separated) subject subcategories for • • `Literature & Writing, Social`
`project_resource_summary`	An explanation of the resources needed for the project • `My students need hands on literacy materials sensory need`
`project_essay_1`	First applic
`project_essay_2`	Second applic
`project_essay_3`	Third applic
`project_essay_4`	Fourth applic
`project_submitted_datetime`	Datetime when project application was submitted. **Example:** `20 12:4`
`teacher_id`	A unique identifier for the teacher of the proposed projec `bdf8baa8fedef6bfeec7ae4f`
`teacher_prefix`	Teacher's title. One of the following enumera • • • • • •
`teacher_number_of_previously_posted_projects`	Number of project applications previously submitted by the sa **E**

[*] See the section **Notes on the Essay Data** for more details about these features.

Additionally, the `resources.csv` data set provides more data about the resources required for each project. Each line in this file represents a resource required by a project:

Feature	Description
`id`	A `project_id` value from the `train.csv` file. **Example:** `p036502`
`description`	Desciption of the resource. **Example:** `Tenor Saxophone Reeds, Box of 25`

Feature	Description
`quantity`	Quantity of the resource required. **Example:** `3`
`price`	Price of the resource required. **Example:** `9.95`

Note: Many projects require multiple resources. The `id` value corresponds to a `project_id` in train.csv, so you use it as a key to retrieve all resources needed for a project:

The data set contains the following label (the value you will attempt to predict):

Label	Description
`project_is_approved`	A binary flag indicating whether DonorsChoose approved the project. A value of `0` indicates the project was not approved, and a value of `1` indicates the project was approved.

Notes on the Essay Data

Prior to May 17, 2016, the prompts for the essays were as follows:

- **project_essay_1:** "Introduce us to your classroom"
- **project_essay_2:** "Tell us more about your students"
- **project_essay_3:** "Describe how your students will use the materials you're requesting"
- **project_essay_3:** "Close by sharing why your project will make a difference"

Starting on May 17, 2016, the number of essays was reduced from 4 to 2, and the prompts for the first 2 essays were changed to the following:

- **project_essay_1:** "Describe your students: What makes your students special? Specific details about their background, your neighborhood, and your school are all helpful."
- **project_essay_2:** "About your project: How will these materials make a difference in your students' learning and improve their school lives?"

For all projects with project_submitted_datetime of 2016-05-17 and later, the values of project_essay_3 and project_essay_4 will be NaN.

In [1]:

```
%matplotlib inline
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

from plotly import plotly
import plotly.offline as offline
import plotly.graph_objs as go
offline.init_notebook_mode()
from collections import Counter
from scipy.sparse import hstack
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import RandomizedSearchCV
from sklearn.model_selection import GridSearchCV
from sklearn import preprocessing
from sklearn.metrics import confusion_matrix
from prettytable import PrettyTable
import nltk
from nltk.sentiment.vader import SentimentIntensityAnalyzer
from sklearn.tree import DecisionTreeClassifier, export_graphviz
from sklearn import tree
from IPython.display import SVG
from graphviz import Source
from IPython.display import display
from sklearn.naive_bayes import MultinomialNB
from wordcloud import WordCloud
```

1.1 Reading Data

In [2]:

```
project_data = pd.read_csv('train_data.csv')
resource_data = pd.read_csv('resources.csv')
```

Adding price attribute to project_data dataframe from resources using merge function

In [3]:

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

In [4]:

```
print("Number of data points in train data", project_data.shape)
print('-'*50)
print("The attributes of data :", project_data.columns.values)
```

```
Number of data points in train data (109248, 19)
--------------------------------------------------
The attributes of data : ['Unnamed: 0' 'id' 'teacher_id' 'teacher_pref
ix' 'school_state'
 'project_submitted_datetime' 'project_grade_category'
 'project_subject_categories' 'project_subject_subcategories'
 'project_title' 'project_essay_1' 'project_essay_2' 'project_essay_3'
 'project_essay_4' 'project_resource_summary'
 'teacher_number_of_previously_posted_projects' 'project_is_approved'
 'price' 'quantity']
```

In [5]:

```
print("Number of data points in train data", resource_data.shape)
print(resource_data.columns.values)
resource_data.head(2)
```

```
Number of data points in train data (1541272, 4)
['id' 'description' 'quantity' 'price']
```

Out[5]:

	id	description	quantity	price
0	p233245	LC652 - Lakeshore Double-Space Mobile Drying Rack	1	149.00
1	p069063	Bouncy Bands for Desks (Blue support pipes)	3	14.95

1.2 preprocessing of `project_subject_categories`

In [6]:

```
catogories = list(project_data['project_subject_categories'].values)
# remove special characters from list of strings python: https://stackoverflow.com/

# https://www.geeksforgeeks.org/removing-stop-words-nltk-python/
# https://stackoverflow.com/questions/23669024/how-to-strip-a-specific-word-from-a-
# https://stackoverflow.com/questions/8270092/remove-all-whitespace-in-a-string-in-
cat_list = []
for i in catogories:
    temp = ""
    # consider we have text like this "Math & Science, Warmth, Care & Hunger"
    for j in i.split(','): # it will split it in three parts ["Math & Science", "Wa
        if 'The' in j.split(): # this will split each of the catogory based on spac
            j=j.replace('The','') # if we have the words "The" we are going to repl
        j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty) e
        temp+=j.strip()+" " #" abc ".strip() will return "abc", remove the trailing
        temp = temp.replace('&','_') # we are replacing the & value into
    cat_list.append(temp.strip())

project_data['clean_categories'] = cat_list
project_data.drop(['project_subject_categories'], axis=1, inplace=True)

from collections import Counter
my_counter = Counter()
for word in project_data['clean_categories'].values:
    my_counter.update(word.split())

cat_dict = dict(my_counter)
sorted_cat_dict = dict(sorted(cat_dict.items(), key=lambda kv: kv[1]))
```

1.3 preprocessing of `project_subject_subcategories`

In [7]:

```
sub_catogories = list(project_data['project_subject_subcategories'].values)
# remove special characters from list of strings python: https://stackoverflow.com/

# https://www.geeksforgeeks.org/removing-stop-words-nltk-python/
# https://stackoverflow.com/questions/23669024/how-to-strip-a-specific-word-from-a-
# https://stackoverflow.com/questions/8270092/remove-all-whitespace-in-a-string-in-

sub_cat_list = []
for i in sub_catogories:
    temp = ""
    # consider we have text like this "Math & Science, Warmth, Care & Hunger"
    for j in i.split(','): # it will split it in three parts ["Math & Science", "Wa
        if 'The' in j.split(): # this will split each of the catogory based on spac
            j=j.replace('The','') # if we have the words "The" we are going to repl
        j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty) e
        temp +=j.strip()+" "#" abc ".strip() will return "abc", remove the trailing
        temp = temp.replace('&','_')
    sub_cat_list.append(temp.strip())

project_data['clean_subcategories'] = sub_cat_list
project_data.drop(['project_subject_subcategories'], axis=1, inplace=True)

# count of all the words in corpus python: https://stackoverflow.com/a/22898595/408
my_counter = Counter()
for word in project_data['clean_subcategories'].values:
    my_counter.update(word.split())

sub_cat_dict = dict(my_counter)
sorted_sub_cat_dict = dict(sorted(sub_cat_dict.items(), key=lambda kv: kv[1]))
```

1.3 Text preprocessing

In [8]:

```
# merge two column text dataframe:
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)
```

In [9]:

```
project_data.head(2)
```

Out[9]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs.	IN	
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr.	FL	

In [10]:

```
#### 1.4.2.3 Using Pretrained Models: TFIDF weighted W2V
```

In [11]:

```
# printing some random reviews
print(project_data['essay'].values[0])
print("="*50)
print(project_data['essay'].values[150])
print("="*50)
print(project_data['essay'].values[1000])
print("="*50)
print(project_data['essay'].values[20000])
print("="*50)
print(project_data['essay'].values[99999])
print("="*50)
```

```
My students are English learners that are working on English as their
second or third languages. We are a melting pot of refugees, immigrant
s, and native-born Americans bringing the gift of language to our scho
ol. \r\n\r\n We have over 24 languages represented in our English Lear
ner program with students at every level of mastery.  We also have ove
r 40 countries represented with the families within our school.  Each
student brings a wealth of knowledge and experiences to us that open o
ur eyes to new cultures, beliefs, and respect.\"The limits of your lan
guage are the limits of your world.\"-Ludwig Wittgenstein  Our English
learner's have a strong support system at home that begs for more reso
urces.  Many times our parents are learning to read and speak English
along side of their children.  Sometimes this creates barriers for par
ents to be able to help their child learn phonetics, letter recognitio
n, and other reading skills.\r\n\r\nBy providing these dvd's and playe
rs, students are able to continue their mastery of the English languag
e even if no one at home is able to assist.  All families with student
s within the Level 1 proficiency status, will be a offered to be a par
t of this program.  These educational videos will be specially chosen
by the English Learner Teacher and will be sent home regularly to watc
h.  The videos are to help the child develop early reading skills.\r\n
\r\nParents that do not have access to a dvd player will have the oppo
rtunity to check out a dvd player to use for the year.  The plan is to
use these videos and educational dvd's for the years to come for other
EL students.\r\nnannan
==================================================
The 51 fifth grade students that will cycle through my classroom this
year all love learning, at least most of the time. At our school, 97.
3% of the students receive free or reduced price lunch. Of the 560 stu
dents, 97.3% are minority students. \r\nThe school has a vibrant commu
nity that loves to get together and celebrate. Around Halloween there
is a whole school parade to show off the beautiful costumes that stude
nts wear. On Cinco de Mayo we put on a big festival with crafts made b
y the students, dances, and games. At the end of the year the school h
osts a carnival to celebrate the hard work put in during the school ye
ar, with a dunk tank being the most popular activity.My students will
use these five brightly colored Hokki stools in place of regular, stat
ionary, 4-legged chairs. As I will only have a total of ten in the cla
ssroom and not enough for each student to have an individual one, they
will be used in a variety of ways. During independent reading time the
y will be used as special chairs students will each use on occasion. I
will utilize them in place of chairs at my small group tables during m
ath and reading times. The rest of the day they will be used by the st
udents who need the highest amount of movement in their life in order
to stay focused on school.\r\n\r\nWhenever asked what the classroom is
missing, my students always say more Hokki Stools. They can't get thei
r fill of the 5 stools we already have. When the students are sitting
in group with me on the Hokki Stools, they are always moving, but at t
```

```
he same time doing their work. Anytime the students get to pick where
they can sit, the Hokki Stools are the first to be taken. There are al
ways students who head over to the kidney table to get one of the stoo
ls who are disappointed as there are not enough of them. \r\n\r\nWe as
k a lot of students to sit for 7 hours a day. The Hokki stools will be
a compromise that allow my students to do desk work and move at the sa
me time. These stools will help students to meet their 60 minutes a da
y of movement by allowing them to activate their core muscles for bala
nce while they sit. For many of my students, these chairs will take aw
ay the barrier that exists in schools for a child who can't sit still.
nannan
==================================================
How do you remember your days of school? Was it in a sterile environme
nt with plain walls, rows of desks, and a teacher in front of the roo
m? A typical day in our room is nothing like that. I work hard to crea
te a warm inviting themed room for my students look forward to coming
to each day.\r\n\r\nMy class is made up of 28 wonderfully unique boys
and girls of mixed races in Arkansas.\r\nThey attend a Title I school,
which means there is a high enough percentage of free and reduced-pric
e lunch to qualify. Our school is an \"open classroom\" concept, which
is very unique as there are no walls separating the classrooms. These
9 and 10 year-old students are very eager learners; they are like spon
ges, absorbing all the information and experiences and keep on wanting
more.With these resources such as the comfy red throw pillows and the
whimsical nautical hanging decor and the blue fish nets, I will be abl
e to help create the mood in our classroom setting to be one of a them
ed nautical environment. Creating a classroom environment is very impo
rtant in the success in each and every child's education. The nautical
photo props will be used with each child as they step foot into our cl
assroom for the first time on Meet the Teacher evening. I'll take pict
ures of each child with them, have them developed, and then hung in ou
r classroom ready for their first day of 4th grade.  This kind gesture
will set the tone before even the first day of school! The nautical th
ank you cards will be used throughout the year by the students as they
create thank you cards to their team groups.\r\n\r\nYour generous dona
tions will help me to help make our classroom a fun, inviting, learnin
g environment from day one.\r\n\r\nIt costs lost of money out of my ow
n pocket on resources to get our classroom ready. Please consider help
ing with this project to make our new school year a very successful on
e. Thank you!nannan
==================================================
My kindergarten students have varied disabilities ranging from speech
and language delays, cognitive delays, gross/fine motor delays, to aut
ism. They are eager beavers and always strive to work their hardest wo
rking past their limitations. \r\n\r\nThe materials we have are the on
es I seek out for my students. I teach in a Title I school where most
of the students receive free or reduced price lunch.  Despite their di
sabilities and limitations, my students love coming to school and come
eager to learn and explore.Have you ever felt like you had ants in you
r pants and you needed to groove and move as you were in a meeting? Th
is is how my kids feel all the time. The want to be able to move as th
ey learn or so they say.Wobble chairs are the answer and I love then b
ecause they develop their core, which enhances gross motor and in Turn
fine motor skills. \r\nThey also want to learn through games, my kids
don't want to sit and do worksheets. They want to learn to count by ju
mping and playing. Physical engagement is the key to our success. The
number toss and color and shape mats can make that happen. My students
will forget they are doing work and just have the fun a 6 year old des
erves.nannan
==================================================
The mediocre teacher tells. The good teacher explains. The superior te
```

```
acher demonstrates. The great teacher inspires. -William A. Ward\r\n\r
\nMy school has 803 students which is makeup is 97.6% African-America
n, making up the largest segment of the student body. A typical school
in Dallas is made up of 23.2% African-American students. Most of the s
tudents are on free or reduced lunch. We aren't receiving doctors, law
yers, or engineers children from rich backgrounds or neighborhoods. As
an educator I am inspiring minds of young children and we focus not on
ly on academics but one smart, effective, efficient, and disciplined s
tudents with good character.In our classroom we can utilize the Blueto
oth for swift transitions during class. I use a speaker which doesn't
amplify the sound enough to receive the message. Due to the volume of
my speaker my students can't hear videos or books clearly and it isn't
making the lessons as meaningful. But with the bluetooth speaker my st
udents will be able to hear and I can stop, pause and replay it at any
time.\r\nThe cart will allow me to have more room for storage of thing
s that are needed for the day and has an extra part to it I can use.
The table top chart has all of the letter, words and pictures for stud
ents to learn about different letters and it is more accessible.nannan
==================================================
```

In [12]:

```python
# https://stackoverflow.com/a/47091490/4084039
import re

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 [13]:

```
sent = decontracted(project_data['essay'].values[20000])
print(sent)
print("="*50)
```

```
My kindergarten students have varied disabilities ranging from speech 
and language delays, cognitive delays, gross/fine motor delays, to aut
ism. They are eager beavers and always strive to work their hardest wo
rking past their limitations. \r\n\r\nThe materials we have are the on
es I seek out for my students. I teach in a Title I school where most 
of the students receive free or reduced price lunch.  Despite their di
sabilities and limitations, my students love coming to school and come
eager to learn and explore.Have you ever felt like you had ants in you
r pants and you needed to groove and move as you were in a meeting? Th
is is how my kids feel all the time. The want to be able to move as th
ey learn or so they say.Wobble chairs are the answer and I love then b
ecause they develop their core, which enhances gross motor and in Turn
fine motor skills. \r\nThey also want to learn through games, my kids 
do not want to sit and do worksheets. They want to learn to count by j
umping and playing. Physical engagement is the key to our success. The
number toss and color and shape mats can make that happen. My students
will forget they are doing work and just have the fun a 6 year old des
erves.nannan
==================================================
```

In [14]:

```
# \r \n \t remove from string python: http://texthandler.com/info/remove-line-break
sent = sent.replace('\\r', ' ')
sent = sent.replace('\\"', ' ')
sent = sent.replace('\\n', ' ')
print(sent)
```

```
My kindergarten students have varied disabilities ranging from speech 
and language delays, cognitive delays, gross/fine motor delays, to aut
ism. They are eager beavers and always strive to work their hardest wo
rking past their limitations.     The materials we have are the ones I
seek out for my students. I teach in a Title I school where most of th
e students receive free or reduced price lunch.  Despite their disabil
ities and limitations, my students love coming to school and come eage
r to learn and explore.Have you ever felt like you had ants in your pa
nts and you needed to groove and move as you were in a meeting? This i
s how my kids feel all the time. The want to be able to move as they l
earn or so they say.Wobble chairs are the answer and I love then becau
se they develop their core, which enhances gross motor and in Turn fin
e motor skills.   They also want to learn through games, my kids do no
t want to sit and do worksheets. They want to learn to count by jumpin
g and playing. Physical engagement is the key to our success. The numb
er toss and color and shape mats can make that happen. My students wil
l forget they are doing work and just have the fun a 6 year old deserv
es.nannan
```

In [15]:

```
#remove spacial character: https://stackoverflow.com/a/5843547/4084039
sent = re.sub('[^A-Za-z0-9]+', ' ', sent)
print(sent)
```

```
My kindergarten students have varied disabilities ranging from speech
and language delays cognitive delays gross fine motor delays to autism
They are eager beavers and always strive to work their hardest working
past their limitations The materials we have are the ones I seek out f
or my students I teach in a Title I school where most of the students
receive free or reduced price lunch Despite their disabilities and lim
itations my students love coming to school and come eager to learn and
explore Have you ever felt like you had ants in your pants and you nee
ded to groove and move as you were in a meeting This is how my kids fe
el all the time The want to be able to move as they learn or so they s
ay Wobble chairs are the answer and I love then because they develop t
heir core which enhances gross motor and in Turn fine motor skills The
y also want to learn through games my kids do not want to sit and do w
orksheets They want to learn to count by jumping and playing Physical
engagement is the key to our success The number toss and color and sha
pe mats can make that happen My students will forget they are doing wo
rk and just have the fun a 6 year old deserves nannan
```

In [16]:

```
# https://gist.github.com/sebleier/554280
# we are removing the words from the stop words list: 'no', 'nor', 'not'
stopwords= {'i', 'me', 'my', 'myself', 'we', 'our', 'ours', 'ourselves', 'you', "yo
            "you'll", "you'd", 'your', 'yours', 'yourself', 'yourselves', 'he', 'hi
            'she', "she's", 'her', 'hers', 'herself', 'it', "it's", 'its', 'itself'
            'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'that',
            'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'has',
            'did', 'doing', 'a', 'an', 'the', 'and', 'but', 'if', 'or', 'because',
            'at', 'by', 'for', 'with', 'about', 'against', 'between', 'into', 'thro
            'above', 'below', 'to', 'from', 'up', 'down', 'in', 'out', 'on', 'off',
            'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'all',
            'most', 'other', 'some', 'such', 'only', 'own', 'same', 'so', 'than', '
            's', 't', 'can', 'will', 'just', 'don', "don't", 'should', "should've",
            've', 'y', 'ain', 'aren', "aren't", 'couldn', "couldn't", 'didn', "didn
            "hadn't", 'hasn', "hasn't", 'haven', "haven't", 'isn', "isn't", 'ma', '
            "mustn't", 'needn', "needn't", 'shan', "shan't", 'shouldn', "shouldn't"
            'won', "won't", 'wouldn', "wouldn't"}
```

In [17]:

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

```
100%|██████████| 109248/109248 [00:14<00:00, 7526.99it/s]
```

In [18]:

```
# after preprocesing
preprocessed_essays[20000]
```

Out[18]:

```
'kindergarten students varied disabilities ranging speech language del
ays cognitive delays gross fine motor delays autism eager beavers alwa
ys strive work hardest working past limitations the materials ones see
k students teach title school students receive free reduced price lunc
h despite disabilities limitations students love coming school come ea
ger learn explore have ever felt like ants pants needed groove move me
eting kids feel time want able move learn say wobble chairs answer lov
e develop core enhances gross motor turn fine motor skills they also w
ant learn games kids want sit worksheets want learn count jumping play
ing physical engagement key success number toss color shape mats make
happen students forget work fun 6 year old deserves nannan'
```

In [19]:

```
project_data['clean_essay'] = preprocessed_essays
```

In [20]:

```
project_data.drop(['project_essay_1','project_essay_2','project_essay_3','project_e
```

1.4 Preprocessing of `project_title`

- Decontract project titles, remove line breaks and extra spaces, convert everything to lowercase and then remove all the stop words.

In [21]:

```
preprocessed_titles = []

for title in tqdm(project_data['project_title'].values):
    title = title.lower().strip()
    title = ' '.join(e for e in title.split() if e.lower() not in stopwords)
    title = decontracted(title)
    title = title.replace('\\r', ' ')
    title = title.replace('\\"', ' ')
    title = title.replace('\\n', ' ')
    title = re.sub('[^A-Za-z0-9]+', ' ', title)
    preprocessed_titles.append(title)
```

```
100%|██████████| 109248/109248 [00:01<00:00, 67281.80it/s]
```

In [22]:

```
project_data['clean_title'] = preprocessed_titles
project_data.drop(['project_title'],axis=1,inplace=True)
```

Pre-processing teacher_prefix

In [23]:

```
#remove nan from teacher prefix:
#https://stackoverflow.com/questions/21011777/how-can-i-remove-nan-from-list-python
def remove_nan(prefix):
    if str(prefix)!='nan':
        pr = str(prefix)
        pr = re.sub("\\.","",pr) #remove dot from the end of prefix
        return pr
    return "none"

cleaned_teacher_prefix = project_data['teacher_prefix'].map(remove_nan)
project_data['clean_teacher_prefix'] = cleaned_teacher_prefix
```

In [24]:

```
project_data.drop(['teacher_prefix'],axis=1,inplace=True)
```

Pre-process project_grade_category

- Clean the project grade categories:
  - `Convert Grades 3-5 ==> Grades_3_5`

In [25]:

```
def clean_project_grades(grade):
    grade = re.sub("\-","_",grade)
    grade = re.sub(" ","_",grade)
    return grade.strip()

clean_grades = project_data['project_grade_category'].map(clean_project_grades)
project_data['clean_grade_category'] = clean_grades
```

In [26]:

```
project_data.drop(['project_grade_category'],axis=1,inplace=True)
```

In [27]:

```
# Dropping all features we won't need going forward
project_data.drop(['project_resource_summary'],axis=1,inplace=True)
project_data.drop(['Unnamed: 0','teacher_id'],axis=1,inplace=True)
```

In [28]:

```
project_data.head(2)
```

Out[28]:

	id	school_state	project_submitted_datetime	teacher_number_of_previously_posted_proj
0	p253737	IN	2016-12-05 13:43:57	
1	p258326	FL	2016-10-25 09:22:10	

Assignment 8: DT

1. **Apply Decision Tree Classifier(DecisionTreeClassifier) on these feature sets**
   - Set 1: categorical, numerical features + project_title(BOW) + preprocessed_eassay (BOW)
   - Set 2: categorical, numerical features + project_title(TFIDF)+ preprocessed_eassay (TFIDF)
   - Set 3: categorical, numerical features + project_title(AVG W2V)+ preprocessed_eassay (AVG W2V)
   - Set 4: categorical, numerical features + project_title(TFIDF W2V)+ preprocessed_eassay (TFIDF W2V)
2. **Hyper paramter tuning (best `depth` in range [1, 5, 10, 50, 100, 500, 100], and the best `min_samples_split` in range [5, 10, 100, 500])**

- Find the best hyper parameter which will give the maximum AUC (https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/receiver-operating-characteristic-curve-roc-curve-and-auc-1/) value
- Find the best hyper paramter using k-fold cross validation or simple cross validation data
- Use gridsearch cv or randomsearch cv or you can also write your own for loops to do this task of hyperparameter tuning

3. **Graphviz**

- Visualize your decision tree with Graphviz. It helps you to understand how a decision is being made, given a new vector.
- Since feature names are not obtained from word2vec related models, visualize only BOW & TFIDF decision trees using Graphviz
- Make sure to print the words in each node of the decision tree instead of printing its index.
- Just for visualization purpose, limit max_depth to 2 or 3 and either embed the generated images of graphviz in your notebook, or directly upload them as .png files.

4. **Representation of results**

- You need to plot the performance of model both on train data and cross validation data for each hyper parameter, like shown in the figure
- Once after you found the best hyper parameter, you need to train your model with it, and find the AUC on test data and plot the ROC curve on both train and test.
- Along with plotting ROC curve, you need to print the confusion matrix (https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/confusion-matrix-tpr-fpr-fnr-tnr-1/) with predicted and original labels of test data points
- Once after you plot the confusion matrix with the test data, get all the `false positive data points`
  - Plot the WordCloud WordCloud (https://www.geeksforgeeks.org/generating-word-cloud-python/)
  - Plot the box plot with the `price` of these `false positive data points`
  - Plot the pdf with the `teacher_number_of_previously_posted_projects` of these `false positive data points`

5. **[Task-2]**

- Select 5k best features from features of Set 2 using `feature_importances_` (https://scikit-learn.org/stable/modules/generated/sklearn.tree.DecisionTreeClassifier.html), discard all the other remaining features and then apply any of the model of you choice i.e. (Dession tree, Logistic Regression, Linear SVM), you need to do hyperparameter tuning corresponding to the model you selected and procedure in step 2 and step 3

6. **Conclusion**

- You need to summarize the results at the end of the notebook, summarize it in the table format. To print out a table please refer to this prettytable library link (http://zetcode.com/python/prettytable/)

Note: Data Leakage

1. There will be an issue of data-leakage if you vectorize the entire data and then split it into train/cv/test.
2. To avoid the issue of data-leakage, make sure to split your data first and then vectorize it.
3. While vectorizing your data, apply the method fit_transform() on you train data, and apply the method transform() on cv/test data.
4. For more details please go through this link. (https://soundcloud.com/applied-ai-course/leakage-bow-and-tfidf)

2. Decision Tree

2.1 Splitting data into Train and cross validation(or test): Stratified Sampling

In [29]:

```
#Separating features and label column
Y = project_data['project_is_approved']
X = project_data.drop(['project_is_approved','id'],axis=1)
print("Shape of X: ",X.shape)
print("Shape of Y: ",Y.shape)
```

```
Shape of X:  (109248, 12)
Shape of Y:  (109248,)
```

In [30]:

```
#separating data into train and test
X_train, X_test, Y_train, Y_test = train_test_split(X,Y,test_size=0.30,stratify=Y)
print("Shape of X_train: ", X_train.shape)
print("Shape of Y_train: ",Y_train.shape)
print("Shape of X_test: ",X_test.shape)
print("Shape of Y_test: ",Y_test.shape)
```

```
Shape of X_train:  (76473, 12)
Shape of Y_train:  (76473,)
Shape of X_test:  (32775, 12)
Shape of Y_test:  (32775,)
```

In [31]:

```
X_train.columns
```

Out[31]:

```
Index(['school_state', 'project_submitted_datetime',
       'teacher_number_of_previously_posted_projects', 'price', 'quant
ity',
       'clean_categories', 'clean_subcategories', 'essay', 'clean_essa
y',
       'clean_title', 'clean_teacher_prefix', 'clean_grade_category'],
      dtype='object')
```

2.2 Make Data Model Ready: encoding numerical, categorical features

2.2.1 Encoding Categorical Features

One hot encoding: clean_categories

In [32]:

```
from collections import Counter
my_counter = Counter()
for word in X_train['clean_categories'].values:
    my_counter.update(word.split())

cat_dict = dict(my_counter)
sorted_cat_dict = dict(sorted(cat_dict.items(), key=lambda kv: kv[1]))
```

In [33]:

```
# we use count vectorizer to convert the values into one
vectorizer_category = CountVectorizer(vocabulary=list(sorted_cat_dict.keys()), lowe
vectorizer_category.fit(X_train['clean_categories'].values)

X_train_category_ohe = vectorizer_category.transform(X_train['clean_categories'].va
X_test_category_ohe = vectorizer_category.transform(X_test['clean_categories'].valu
```

In [34]:

```
print(vectorizer_category.get_feature_names())
print("Shape of X_train after one hot encodig ",X_train_category_ohe.shape)
print("Shape of X_test after one hot encodig ",X_test_category_ohe.shape)
print("Print some random encoded categories: ")
print(X_train_category_ohe[0].toarray())
print(X_test_category_ohe[15].toarray())
```

```
['Warmth', 'Care_Hunger', 'History_Civics', 'Music_Arts', 'AppliedLear
ning', 'SpecialNeeds', 'Health_Sports', 'Math_Science', 'Literacy_Lang
uage']
Shape of X_train after one hot encodig  (76473, 9)
Shape of X_test after one hot encodig  (32775, 9)
Print some random encoded categories:
[[0 0 0 0 0 0 0 1 1]]
[[0 0 0 0 0 1 0 0 1]]
```

One hot encoding: clean_subcategories

In [35]:

```
# count of all the words in corpus python: https://stackoverflow.com/a/22898595/408
my_counter = Counter()
for word in X_train['clean_subcategories'].values:
    my_counter.update(word.split())

sub_cat_dict = dict(my_counter)
sorted_sub_cat_dict = dict(sorted(sub_cat_dict.items(), key=lambda kv: kv[1]))
```

In [36]:

```
# we use count vectorizer to convert the values into one
vectorizer_subcategory = CountVectorizer(vocabulary=list(sorted_sub_cat_dict.keys()
vectorizer_subcategory.fit(X_train['clean_subcategories'].values)

X_train_subcategory_ohe = vectorizer_subcategory.transform(X_train['clean_subcatego
X_test_subcategory_ohe = vectorizer_subcategory.transform(X_test['clean_subcategori
```

In [37]:

```
print(vectorizer_subcategory.get_feature_names())
print("Shape of X_train subcategory after one hot encodig ",X_train_subcategory_ohe
print("Shape of X_test subcategory after one hot encodig ",X_test_subcategory_ohe.s
print("Print some random encoded categories: ")
print(X_train_subcategory_ohe[0].toarray())
print(X_test_subcategory_ohe[10].toarray())
```

```
['Economics', 'CommunityService', 'FinancialLiteracy', 'ParentInvolvem
ent', 'Extracurricular', 'Civics_Government', 'ForeignLanguages', 'Nut
ritionEducation', 'Warmth', 'Care_Hunger', 'SocialSciences', 'Performi
ngArts', 'CharacterEducation', 'TeamSports', 'Other', 'College_CareerP
rep', 'Music', 'History_Geography', 'EarlyDevelopment', 'Health_LifeSc
ience', 'ESL', 'Gym_Fitness', 'EnvironmentalScience', 'VisualArts', 'H
ealth_Wellness', 'AppliedSciences', 'SpecialNeeds', 'Literature_Writin
g', 'Mathematics', 'Literacy']
Shape of X_train subcategory after one hot encodig  (76473, 30)
Shape of X_test subcategory after one hot encodig  (32775, 30)
Print some random encoded categories: 
[[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1]]
[[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0]]
```

One hot encoding: school_state

In [38]:

```
# create a vocabulary for states
unique_states = np.unique(X_train['school_state'].values)

vectorizer_state = CountVectorizer(vocabulary=unique_states,lowercase=False,binary=
vectorizer_state.fit(X_train['school_state'].values)

X_train_school_state_ohe = vectorizer_state.transform(X_train['school_state'].value
X_test_school_state_ohe = vectorizer_state.transform(X_test['school_state'].values)
```

In [39]:

```
print(vectorizer_state.get_feature_names())
print("Shape of X_train school_state after one hot encodig ",X_train_school_state_o
print("Shape of X_test school_state after one hot encodig ",X_test_school_state_ohe
print("Print some random encoded school_state: ")
print(X_train_school_state_ohe[0].toarray())
print(X_test_school_state_ohe[15].toarray())
```

```
['AK', 'AL', 'AR', 'AZ', 'CA', 'CO', 'CT', 'DC', 'DE', 'FL', 'GA', 'H
I', 'IA', 'ID', 'IL', 'IN', 'KS', 'KY', 'LA', 'MA', 'MD', 'ME', 'MI',
'MN', 'MO', 'MS', 'MT', 'NC', 'ND', 'NE', 'NH', 'NJ', 'NM', 'NV', 'N
Y', 'OH', 'OK', 'OR', 'PA', 'RI', 'SC', 'SD', 'TN', 'TX', 'UT', 'VA',
'VT', 'WA', 'WI', 'WV', 'WY']
Shape of X_train school_state after one hot encodig  (76473, 51)
Shape of X_test school_state after one hot encodig  (32775, 51)
Print some random encoded school_state:
[[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]]
[[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0
0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]]
```

One hot encoding: teacher_prefix

In [40]:

```
unique_teacher_prefix = np.unique(X_train['clean_teacher_prefix'])

vectorizer_teacher_prefix = CountVectorizer(vocabulary=unique_teacher_prefix,lowerc
vectorizer_teacher_prefix.fit(X_train['clean_teacher_prefix'].values)

X_train_teacher_prefix_ohe = vectorizer_teacher_prefix.transform(X_train['clean_tea
X_test_teacher_prefix_ohe = vectorizer_teacher_prefix.transform(X_test['clean_teach
```

In [41]:

```
print(vectorizer_teacher_prefix.get_feature_names())
print("Shape of X_train clean_teacher_prefix after one hot encodig ",X_train_teache
print("Shape of X_test clean_teacher_prefix after one hot encodig ",X_test_teacher_
print("Print some random encoded clean_teacher_prefix: ")
print(X_train_teacher_prefix_ohe[0].toarray())
print(X_test_teacher_prefix_ohe[15].toarray())
```

```
['Dr', 'Mr', 'Mrs', 'Ms', 'Teacher', 'none']
Shape of X_train clean_teacher_prefix after one hot encodig  (76473,
6)
Shape of X_test clean_teacher_prefix after one hot encodig  (32775, 6)
Print some random encoded clean_teacher_prefix:
[[0 0 1 0 0 0]]
[[0 0 1 0 0 0]]
```

One hot encoding: project_grade_category

In [42]:

```
unique_grades = np.unique(X_train['clean_grade_category'])

vectorizer_grade = CountVectorizer(vocabulary=unique_grades,lowercase=False,binary=
vectorizer_grade.fit(X_train['clean_grade_category'].values)


X_train_grade_category_ohe = vectorizer_grade.transform(X_train['clean_grade_catego
X_test_grade_category_ohe = vectorizer_grade.transform(X_test['clean_grade_category
```

In [43]:

```
print(vectorizer_grade.get_feature_names())
print("Shape of X_train clean_grade_category after one hot encodig ",X_train_grade_
print("Shape of X_test clean_grade_category after one hot encodig ",X_test_grade_ca
print("Print some random encoded clean_grade_category: ")
print(X_train_grade_category_ohe[0].toarray())
print(X_test_grade_category_ohe[15].toarray())
```

```
['Grades_3_5', 'Grades_6_8', 'Grades_9_12', 'Grades_PreK_2']
Shape of X_train clean_grade_category after one hot encodig  (76473,
4)
Shape of X_test clean_grade_category after one hot encodig  (32775, 4)
Print some random encoded clean_grade_category:
[[1 0 0 0]]
[[1 0 0 0]]
```

2.2.2 Encoding Numerical features

Normalizing Price

In [44]:

```
price_vectorizer = preprocessing.Normalizer().fit(X_train['price'].values.reshape(1
```

In [45]:

```
X_train_price_normalized = price_vectorizer.transform(X_train['price'].values.resha
X_test_price_normalized = price_vectorizer.transform(X_test['price'].values.reshape
```

In [46]:

```
X_train_price_normalized
```

Out[46]:

```
array([[1.51859071e-03, 2.43500678e-03, 3.91171908e-05, ...,
        3.05574291e-03, 2.03846584e-03, 4.84669664e-04]])
```

In [47]:

```
X_test_price_normalized
```

Out[47]:

```
array([[0.00057857, 0.00028876, 0.00073933, ..., 0.00069419, 0.0044530
9,
        0.00169577]])
```

Normalize teacher_number_of_previously_posted_projects

In [48]:

```
project_vectorizer = preprocessing.Normalizer().fit(X_train['teacher_number_of_prev
```

In [49]:

```
X_train_normal_previous_project = project_vectorizer.transform(X_train['teacher_num
X_test_normal_previous_project = project_vectorizer.transform(X_test['teacher_numbe
```

2.3 Make Data Model Ready: encoding eassay, and project_title

2.3.1 Bag of words : Essay

In [50]:

```
# We are considering only the words which appeared in at least 10 documents(rows or
vectorizer_essay_bow = CountVectorizer(min_df=10,ngram_range=(1,2), max_features=50
vectorizer_essay_bow.fit(X_train['clean_essay'])
```

Out[50]:

```
CountVectorizer(analyzer='word', binary=False, decode_error='strict',
        dtype=<class 'numpy.int64'>, encoding='utf-8', input='conten
t',
        lowercase=True, max_df=1.0, max_features=5000, min_df=10,
        ngram_range=(1, 2), preprocessor=None, stop_words=None,
        strip_accents=None, token_pattern='(?u)\\b\\w\\w+\\b',
        tokenizer=None, vocabulary=None)
```

In [51]:

```
X_train_essay_bow = vectorizer_essay_bow.transform(X_train['clean_essay'])
X_test_essay_bow = vectorizer_essay_bow.transform(X_test['clean_essay'])

print("Shape of X_train_essay_bow ",X_train_essay_bow.shape)
print("Shape of X_test_essay_bow ",X_test_essay_bow.shape)
```

```
Shape of X_train_essay_bow  (76473, 5000)
Shape of X_test_essay_bow  (32775, 5000)
```

2.3.2 Bag of words : Project Title

In [52]:

```
# you can vectorize the title also
# before you vectorize the title make sure you preprocess it
vectorizer_title_bow = CountVectorizer(min_df=10,ngram_range=(1,2), max_features=50
vectorizer_title_bow.fit(X_train['clean_title'])
```

Out[52]:

```
CountVectorizer(analyzer='word', binary=False, decode_error='strict',
        dtype=<class 'numpy.int64'>, encoding='utf-8', input='conten
t',
        lowercase=True, max_df=1.0, max_features=5000, min_df=10,
        ngram_range=(1, 2), preprocessor=None, stop_words=None,
        strip_accents=None, token_pattern='(?u)\\b\\w\\w+\\b',
        tokenizer=None, vocabulary=None)
```

In [53]:

```
X_train_title_bow = vectorizer_title_bow.transform(X_train['clean_title'])
X_test_title_bow = vectorizer_title_bow.transform(X_test['clean_title'])

print("Shape of X_train_title_bow ",X_train_title_bow.shape)
print("Shape of X_test_title_bow ",X_test_title_bow.shape)
```

```
Shape of X_train_title_bow  (76473, 4864)
Shape of X_test_title_bow  (32775, 4864)
```

2.3.3 TFIDF vectorizer: Essay

In [54]:

```
vectorizer_essay_tfidf = TfidfVectorizer(min_df=10,ngram_range=(1,2), max_features=
vectorizer_essay_tfidf.fit(X_train['clean_essay'])
```

Out[54]:

```
TfidfVectorizer(analyzer='word', binary=False, decode_error='strict',
        dtype=<class 'numpy.float64'>, encoding='utf-8', input='conten
t',
        lowercase=True, max_df=1.0, max_features=5000, min_df=10,
        ngram_range=(1, 2), norm='l2', preprocessor=None, smooth_idf=T
rue,
        stop_words=None, strip_accents=None, sublinear_tf=False,
        token_pattern='(?u)\\b\\w\\w+\\b', tokenizer=None, use_idf=Tru
e,
        vocabulary=None)
```

In [55]:

```
X_train_essay_tfidf = vectorizer_essay_tfidf.transform(X_train['clean_essay'])
X_test_essay_tfidf = vectorizer_essay_tfidf.transform(X_test['clean_essay'])

print("Shape of X_train_essay_tfidf ",X_train_essay_tfidf.shape)
print("Shape of X_test_essay_tfidf ",X_test_essay_tfidf.shape)
```

```
Shape of X_train_essay_tfidf  (76473, 5000)
Shape of X_test_essay_tfidf  (32775, 5000)
```

2.3.4 TFIDF vectorizer: Project title

2.3.4 TFIDF vectorizer: Project title

In [56]:

```
vectorizer_title_tfidf = TfidfVectorizer(min_df=10,ngram_range=(1,2), max_features=
vectorizer_title_tfidf.fit(X_train['clean_title'])
```

Out[56]:

```
TfidfVectorizer(analyzer='word', binary=False, decode_error='strict',
        dtype=<class 'numpy.float64'>, encoding='utf-8', input='conten
t',
        lowercase=True, max_df=1.0, max_features=5000, min_df=10,
        ngram_range=(1, 2), norm='l2', preprocessor=None, smooth_idf=T
rue,
        stop_words=None, strip_accents=None, sublinear_tf=False,
        token_pattern='(?u)\\b\\w\\w+\\b', tokenizer=None, use_idf=Tru
e,
        vocabulary=None)
```

In [57]:

```
X_train_title_tfidf = vectorizer_title_tfidf.transform(X_train['clean_title'])
X_test_title_tfidf = vectorizer_title_tfidf.transform(X_test['clean_title'])

print("Shape of X_train_title_tfidf ",X_train_title_tfidf.shape)
print("Shape of X_test_title_tfidf",X_test_title_tfidf.shape)
```

```
Shape of X_train_title_tfidf  (76473, 4864)
Shape of X_test_title_tfidf (32775, 4864)
```

2.3.5 Using Pretrained Models: Avg W2V : Essay

In [58]:

```
# stronging variables into pickle files python: http://www.jessicayung.com/how-to-u
# make sure you have the glove_vectors file
with open('glove_vectors', 'rb') as f:
    model = pickle.load(f)
    glove_words =  set(model.keys())
```

In [59]:

```
# average Word2Vec
def get_avg_w2v(corpus):
    avg_w2v_vectors=[]
    for sentence in tqdm(corpus): # for each review/sentence
        vector = np.zeros(300) # as word vectors are of zero length
        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
        avg_w2v_vectors.append(vector)
    return avg_w2v_vectors

X_train_essay_avg_w2v_vectors = get_avg_w2v(X_train['clean_essay'])
X_test_essay_avg_w2v_vectors = get_avg_w2v(X_test['clean_essay'])
```

```
100%|██████████| 76473/76473 [00:23<00:00, 3225.65it/s]
100%|██████████| 32775/32775 [00:10<00:00, 3150.14it/s]
```

In [60]:

```
print("Shape of X_train_essay_avg_w2v_vectors",len(X_train_essay_avg_w2v_vectors),l
print("Shape of X_test_essay_avg_w2v_vectors ",len(X_test_essay_avg_w2v_vectors),le
```

```
Shape of X_train_essay_avg_w2v_vectors 76473 300
Shape of X_test_essay_avg_w2v_vectors  32775 300
```

2.3.6 Using Pretrained Models: Avg W2V : Project Title

In [61]:

```
X_train_title_avg_w2v_vectors = get_avg_w2v(X_train['clean_title'])
X_test_title_avg_w2v_vectors = get_avg_w2v(X_test['clean_title'])
```

```
100%|██████████| 76473/76473 [00:01<00:00, 61407.84it/s]
100%|██████████| 32775/32775 [00:00<00:00, 59932.92it/s]
```

2.3.7 Using Pretrained Models: TFIDF weighted W2V : Essay

In [62]:

```
def get_tfidf_weighted_w2v(corpus,dictionary,tfidf_words):
    tfidf_w2v_vectors = []; # the avg-w2v for each sentence/review is stored in thi
    for sentence in tqdm(corpus): # for each review/sentence
        vector = np.zeros(300) # 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(): # for each word in a review/sentence
            if (word in glove_words) and (word in tfidf_words):
                vec = model[word] # getting the vector for each word
                # here we are multiplying idf value(dictionary[word]) and the tf va
                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
        tfidf_w2v_vectors.append(vector)
    return tfidf_w2v_vectors
```

In [63]:

```
dictionary = dict(zip(vectorizer_essay_tfidf.get_feature_names(), list(vectorizer_e
tfidf_words = set(vectorizer_essay_tfidf.get_feature_names())

X_train_essay_tfidf_w2v_vectors = get_tfidf_weighted_w2v(X_train['clean_essay'].val
X_test_essay_tfidf_w2v_vectors = get_tfidf_weighted_w2v(X_test['clean_essay'].value
```

```
100%|██████████| 76473/76473 [02:06<00:00, 604.24it/s]
100%|██████████| 32775/32775 [00:54<00:00, 605.38it/s]
```

In [64]:

```
print("Shape of X_train_essay_tfidf_w2v_vectors",len(X_train_essay_tfidf_w2v_vector
print("Shape of X_test_essay_tfidf_w2v_vectors ",len(X_test_essay_tfidf_w2v_vectors
```

```
Shape of X_train_essay_tfidf_w2v_vectors 76473 300
Shape of X_test_essay_tfidf_w2v_vectors  32775 300
```

2.3.7 Using Pretrained Models: TFIDF weighted W2V : Project Title

In [65]:

```
dictionary = dict(zip(vectorizer_title_tfidf.get_feature_names(), list(vectorizer_t
tfidf_words = set(vectorizer_title_tfidf.get_feature_names())

X_train_title_tfidf_w2v_vectors = get_tfidf_weighted_w2v(X_train['clean_title'],dic
X_test_title_tfidf_w2v_vectors = get_tfidf_weighted_w2v(X_test['clean_title'],dicti

print("Shape of X_train_title_tfidf_w2v_vectors",len(X_train_title_tfidf_w2v_vector
print("Shape of X_title_title_tfidf_w2v_vectors ",len(X_test_title_tfidf_w2v_vector
```

```
100%|██████████| 76473/76473 [00:02<00:00, 29778.63it/s]
100%|██████████| 32775/32775 [00:01<00:00, 30646.05it/s]

Shape of X_train_title_tfidf_w2v_vectors 76473 300
Shape of X_title_title_tfidf_w2v_vectors  32775 300
```

2.4 Appling Decision Tree on different kind of featurization as mentioned in the instructions

Apply Decision Tree on different kind of featurization as mentioned in the instructions
For Every model that you work on make sure you do the step 2 and step 3 of instrucations

2.4.1 SET 1 : BOW

In [66]:

```
f1 = X_train_school_state_ohe
f2 = X_train_category_ohe
f3 = X_train_subcategory_ohe
f4 = X_train_grade_category_ohe
f5 = X_train_teacher_prefix_ohe
f6 = np.array(X_train_price_normalized).reshape(-1,1)
f7 = np.array(X_train_normal_previous_project).reshape(-1,1)

X_train_dt = hstack((f1,f2,f3,f4,f5,f6,f7,X_train_essay_bow,X_train_title_bow))
X_train_dt.shape
```

Out[66]:

```
(76473, 9979)
```

In [67]:

```
f1 = X_test_school_state_ohe
f2 = X_test_category_ohe
f3 = X_test_subcategory_ohe
f4 = X_test_grade_category_ohe
f5 = X_test_teacher_prefix_ohe
f6 = np.array(X_test_price_normalized).reshape(-1,1)
f7 = np.array(X_test_normal_previous_project).reshape(-1,1)

X_test_dt = hstack((f1,f2,f3,f4,f5,f6,f7,X_test_essay_bow,X_test_title_bow))
X_test_dt.shape
```

Out[67]:

```
(32775, 9979)
```

Hyperparameter Tuning: Lambda

In [82]:

```
tune_parameters = {'max_depth':[5, 10,20,30,50,80], 'min_samples_split': [5, 10, 10

#Using GridSearchCV
model = GridSearchCV(DecisionTreeClassifier(class_weight='balanced'), tune_paramete
model.fit(X_train_dt, Y_train)
```

```
Fitting 3 folds for each of 24 candidates, totalling 72 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent wo
rkers.
[Parallel(n_jobs=-1)]: Done  18 tasks      | elapsed:   15.6s
[Parallel(n_jobs=-1)]: Done  72 out of  72 | elapsed:  4.1min finished
```

Out[82]:

```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=DecisionTreeClassifier(class_weight='balanced', crite
rion='gini',
            max_depth=None, max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=
None,
            splitter='best'),
       fit_params=None, iid='warn', n_jobs=-1,
       param_grid={'max_depth': [5, 10, 20, 30, 50, 80], 'min_samples_
split': [5, 10, 100, 500]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
       scoring='roc_auc', verbose=True)
```

In [70]:

```
def train_cv_scores_for_params(model):
    results = pd.DataFrame.from_dict(model.cv_results_)
    max_depths = []
    min_samples = []
    mean_cv_scores = []
    mean_train_scores = []
    for p in zip(results['params'], results['mean_test_score'], results['mean_train
        param_dict, score_test, score_train = p
        max_depth,min_sample = param_dict.values()
        max_depths.append(max_depth)
        min_samples.append(min_sample)
        mean_cv_scores.append(score_test)
        mean_train_scores.append(score_train)
    return max_depths, min_samples, mean_train_scores, mean_cv_scores
```

In [84]:

```
max_depths,min_samples,mean_train_scores, mean_cv_scores = train_cv_scores_for_para
df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_train_scor
pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_train_sc
```

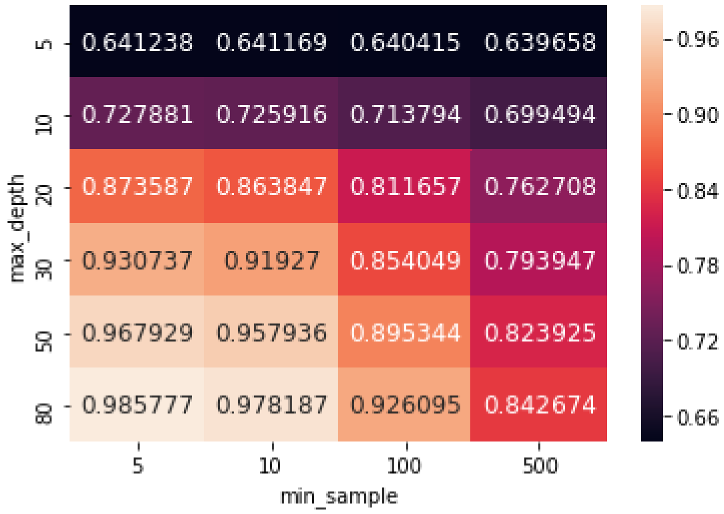
Heatmap for train data

In [85]:

```
sns.heatmap(pivot,annot=True, annot_kws={"size": 12}, fmt='g')
```

Out[85]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f1bed61d048>
```



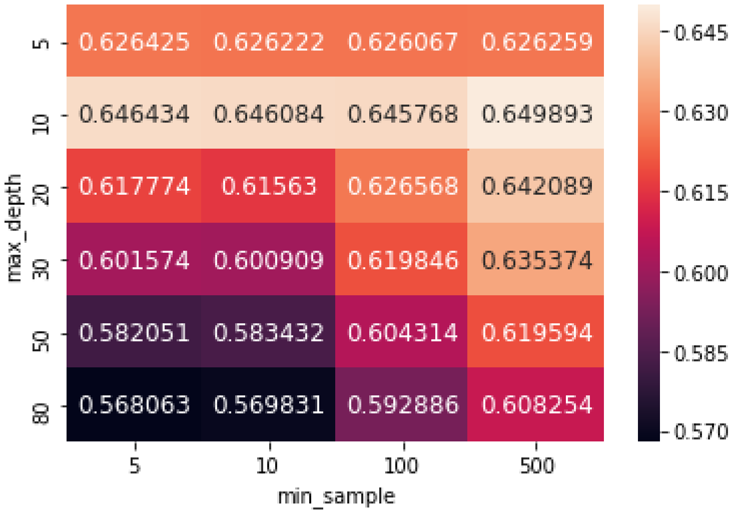
Heatmap for CV

In [86]:

```
df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_cv_score':
pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_cv_score
sns.heatmap(pivot,annot=True, annot_kws={"size": 12}, fmt='g')
```

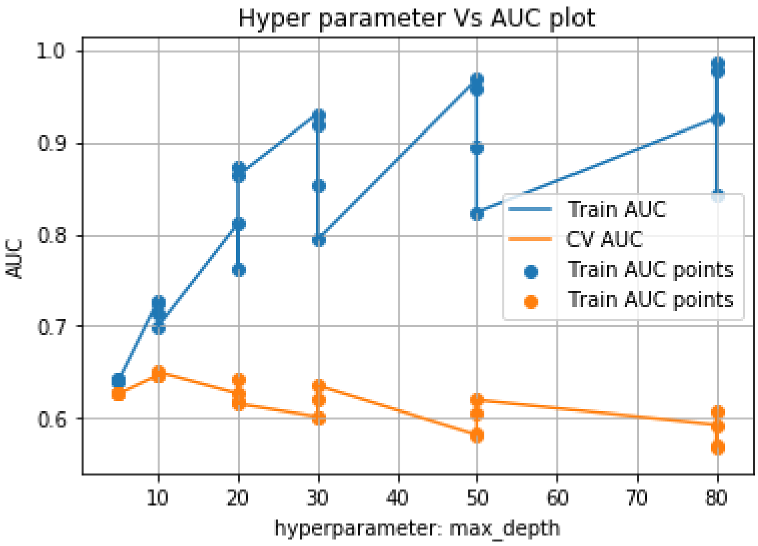
Out[86]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f1bfc13f9e8>
```



In [87]:

```
auc_df_train = pd.DataFrame({'max_depth':max_depths,'train_auc':mean_train_scores})
auc_df_train = auc_df_train.sort_values(by='max_depth')

auc_df_cv = pd.DataFrame({'max_depth':max_depths,'cv_auc':mean_cv_scores})
auc_df_cv = auc_df_cv.sort_values(by='max_depth')

plt.plot(auc_df_train['max_depth'], auc_df_train['train_auc'], label='Train AUC')
plt.plot(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='CV AUC')

plt.scatter(auc_df_train['max_depth'], auc_df_train['train_auc'], label='Train AUC
plt.scatter(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='Train AUC points')


plt.legend()
plt.xlabel("hyperparameter: max_depth")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [88]:

```
model.best_estimator_
```

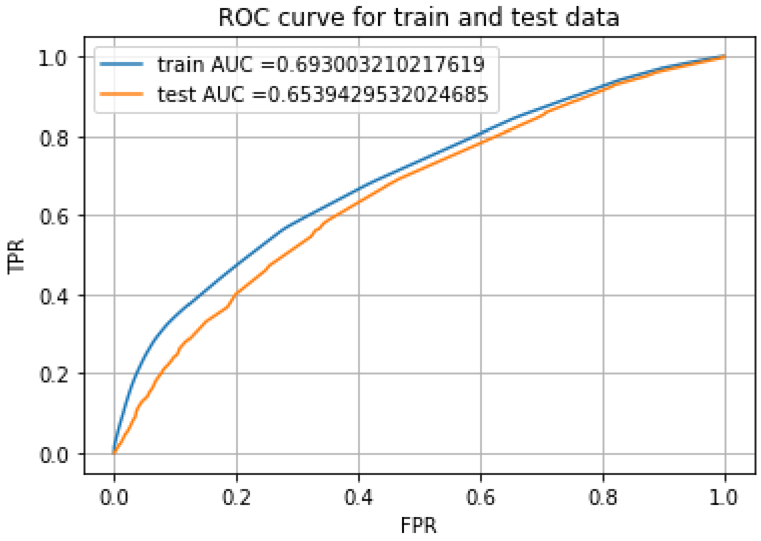
Out[88]:

```
DecisionTreeClassifier(class_weight='balanced', criterion='gini',
            max_depth=10, max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=500,
            min_weight_fraction_leaf=0.0, presort=False, random_state=
None,
            splitter='best')
```

Training the model on optimal value of parameters: max_depth=10 and min_samples_split=500

In [89]:

```
dt_bow = model.best_estimator_#DecisionTreeClassifier(class_weight='balanced',max_d
dt_bow.fit(X_train_dt,Y_train)

y_train_pred = dt_bow.predict_proba(X_train_dt)
y_test_pred = dt_bow.predict_proba(X_test_dt)

# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates
# not the predicted outputs
train_fpr, train_tpr, tr_thresholds = roc_curve(Y_train, y_train_pred[:,1])
test_fpr, test_tpr, te_thresholds = roc_curve(Y_test, y_test_pred[:,1])

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("FPR")
plt.ylabel("TPR")
plt.title("ROC curve for train and test data")
plt.grid()
plt.show()
```



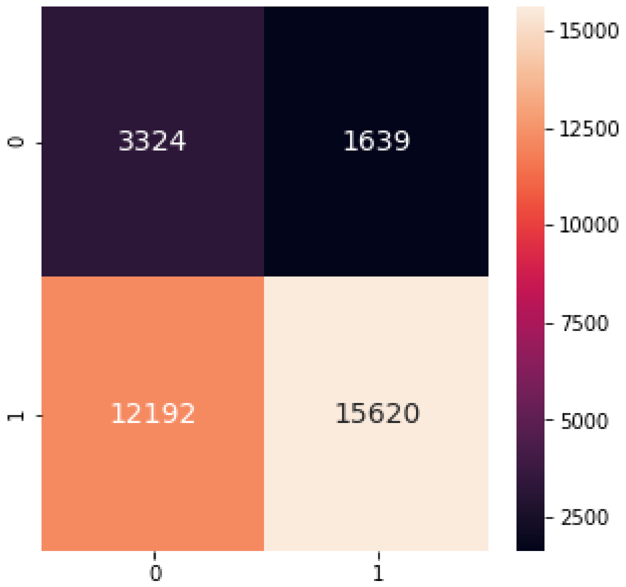
Confusion Matrix

In [90]:

```
y_test_predict = dt_bow.predict(X_test_dt)

results = confusion_matrix(Y_test, y_test_predict)
plt.figure(figsize = (5,5))
sns.heatmap(results, annot=True,annot_kws={"size": 14}, fmt='g')
```

Out[90]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f1bd8b3ccf8>
```



Analysis of False Positive Data points

In [91]:

```
from wordcloud import WordCloud
```

In [92]:

```
fp_df = X_test.reset_index(drop=True)
fp_df['y'] = Y_test.values
fp_df['y_hat'] = y_test_predict
fp_df = fp_df.loc[(fp_df['y']==0) & (fp_df['y_hat']==1)]
```

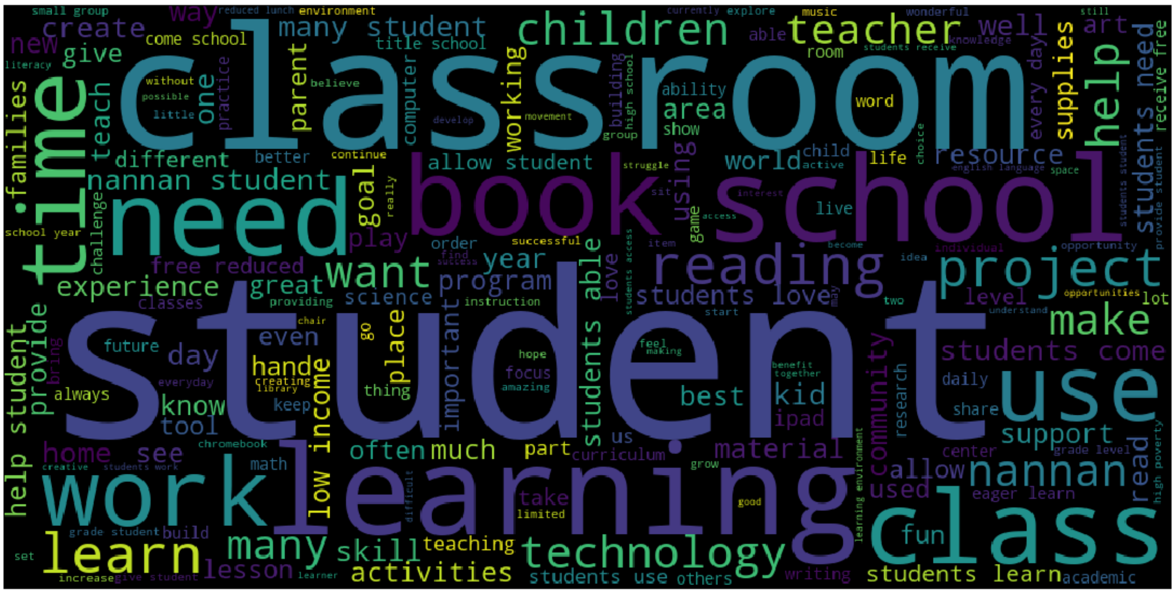
In [93]:

```
fp_bow_essays = fp_df['clean_essay'].values
```

Creating a word cloud of essays

In [94]:

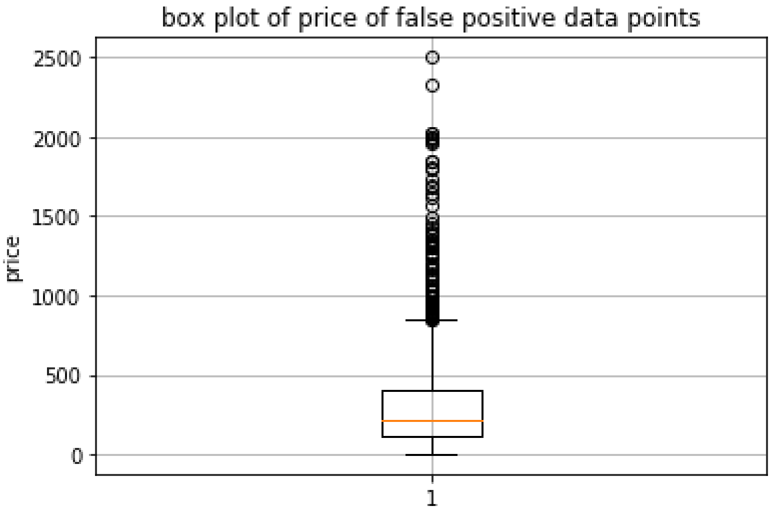
```
unique_string=(" ").join(fp_bow_essays)
wordcloud = WordCloud(width = 1000, height = 500).generate(unique_string)
plt.figure(figsize=(25,10))
plt.imshow(wordcloud)
plt.axis("off")
plt.show()
plt.close()
```



Boxplot of price

In [95]:

```
fp_prices_bow = fp_df['price']
plt.boxplot(fp_prices_bow)
plt.grid()
plt.ylabel("price")
plt.title("box plot of price of false positive data points")
plt.show()
```



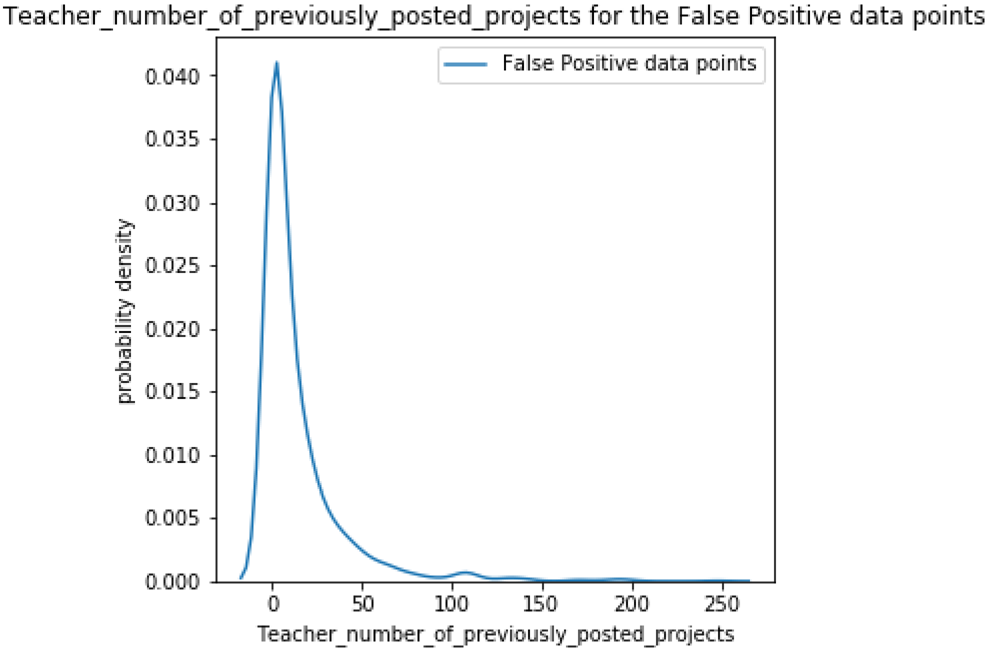
Conclusion

- Most of the project which were actually rejected but predicted as positive have price less tha $500.
- Only a very few rejected projects have very high price.

PDF of previous projects

In [96]:

```
plt.figure(figsize=(5,5))
sns.distplot(fp_df['teacher_number_of_previously_posted_projects'].values, hist=Fal
plt.title('Teacher_number_of_previously_posted_projects for the False Positive data
plt.xlabel('Teacher_number_of_previously_posted_projects')
plt.ylabel('probability density')
plt.legend()
plt.show()
```



Conclusion:

- The previously posted projects between 0-25 have maximum probability of being classified as false positive.

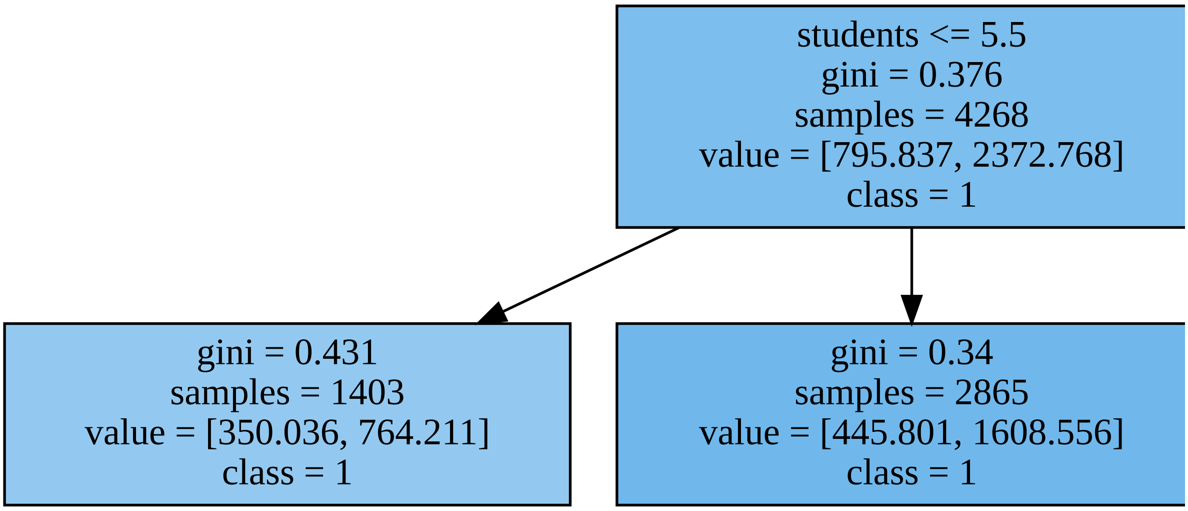
2.4.1.1 Graphviz visualization of Decision Tree on BOW, SET 1

In [97]:

```
bow_feature_names = []
for name in vectorizer_state.get_feature_names():
    bow_feature_names.append(name)
for name in vectorizer_category.get_feature_names():
    bow_feature_names.append(name)
for name in vectorizer_subcategory.get_feature_names():
    bow_feature_names.append(name)
for name in vectorizer_grade.get_feature_names():
    bow_feature_names.append(name)
for name in vectorizer_teacher_prefix.get_feature_names():
    bow_feature_names.append(name)
bow_feature_names.append("price")
bow_feature_names.append("teacher_number_of_previous_project")

for name in vectorizer_essay_bow.get_feature_names():
    bow_feature_names.append(name)
for name in vectorizer_title_bow.get_feature_names():
    bow_feature_names.append(name)
```

In [98]:

```
dt_bow_viz = DecisionTreeClassifier(class_weight='balanced',max_depth=3,min_samples
dt_bow_viz.fit(X_train_dt,Y_train)
graph = Source(tree.export_graphviz(dt_bow_viz, out_file=None
   , feature_names=bow_feature_names, class_names=['0', '1']
   , filled = True))
display(SVG(graph.pipe(format='svg')))
```



In [99]:

```
# from IPython.display import Image
# graph = tree.export_graphviz(dt_bow, out_file=None
#    , feature_names=bow_feature_names, class_names=['0', '1']
#    , filled = True)
# # Draw graph
# graph = pydotplus.graph_from_dot_data(dot_data)
# # Show graph
# Image(graph.create_png())
# # Create PNG
# graph.write_png("DT_BOW.png")
```

2.4.2 SET 2 : TFIDF

In [81]:

```
f1 = X_train_school_state_ohe
f2 = X_train_category_ohe
f3 = X_train_subcategory_ohe
f4 = X_train_grade_category_ohe
f5 = X_train_teacher_prefix_ohe
f6 = np.array(X_train_price_normalized).reshape(-1,1)
f7 = np.array(X_train_normal_previous_project).reshape(-1,1)

X_train_tfidf = hstack((f1,f2,f3,f4,f5,f6,f7,X_train_essay_tfidf,X_train_title_tfid
X_train_tfidf.shape
```

Out[81]:

```
(76473, 9966)
```

In [82]:

```
f1 = X_test_school_state_ohe
f2 = X_test_category_ohe
f3 = X_test_subcategory_ohe
f4 = X_test_grade_category_ohe
f5 = X_test_teacher_prefix_ohe
f6 = X_test_price_normalized.reshape(-1,1)
f7 = X_test_normal_previous_project.reshape(-1,1)

X_test_tfidf = hstack((f1,f2,f3,f4,f5,f6,f7,X_test_essay_tfidf,X_test_title_tfidf))
X_test_tfidf.shape
```

Out[82]:

```
(32775, 9966)
```

Hyperparameter Tuning: Lambda

In [68]:

```
tune_parameters = {'max_depth':[1, 5, 10, 50, 100, 500, 1000], 'min_samples_split':

#Using GridSearchCV
model = GridSearchCV(DecisionTreeClassifier(class_weight='balanced'), tune_paramete
model.fit(X_train_tfidf, Y_train)
```

```
Fitting 3 folds for each of 28 candidates, totalling 84 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent wo
rkers.
[Parallel(n_jobs=-1)]: Done  18 tasks      | elapsed:   14.2s
[Parallel(n_jobs=-1)]: Done  84 out of  84 | elapsed:  7.8min finished
```

Out[68]:

```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=DecisionTreeClassifier(class_weight='balanced', crite
rion='gini',
            max_depth=None, max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=
None,
            splitter='best'),
       fit_params=None, iid='warn', n_jobs=-1,
       param_grid={'max_depth': [1, 5, 10, 50, 100, 500, 1000], 'min_s
amples_split': [5, 10, 100, 500]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
       scoring='roc_auc', verbose=True)
```

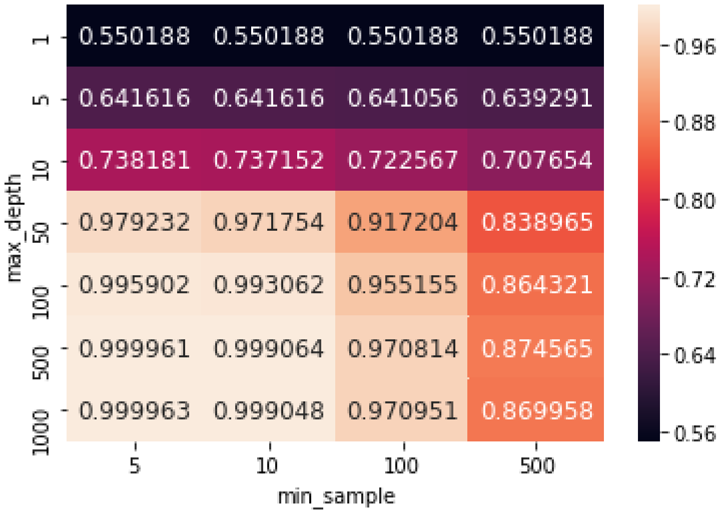
Heatmap for train data

In [71]:

```
max_depths,min_samples,mean_train_scores, mean_cv_scores = train_cv_scores_for_para
df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_train_scor
pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_train_sc
sns.heatmap(pivot,annot=True, annot_kws={"size": 12}, fmt='g')
```

Out[71]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f1a9183feb8>
```



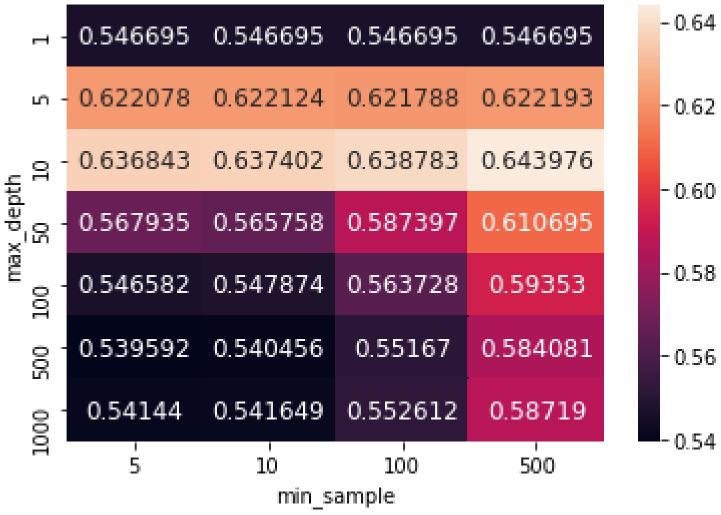
Heatmap for CV data

In [72]:

```
df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_cv_score':
pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_cv_score
sns.heatmap(pivot,annot=True, annot_kws={"size": 12}, fmt='g')
```

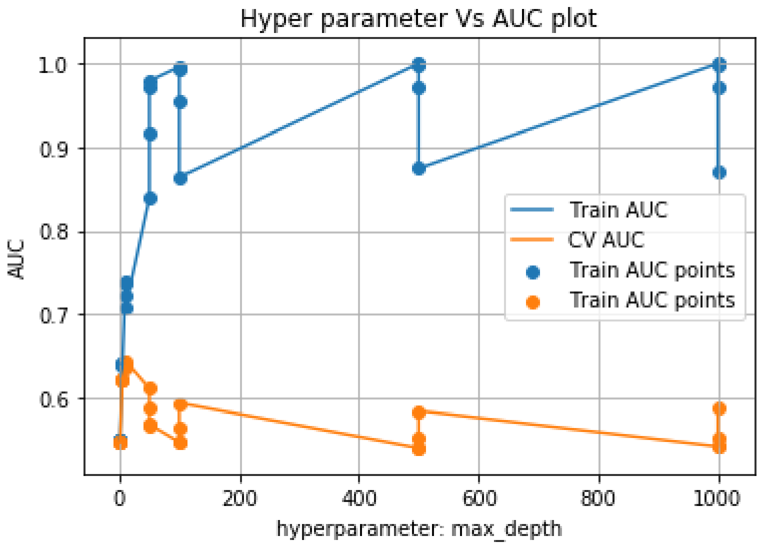
Out[72]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f1acfba0588>
```



In [73]:

```
auc_df_train = pd.DataFrame({'max_depth':max_depths,'train_auc':mean_train_scores})
auc_df_train = auc_df_train.sort_values(by='max_depth')

auc_df_cv = pd.DataFrame({'max_depth':max_depths,'cv_auc':mean_cv_scores})
auc_df_cv = auc_df_cv.sort_values(by='max_depth')

plt.plot(auc_df_train['max_depth'], auc_df_train['train_auc'], label='Train AUC')
plt.plot(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='CV AUC')

plt.scatter(auc_df_train['max_depth'], auc_df_train['train_auc'], label='Train AUC
plt.scatter(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='Train AUC points')


plt.legend()
plt.xlabel("hyperparameter: max_depth")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [74]:

```
model.best_estimator_
```

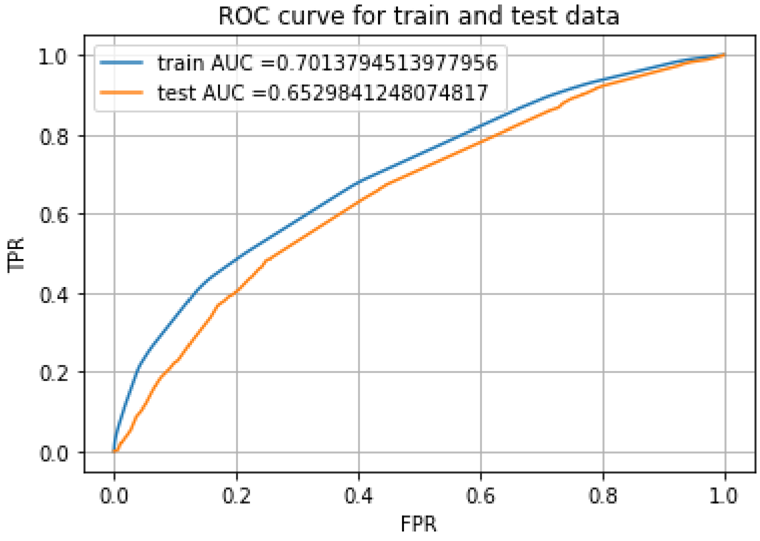
Out[74]:

```
DecisionTreeClassifier(class_weight='balanced', criterion='gini',
            max_depth=10, max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=500,
            min_weight_fraction_leaf=0.0, presort=False, random_state=
None,
            splitter='best')
```

Training the model on the most optimal value of max_depth=10,min_samples_split=500

In [75]:

```
dt_tfidf = model.best_estimator_#DecisionTreeClassifier(class_weight='balanced',max
dt_tfidf.fit(X_train_tfidf,Y_train)

y_train_pred = dt_tfidf.predict_proba(X_train_tfidf)
y_test_pred = dt_tfidf.predict_proba(X_test_tfidf)

# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates
# not the predicted outputs
train_fpr, train_tpr, tr_thresholds = roc_curve(Y_train, y_train_pred[:,1])
test_fpr, test_tpr, te_thresholds = roc_curve(Y_test, y_test_pred[:,1])

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("FPR")
plt.ylabel("TPR")
plt.title("ROC curve for train and test data")
plt.grid()
plt.show()
```



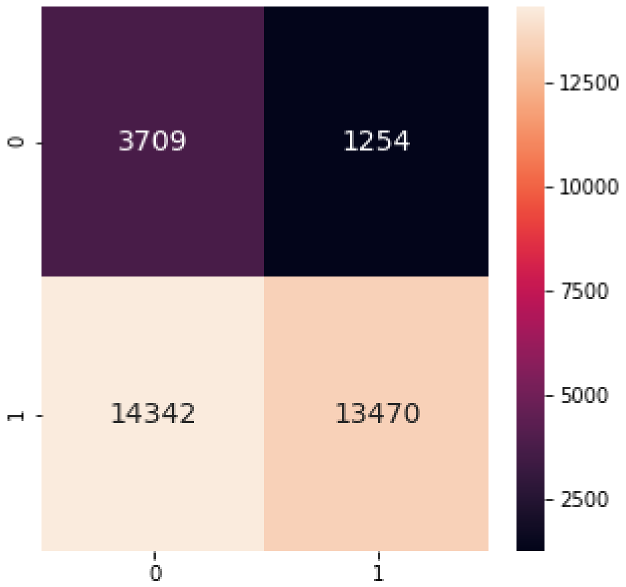
Confusion Matrix

In [76]:

```
y_test_predict = dt_tfidf.predict(X_test_tfidf)

results = confusion_matrix(Y_test, y_test_predict)
plt.figure(figsize = (5,5))
sns.heatmap(results, annot=True,annot_kws={"size": 14}, fmt='g')
```

Out[76]:

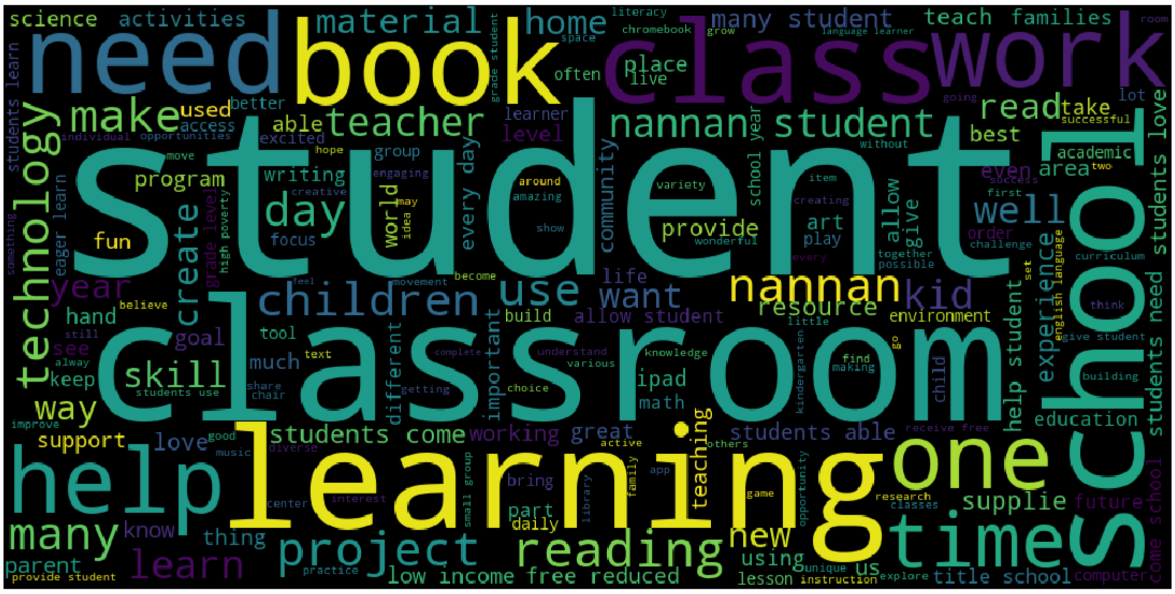
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f1a9d82ae48>
```



Analysis of False Positive

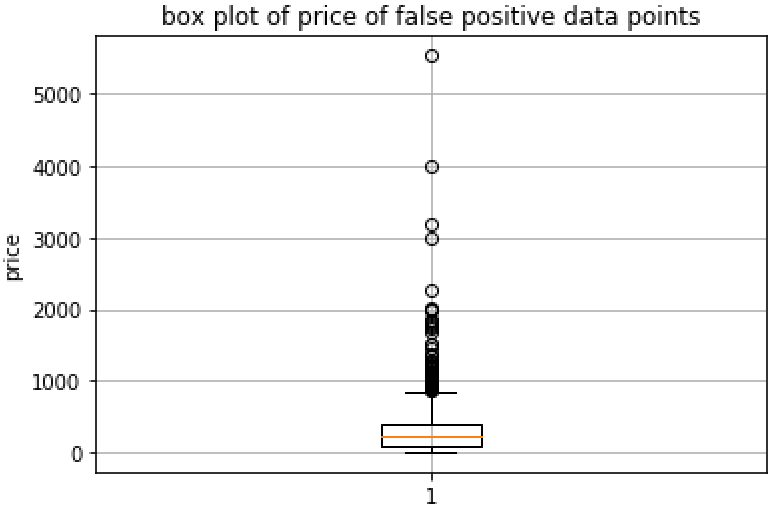
In [79]:

```
fp_df_tfidf = X_test.reset_index(drop=True)
fp_df_tfidf['y'] = Y_test.values
fp_df_tfidf['y_hat'] = y_test_predict
fp_df_tfidf = fp_df_tfidf.loc[(fp_df_tfidf['y']==0) & (fp_df_tfidf['y_hat']==1)]

unique_string=(" ").join(fp_df_tfidf['clean_essay'].values)
wordcloud = WordCloud(width = 1000, height = 500).generate(unique_string)
plt.figure(figsize=(25,10))
plt.imshow(wordcloud)
plt.axis("off")
plt.show()
plt.close()
```



In [80]:

```
plt.boxplot(fp_df_tfidf['price'])
plt.grid()
plt.ylabel("price")
plt.title("box plot of price of false positive data points")
plt.show()
```

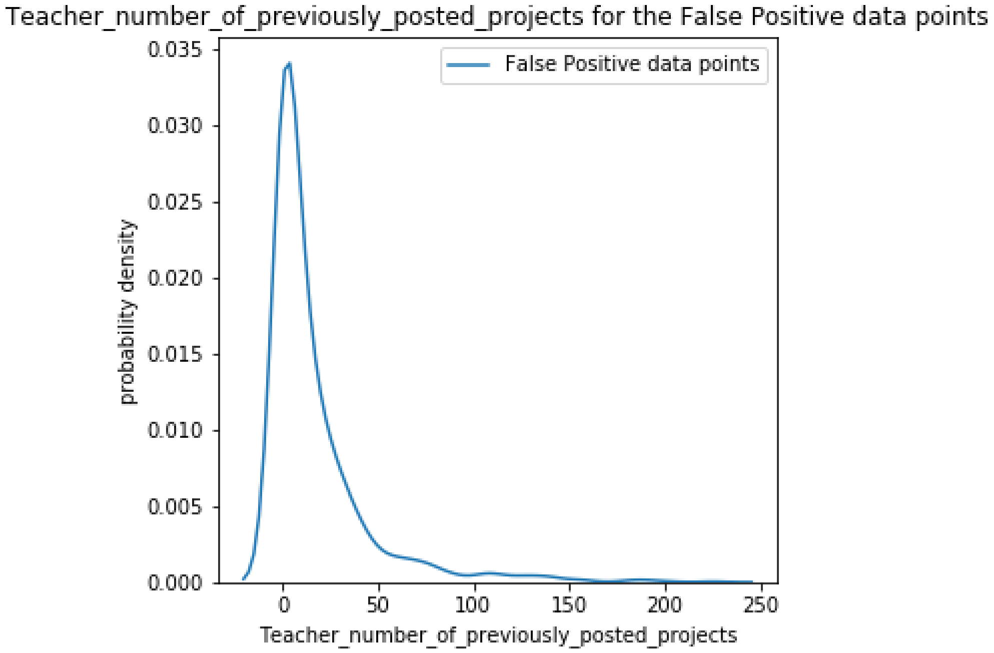


Conclusion:

- Box plot of false positive price of bow and tfidf are almost identical.

In [81]:

```
plt.figure(figsize=(5,5))
sns.distplot(fp_df_tfidf['teacher_number_of_previously_posted_projects'].values, hi
plt.title('Teacher_number_of_previously_posted_projects for the False Positive data
plt.xlabel('Teacher_number_of_previously_posted_projects')
plt.ylabel('probability density')
plt.legend()
plt.show()
```



Conclusion:

- This distribution is similar to BOW and most false positive previously posted project lie between 0-25.

2.4.2.1 Graphviz visualization of Decision Tree on TFIDF, SET 2

In [82]:

```
tfidf_feature_names = []
for name in vectorizer_state.get_feature_names():
    tfidf_feature_names.append(name)
for name in vectorizer_category.get_feature_names():
    tfidf_feature_names.append(name)
for name in vectorizer_subcategory.get_feature_names():
    tfidf_feature_names.append(name)
for name in vectorizer_grade.get_feature_names():
    tfidf_feature_names.append(name)
for name in vectorizer_teacher_prefix.get_feature_names():
    tfidf_feature_names.append(name)
tfidf_feature_names.append("price")
tfidf_feature_names.append("teacher_number_of_previous_project")

for name in vectorizer_essay_tfidf.get_feature_names():
    tfidf_feature_names.append(name)
for name in vectorizer_title_tfidf.get_feature_names():
    tfidf_feature_names.append(name)

dt_tfidf_viz = DecisionTreeClassifier(class_weight='balanced',max_depth=3,min_sampl
dt_tfidf_viz.fit(X_train_tfidf,Y_train)
graph = Source(tree.export_graphviz(dt_tfidf_viz, out_file=None
   , feature_names=tfidf_feature_names, class_names=['0', '1']
   , filled = True))
display(SVG(graph.pipe(format='svg')))
```

2.4.3 SET 3 : W2Vec

In [83]:

```
f1 = X_train_school_state_ohe
f2 = X_train_category_ohe
f3 = X_train_subcategory_ohe
f4 = X_train_grade_category_ohe
f5 = X_train_teacher_prefix_ohe
f6 = np.array(X_train_price_normalized).reshape(-1,1)
f7 = np.array(X_train_normal_previous_project).reshape(-1,1)

X_train_w2v = hstack((f1,f2,f3,f4,f5,f6,f7,X_train_essay_avg_w2v_vectors,X_train_ti
X_train_w2v.shape
```

Out[83]:

```
(76473, 701)
```

In [84]:

```
f1 = X_test_school_state_ohe
f2 = X_test_category_ohe
f3 = X_test_subcategory_ohe
f4 = X_test_grade_category_ohe
f5 = X_test_teacher_prefix_ohe
f6 = X_test_price_normalized.reshape(-1,1)
f7 = X_test_normal_previous_project.reshape(-1,1)

X_test_w2v = hstack((f1,f2,f3,f4,f5,f6,f7,X_test_essay_avg_w2v_vectors,X_test_title
X_test_w2v.shape
```

Out[84]:

```
(32775, 701)
```

Hyperparameter Tuning: Lambda

In [85]:

```
tune_parameters = {'max_depth':[5, 10,20,30,50,80], 'min_samples_split': [5, 10, 10

#Using GridSearchCV
model = GridSearchCV(DecisionTreeClassifier(class_weight='balanced'), tune_paramete
model.fit(X_train_w2v, Y_train)
```

```
Fitting 3 folds for each of 24 candidates, totalling 72 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent wo
rkers.
[Parallel(n_jobs=-1)]: Done  18 tasks      | elapsed:  2.3min
[Parallel(n_jobs=-1)]: Done  72 out of  72 | elapsed: 14.4min finished
```

Out[85]:

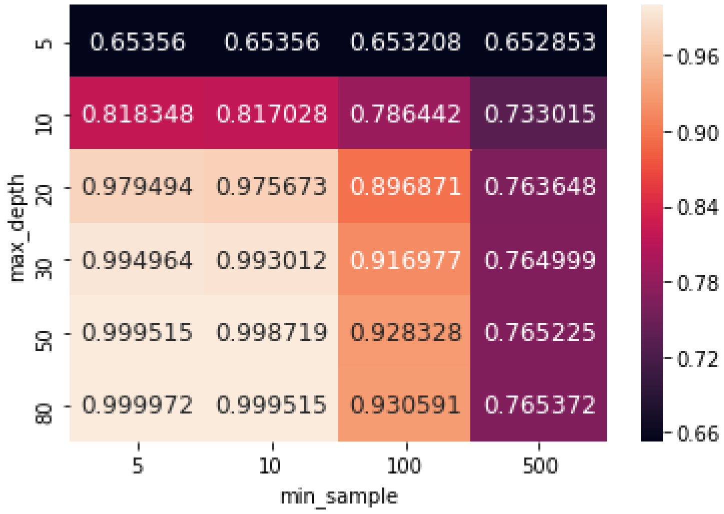
```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=DecisionTreeClassifier(class_weight='balanced', crite
rion='gini',
            max_depth=None, max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=
None,
            splitter='best'),
       fit_params=None, iid='warn', n_jobs=-1,
       param_grid={'max_depth': [5, 10, 20, 30, 50, 80], 'min_samples_
split': [5, 10, 100, 500]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
       scoring='roc_auc', verbose=True)
```

In [90]:

```
# results = pd.DataFrame.from_dict(model.cv_results_)
# max_depths = []
# min_samples = []
# mean_cv_scores = []
# mean_train_scores = []
# for p in zip(results['params'], results['mean_test_score'], results['mean_train_s
#     param_dict, score_test, score_train = p
#     max_depth,min_sample = param_dict.values()
#     max_depths.append(max_depth)
#     min_samples.append(min_sample)
#     mean_cv_scores.append(score_test)
#     mean_train_scores.append(score_train)
max_depths,min_samples,mean_train_scores, mean_cv_scores = train_cv_scores_for_para
df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_train_scor
pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_train_sc
sns.heatmap(pivot,annot=True, annot_kws={"size": 12}, fmt='g')
# df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_test_sco
# pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_test_s
# sns.heatmap(pivot,annot=True, annot_kws={"size": 12}, fmt='g')
```

Out[90]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f1a7a4c5e10>
```



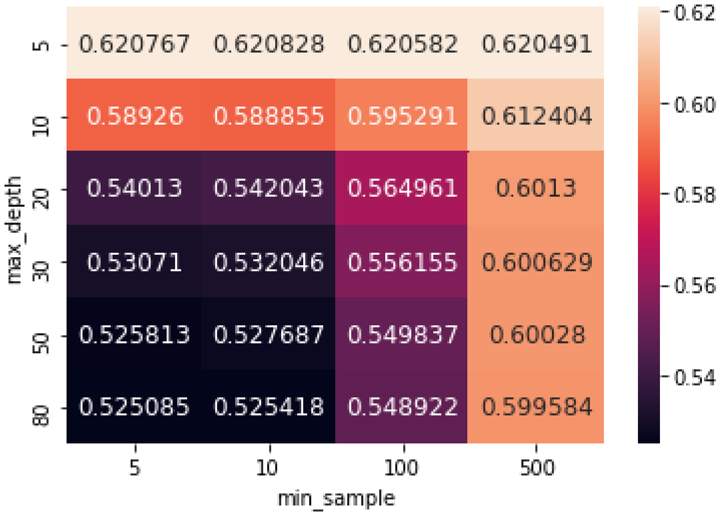
Heatmap for CV data

In [93]:

```
df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_cv_score':
pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_cv_score
sns.heatmap(pivot,annot=True, annot_kws={"size": 12}, fmt='g')
```

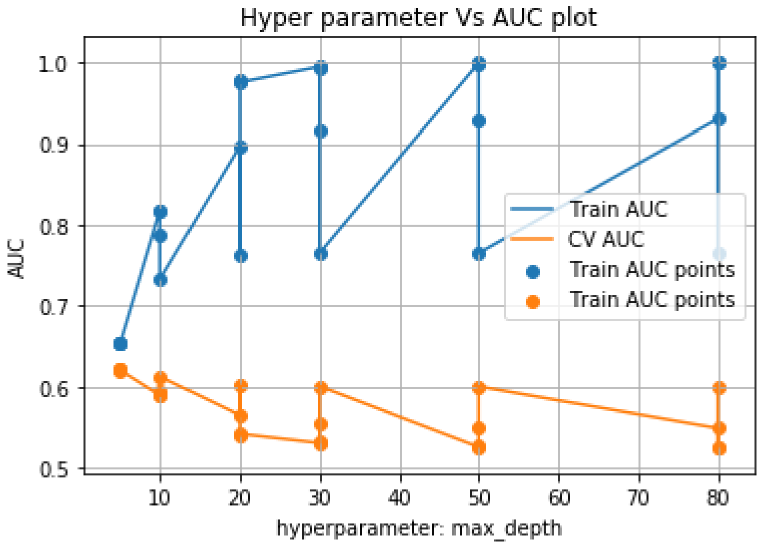
Out[93]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f1a7ecb7eb8>
```



In [94]:

```
auc_df_train = pd.DataFrame({'max_depth':max_depths,'train_auc':mean_train_scores})
auc_df_train = auc_df_train.sort_values(by='max_depth')

auc_df_cv = pd.DataFrame({'max_depth':max_depths,'cv_auc':mean_cv_scores})
auc_df_cv = auc_df_cv.sort_values(by='max_depth')

plt.plot(auc_df_train['max_depth'], auc_df_train['train_auc'], label='Train AUC')
plt.plot(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='CV AUC')

plt.scatter(auc_df_train['max_depth'], auc_df_train['train_auc'], label='Train AUC
plt.scatter(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='Train AUC points')


plt.legend()
plt.xlabel("hyperparameter: max_depth")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()

results.head()
```



Out[94]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_max_depth	param_min
0	44.414473	0.149486	0.835894	0.002347	5	
1	44.768874	0.231216	0.838921	0.010560	5	
2	44.519095	0.192071	0.843066	0.004895	5	
3	44.836103	0.162105	0.823846	0.018824	5	
4	117.172003	1.179970	0.835241	0.035803	10	

In [95]:

```
model.best_estimator_
```

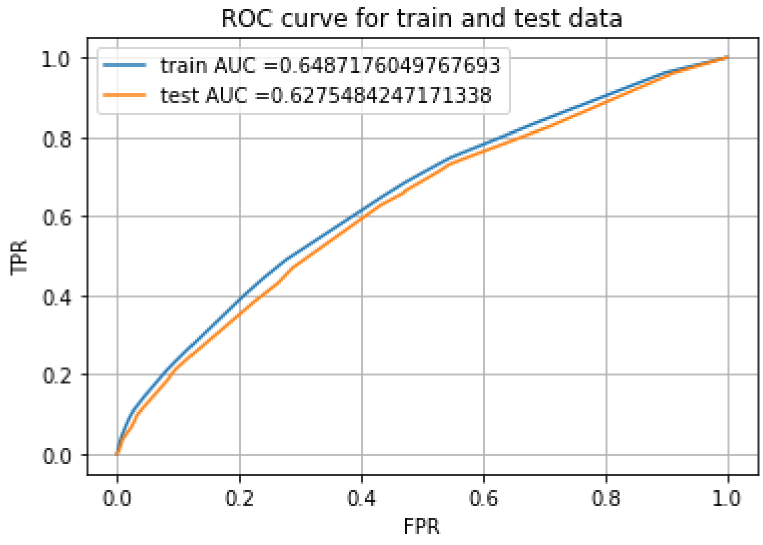
Out[95]:

```
DecisionTreeClassifier(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=1, min_samples_split=10,
            min_weight_fraction_leaf=0.0, presort=False, random_state=
None,
            splitter='best')
```

Training model on the optimal hyperparameters: max_depth=5,min_samples_split=10

In [96]:

```
dt_w2v = model.best_estimator_#DecisionTreeClassifier(class_weight='balanced',max_d
dt_w2v.fit(X_train_w2v,Y_train)

y_train_pred = dt_w2v.predict_proba(X_train_w2v)
y_test_pred = dt_w2v.predict_proba(X_test_w2v)

# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates
# not the predicted outputs
train_fpr, train_tpr, tr_thresholds = roc_curve(Y_train, y_train_pred[:,1])
test_fpr, test_tpr, te_thresholds = roc_curve(Y_test, y_test_pred[:,1])

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("FPR")
plt.ylabel("TPR")
plt.title("ROC curve for train and test data")
plt.grid()
plt.show()
```



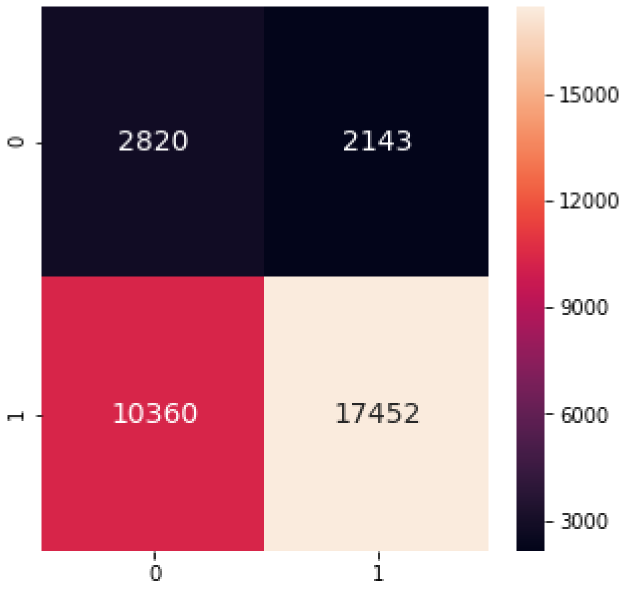
Confusion Matrix

In [98]:

```
y_test_predict = dt_w2v.predict(X_test_w2v)

results = confusion_matrix(Y_test, y_test_predict)
plt.figure(figsize = (5,5))
sns.heatmap(results, annot=True,annot_kws={"size": 14}, fmt='g')
```

Out[98]:

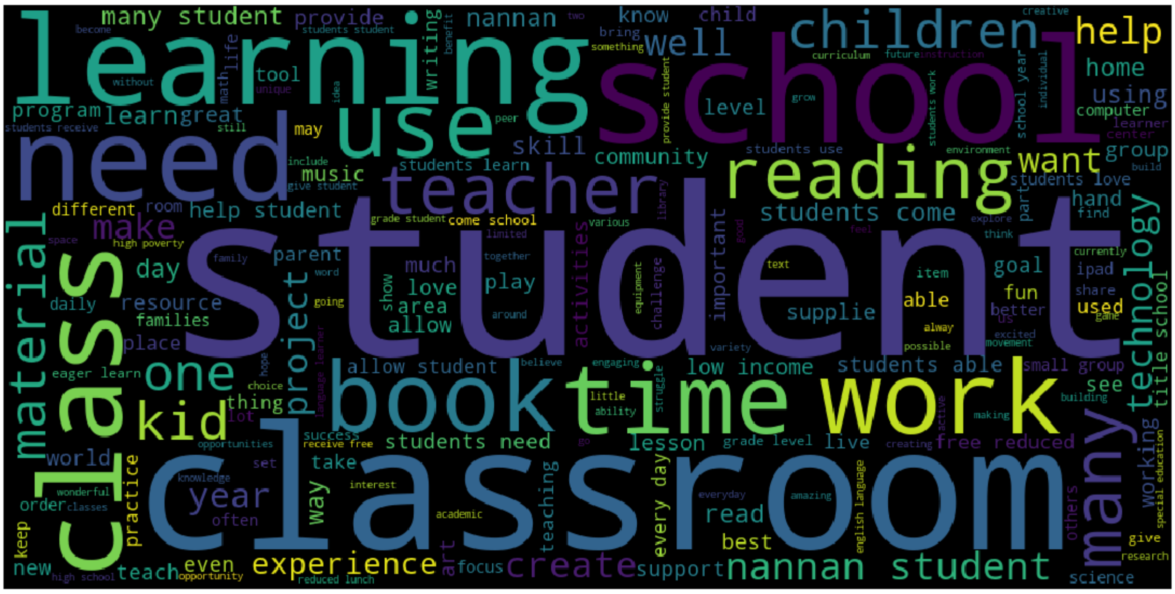
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f1a8af3c048>
```



Analysis of False Positive

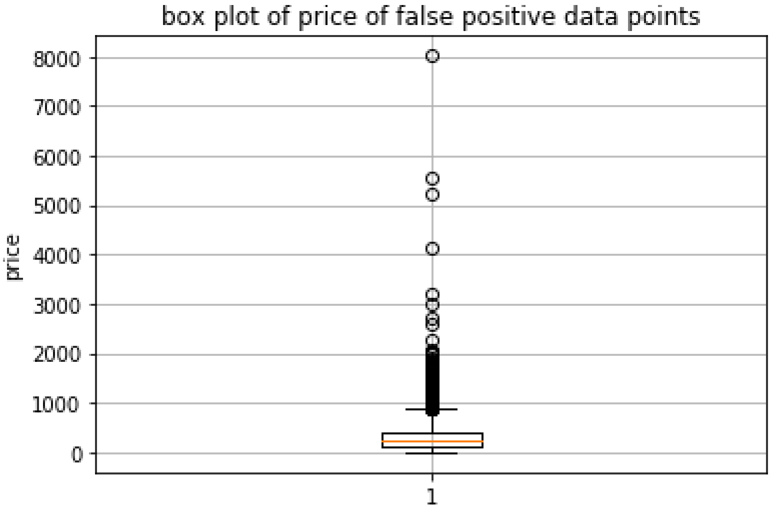
In [99]:

```
fp_df_w2v = X_test.reset_index(drop=True)
fp_df_w2v['y'] = Y_test.values
fp_df_w2v['y_hat'] = y_test_predict
fp_df_w2v = fp_df_w2v.loc[(fp_df_w2v['y']==0) & (fp_df_w2v['y_hat']==1)]

unique_string=(" ").join(fp_df_w2v['clean_essay'].values)
wordcloud = WordCloud(width = 1000, height = 500).generate(unique_string)
plt.figure(figsize=(25,10))
plt.imshow(wordcloud)
plt.axis("off")
plt.show()
plt.close()
```



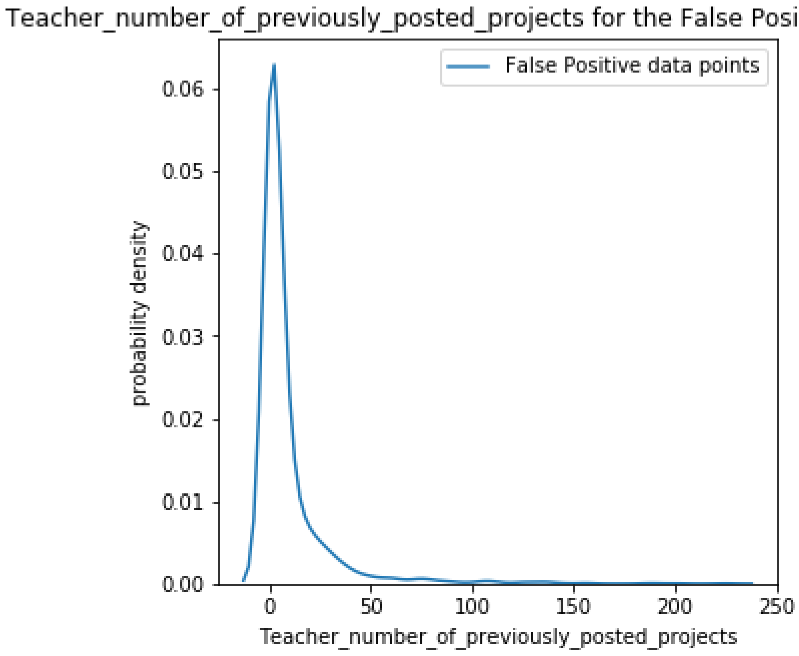
In [100]:

```
plt.boxplot(fp_df_w2v['price'])
plt.grid()
plt.ylabel("price")
plt.title("box plot of price of false positive data points")
plt.show()
```



In [101]:

```
plt.figure(figsize=(5,5))
sns.distplot(fp_df_w2v['teacher_number_of_previously_posted_projects'].values, hist
plt.title('Teacher_number_of_previously_posted_projects for the False Positive data
plt.xlabel('Teacher_number_of_previously_posted_projects')
plt.ylabel('probability density')
plt.legend()
plt.show()
```



Conclusion:

- The pdf of previous projects and box plot of price are similar to the ones obtained in BOW and TFIDF vectorization.

2.4.4 SET 4 : TFIDF-weighted W2Vec

In [66]:

```
f1 = X_train_school_state_ohe
f2 = X_train_category_ohe
f3 = X_train_subcategory_ohe
f4 = X_train_grade_category_ohe
f5 = X_train_teacher_prefix_ohe
f6 = np.array(X_train_price_normalized).reshape(-1,1)
f7 = np.array(X_train_normal_previous_project).reshape(-1,1)

X_train_tfidf_w2v = hstack((f1,f2,f3,f4,f5,f6,f7,X_train_essay_tfidf_w2v_vectors,X_
X_train_tfidf_w2v.shape
```

Out[66]:

```
(76473, 702)
```

In [67]:

```
f1 = X_test_school_state_ohe
f2 = X_test_category_ohe
f3 = X_test_subcategory_ohe
f4 = X_test_grade_category_ohe
f5 = X_test_teacher_prefix_ohe
f6 = X_test_price_normalized.reshape(-1,1)
f7 = X_test_normal_previous_project.reshape(-1,1)

X_test_tfidf_w2v = hstack((f1,f2,f3,f4,f5,f6,f7,X_test_essay_tfidf_w2v_vectors,X_te
X_test_tfidf_w2v.shape
```

Out[67]:

```
(32775, 702)
```

In [68]:

```
tune_parameters = {'max_depth':[1, 5, 10, 50, 100, 500, 1000], 'min_samples_split':

#Using GridSearchCV
model = GridSearchCV(DecisionTreeClassifier(class_weight='balanced'), tune_paramete
model.fit(X_train_tfidf_w2v, Y_train)
```

```
Fitting 3 folds for each of 28 candidates, totalling 84 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent wo
rkers.
[Parallel(n_jobs=-1)]: Done  18 tasks      | elapsed:  1.0min
[Parallel(n_jobs=-1)]: Done  84 out of  84 | elapsed: 15.3min finished
```

Out[68]:

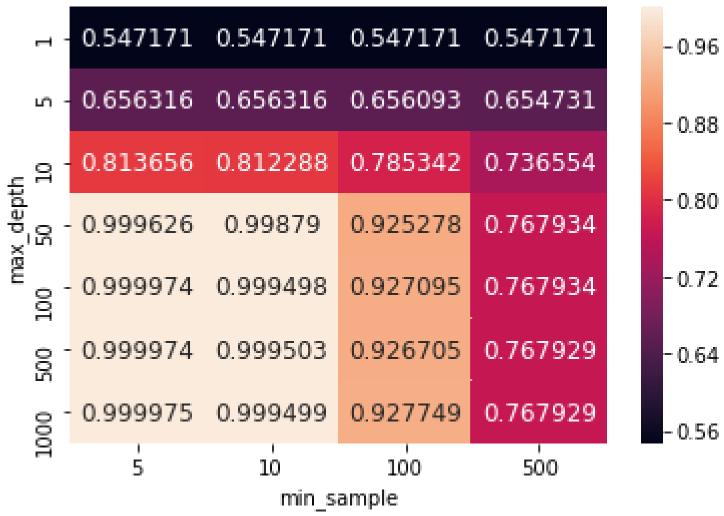
```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=DecisionTreeClassifier(class_weight='balanced', crite
rion='gini',
            max_depth=None, max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=
None,
            splitter='best'),
       fit_params=None, iid='warn', n_jobs=-1,
       param_grid={'max_depth': [1, 5, 10, 50, 100, 500, 1000], 'min_s
amples_split': [5, 10, 100, 500]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
       scoring='roc_auc', verbose=True)
```

In [71]:

```
# results = pd.DataFrame.from_dict(model.cv_results_)
# max_depths = []
# min_samples = []
# mean_cv_scores = []
# mean_train_scores = []
# for p in zip(results['params'], results['mean_test_score'], results['mean_train_s
#     param_dict, score_test, score_train = p
#     max_depth,min_sample = param_dict.values()
#     max_depths.append(max_depth)
#     min_samples.append(min_sample)
#     mean_cv_scores.append(score_test)
#     mean_train_scores.append(score_train)

max_depths,min_samples,mean_train_scores, mean_cv_scores = train_cv_scores_for_para
df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_train_scor
pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_train_sc
sns.heatmap(pivot,annot=True, annot_kws={"size": 12}, fmt='g')
```

Out[71]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fa3180bccf8>
```



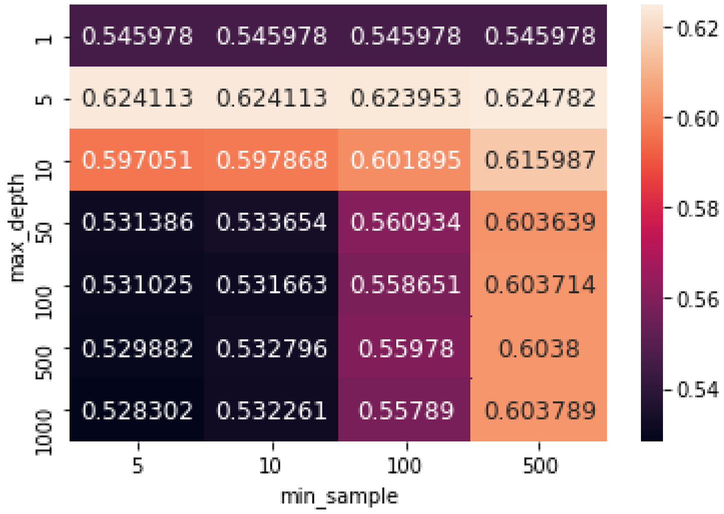
Heatmap for CV

In [72]:

```
df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_cv_score':
pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_cv_score
sns.heatmap(pivot,annot=True, annot_kws={"size": 12}, fmt='g')
```

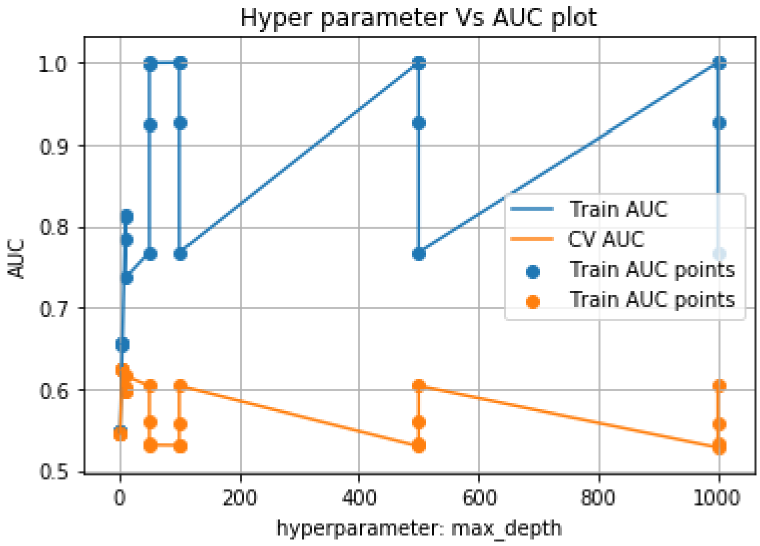
Out[72]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fa311dc0668>
```



In [80]:

```
auc_df_train = pd.DataFrame({'max_depth':max_depths,'train_auc':mean_train_scores})
auc_df_train = auc_df_train.sort_values(by='max_depth')

auc_df_cv = pd.DataFrame({'max_depth':max_depths,'cv_auc':mean_cv_scores})
auc_df_cv = auc_df_cv.sort_values(by='max_depth')

plt.plot(auc_df_train['max_depth'], auc_df_train['train_auc'], label='Train AUC')
plt.plot(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='CV AUC')

plt.scatter(auc_df_train['max_depth'], auc_df_train['train_auc'], label='Train AUC
plt.scatter(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='Train AUC points')


plt.legend()
plt.xlabel("hyperparameter: max_depth")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()

#results.head()
```



In [74]:

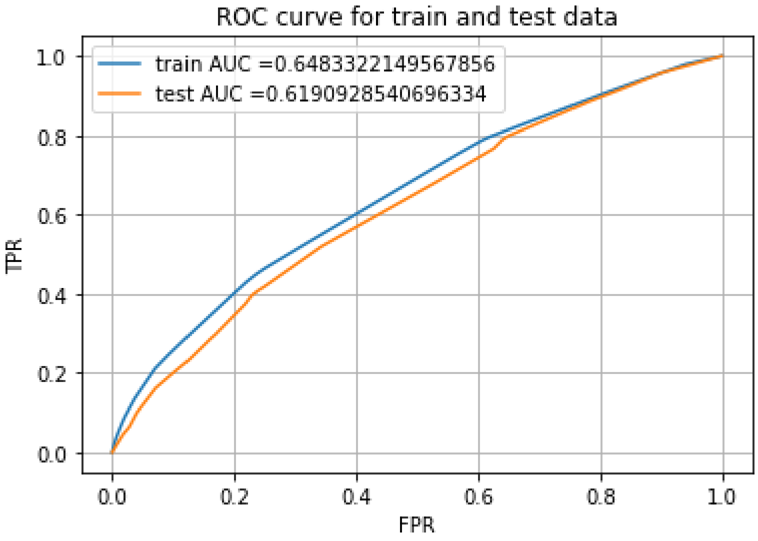
```
model.best_estimator_
```

Out[74]:

```
DecisionTreeClassifier(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=1, min_samples_split=500,
            min_weight_fraction_leaf=0.0, presort=False, random_state=
None,
            splitter='best')
```

In [75]:

```
dt_tfidf_w2v = DecisionTreeClassifier(class_weight='balanced',max_depth=5,min_sampl
dt_tfidf_w2v.fit(X_train_tfidf_w2v,Y_train)

y_train_pred = dt_tfidf_w2v.predict_proba(X_train_tfidf_w2v)
y_test_pred = dt_tfidf_w2v.predict_proba(X_test_tfidf_w2v)

# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates
# not the predicted outputs
train_fpr, train_tpr, tr_thresholds = roc_curve(Y_train, y_train_pred[:,1])
test_fpr, test_tpr, te_thresholds = roc_curve(Y_test, y_test_pred[:,1])

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("FPR")
plt.ylabel("TPR")
plt.title("ROC curve for train and test data")
plt.grid()
plt.show()
```



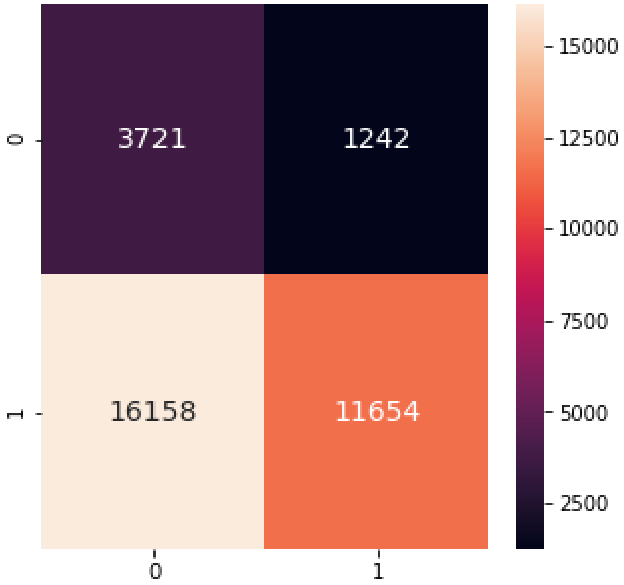
Confusion Matrix

In [76]:

```
y_test_predict = dt_tfidf_w2v.predict(X_test_tfidf_w2v)

results = confusion_matrix(Y_test, y_test_predict)
plt.figure(figsize = (5,5))
sns.heatmap(results, annot=True,annot_kws={"size": 14}, fmt='g')
```

Out[76]:

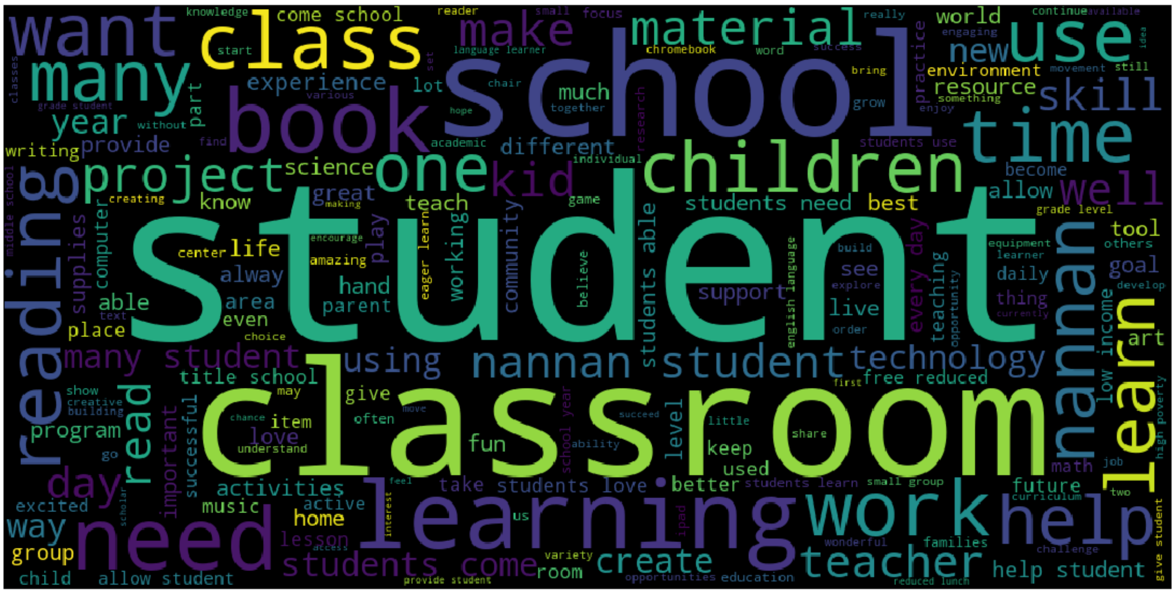
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fa300220198>
```



Analysis of False Positive data

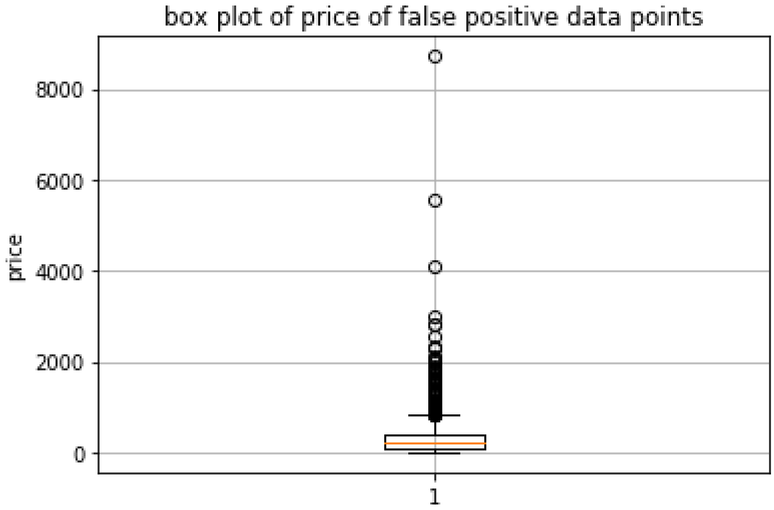
In [77]:

```
fp_df_tf_idf_w2v = X_test.reset_index(drop=True)
fp_df_tf_idf_w2v['y'] = Y_test.values
fp_df_tf_idf_w2v['y_hat'] = y_test_predict
fp_df_tf_idf_w2v = fp_df_tf_idf_w2v.loc[(fp_df_tf_idf_w2v['y']==0) & (fp_df_tf_idf_

unique_string=(" ").join(fp_df_tf_idf_w2v['clean_essay'].values)
wordcloud = WordCloud(width = 1000, height = 500).generate(unique_string)
plt.figure(figsize=(25,10))
plt.imshow(wordcloud)
plt.axis("off")
plt.show()
plt.close()
```



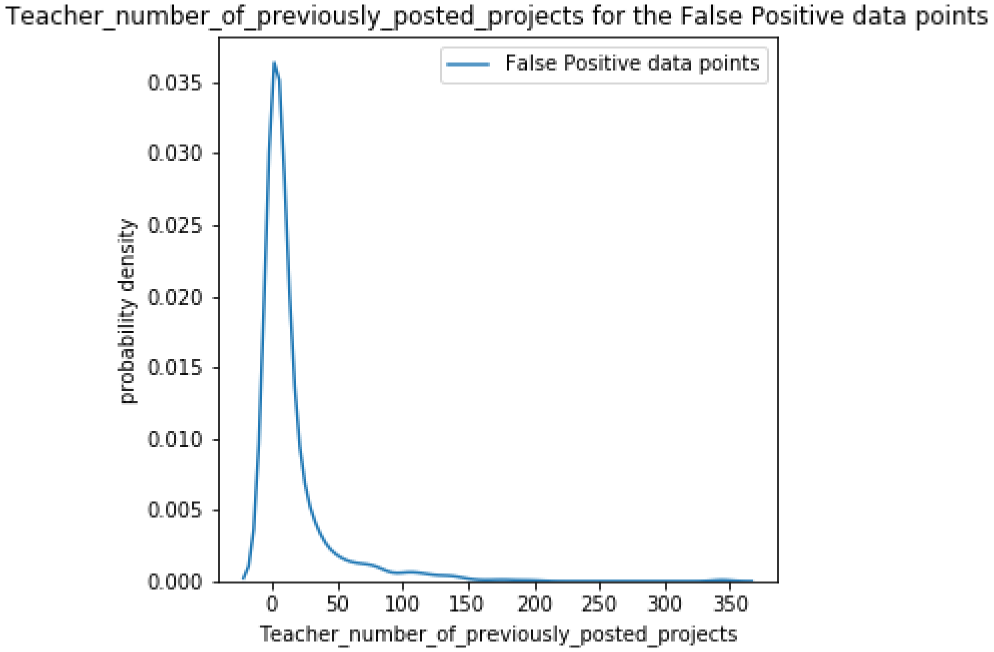
In [269]:

```
plt.boxplot(fp_df_tf_idf_w2v['price'])
plt.grid()
plt.ylabel("price")
plt.title("box plot of price of false positive data points")
plt.show()
```



In [78]:

```
plt.figure(figsize=(5,5))
sns.distplot(fp_df_tf_idf_w2v['teacher_number_of_previously_posted_projects'].value
plt.title('Teacher_number_of_previously_posted_projects for the False Positive data
plt.xlabel('Teacher_number_of_previously_posted_projects')
plt.ylabel('probability density')
plt.legend()
plt.show()
```



2.5 [Task-2]Getting top 5k features using `feature_importances_`

Training the decision tree classifier to full depth so that we can obtain important features

In [83]:

```
dt_tfidf_fimp = DecisionTreeClassifier()
dt_tfidf_fimp.fit(X_train_tfidf,Y_train)
```

Out[83]:

```
DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=
None,
            max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=
None,
            splitter='best')
```

In [84]:

```
fimp = dt_tfidf_fimp.tree_.compute_feature_importances(normalize=False)
df = pd.DataFrame(fimp)
df = np.transpose(df)
df
```

Out[84]:

	0	1	2	3	4	5	6	7	8	9	...	9956	9957	995
0	0.0	0.000063	0.000048	0.000022	0.00011	0.0	0.0	0.0	0.0	0.000041	...	0.0	0.0	0

1 rows × 9966 columns

Remove all the features with importance zero

In [85]:

```
important_features = []

for i in range(df.shape[1]):
    s = df[i].sum()
    if s>0:
        important_features.append(i)
```

Create new datasets with only relevant features

In [86]:

```
tfidf_df_train = pd.DataFrame(X_train_tfidf.todense())
tfidf_df_test = pd.DataFrame(X_test_tfidf.todense())
tfidf_df_train = tfidf_df_train[important_features]
tfidf_df_test = tfidf_df_test[important_features]
```

We were able to find only 3507 important features

In [87]:

```
tfidf_df_train.shape
```

Out[87]:

```
(76473, 3425)
```

Training a MultinomialNB classifier on the transformed dataset

In [88]:

```
multinomial_nb = MultinomialNB(class_prior=[0.5,0.5])
#Set parameters for grid search
parameters = {'alpha':[0.00001, 0.00005, 0.0001, 0.0005, 0.001, 0.005, 0.01, 0.05,
# Use GridSearchCV to search for the optimal value of alpha
# Here, we are using roc_auc as our scoring metric since we have imbalanced dataset
clf = GridSearchCV(estimator = multinomial_nb, param_grid = parameters, cv=3, scori
#pass X_train and Y_train as data to search alpha. Here grid search will automatica
#into stratified samples.
clf.fit(tfidf_df_train.values, Y_train)
```

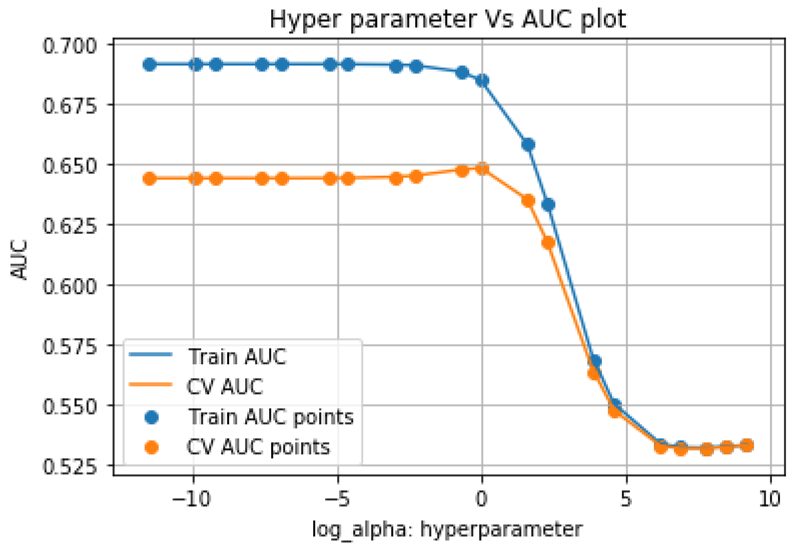
```
Fitting 3 folds for each of 20 candidates, totalling 60 fits

[Parallel(n_jobs=8)]: Using backend LokyBackend with 8 concurrent work
ers.
[Parallel(n_jobs=8)]: Done  34 tasks      | elapsed:   47.7s
[Parallel(n_jobs=8)]: Done  60 out of  60 | elapsed:  1.1min finished
```

Out[88]:

```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=MultinomialNB(alpha=1.0, class_prior=[0.5, 0.5], fit_
prior=True),
       fit_params=None, iid='warn', n_jobs=8,
       param_grid={'alpha': [1e-05, 5e-05, 0.0001, 0.0005, 0.001, 0.00
5, 0.01, 0.05, 0.1, 0.5, 1, 5, 10, 50, 100, 500, 1000, 2500, 5000, 100
00]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
       scoring='roc_auc', verbose=True)
```

In [89]:

```
results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_alpha'])

train_auc= results['mean_train_score']
train_auc_std= results['std_train_score']
cv_auc = results['mean_test_score']
cv_auc_std= results['std_test_score']
alphas =  results['param_alpha']

log_alphas = [np.log(x) for x in alphas]

plt.plot(log_alphas, train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039

plt.plot(log_alphas, cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039

plt.scatter(log_alphas, train_auc, label='Train AUC points')
plt.scatter(log_alphas, cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("log_alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()

results.head()
```



Out[89]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_alpha	params	split
0	18.026681	0.029893	0.300391	0.028268	1e-05	{'alpha': 1e-05}	
1	18.023079	0.017545	0.288423	0.030654	5e-05	{'alpha': 5e-05}	
2	13.956718	5.704124	0.281898	0.041331	0.0001	{'alpha': 0.0001}	

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_alpha	params	split
3	5.857654	0.018132	0.230561	0.004511	0.0005	{'alpha': 0.0005}	

In [399]:

```
clf.best_estimator_
```

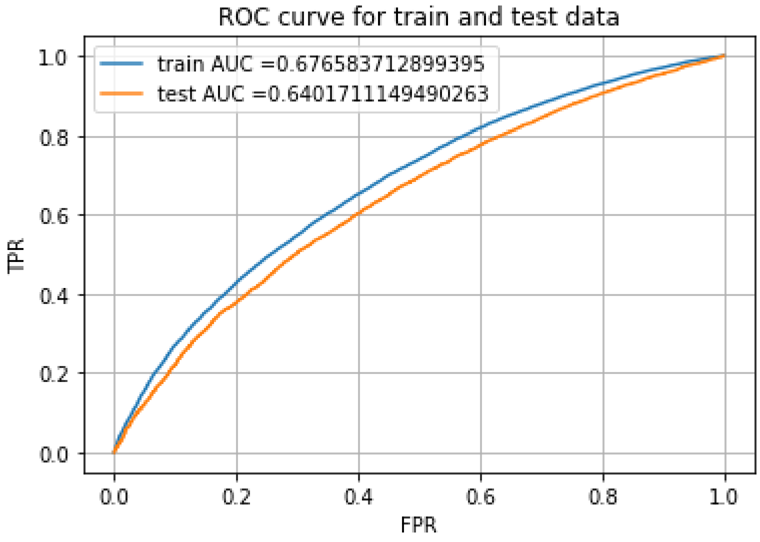
Out[399]:

```
MultinomialNB(alpha=1, class_prior=[0.5, 0.5], fit_prior=True)
```

Training NB on the best value of alpha = 1

In [400]:

```
multinomial_nb = MultinomialNB(alpha=1,class_prior=[0.5,0.5])
multinomial_nb.fit(tfidf_df_train.values, Y_train)

y_train_pred = multinomial_nb.predict_proba(tfidf_df_train.values)
y_test_pred = multinomial_nb.predict_proba(tfidf_df_test.values)

# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates
# not the predicted outputs
train_fpr, train_tpr, tr_thresholds = roc_curve(Y_train, y_train_pred[:,1])
test_fpr, test_tpr, te_thresholds = roc_curve(Y_test, y_test_pred[:,1])

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("FPR")
plt.ylabel("TPR")
plt.title("ROC curve for train and test data")
plt.grid()
plt.show()
```



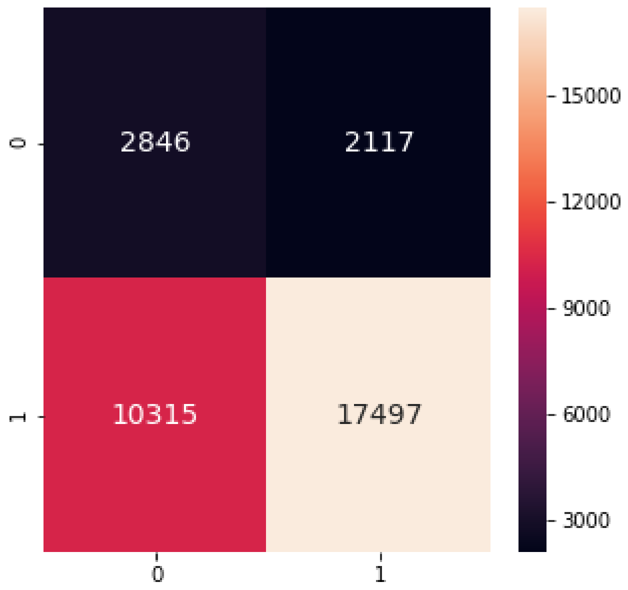
Confusion Matrix

In [401]:

```
y_test_predict = multinomial_nb.predict(tfidf_df_test.values)

results = confusion_matrix(Y_test, y_test_predict)
plt.figure(figsize = (5,5))
sns.heatmap(results, annot=True,annot_kws={"size": 14}, fmt='g')
```

Out[401]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff14b9e08d0>
```



3. Conclusion

In [90]:

```
x = PrettyTable()
x.field_names = ["Vectorizer", "Model", "max_depth:(DT)/aplha(NB)","min_samples_spl

x.add_row(["BOW", "Decision Tree", 10, 500,0.64])
x.add_row(["TFIDF", "Decision Tree", 10,50,0.64])
x.add_row(["W2Vec", "Decision Tree", 5,10,0.62])
x.add_row(["TFIDF-W2Vec", "Decision Tree",5, 100,0.62])
x.add_row(["Best Features TFIDF", "MultiNomial-NB","alpha=1","N.A", 0.64])
print(x)
```

```
+---------------------+----------------+---------------------------+---
----------------+------+
|      Vectorizer     |     Model      | max_depth:(DT)/aplha(NB) | mi
n_samples_split | AUC  |
+---------------------+----------------+---------------------------+---
----------------+------+
|         BOW         | Decision Tree  |            10             |
500         | 0.64 |
|        TFIDF        | Decision Tree  |            10             |
50         | 0.64 |
|        W2Vec        | Decision Tree  |            5              |
10         | 0.62 |
|     TFIDF-W2Vec     | Decision Tree  |            5              |
100         | 0.62 |
| Best Features TFIDF | MultiNomial-NB |          alpha=1          |
N.A         | 0.64 |
+---------------------+----------------+---------------------------+---
----------------+------+
```

In [ ]:

Present Slides Themes Help