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	
project_id	A unique identifier for the proposed project. **Examp**
project_title	Title of the proje • Art Will Make • First
project_grade_category	Grade level of students for which the project is targeted. One enum • Gra • • • (
project_subject_categories	One or more (comma-separated) subject categories for the p following enumerated • Applie • Ca • Healt • Histo • Literacy • Mat • Music • Spe • • • Music • Literacy & Language, Mat
school_state	State where school is located (Two-letter U (https://en.wikipedia.org/wiki/List_of_U.S._state_abbreviations#F
project_subject_subcategories	One or more (comma-separated) subject subcategories • • Literature & Writing, Socia
project_resource_summary	An explanation of the resources needed for the proj • My students need hands on literacy material sens
project_essay_1	First ap
project_essay_2	Second ap
project_essay_3	Third ap
project_essay_4	Fourth ap
project_submitted_datetime	Datetime when project application was submitted. **Example:** 12
teacher_id	A unique identifier for the teacher of the proposed pro bdf8baa8fedef6bfeec7ae

Feature	
teacher_prefix	Teacher's title. One of the following enum • • • • • •
teacher_number_of_previously_posted_projects	Number of project applications previously submitted by the

* 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`
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

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 [393]:

```
%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
```

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'}).
reset_index()
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_pr
efix' '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_approve
d'
 '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/a/47301924/4084039

# https://www.geeksforgeeks.org/removing-stop-words-nltk-python/
# https://stackoverflow.com/questions/23669024/how-to-strip-a-specific-word-from-a-string
# https://stackoverflow.com/questions/8270092/remove-all-whitespace-in-a-string-in-python
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", "Warmth", "Care & Hunger"]
        if 'The' in j.split(): # this will split each of the catogory based on space "Math & Science"=> "Math","&", "Science"
            j=j.replace('The','') # if we have the words "The" we are going to replace it with ''(i.e removing 'The')
        j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty) ex:"Math & Science"=>"Math&Science"
        temp+=j.strip()+" " #" abc ".strip() will return "abc", remove the trailing spaces
        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/a/47301924/4084039

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

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", "Warmth", "Care & Hunger"]
        if 'The' in j.split(): # this will split each of the catogory based on space "Math & Science"=> "Math","&", "Science"
            j=j.replace('The','') # if we have the words "The" we are going to replace it with ''(i.e removing 'The')
        j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty) ex:"Math & Science"=>"Math&Science"
        temp +=j.strip()+" "#" abc ".strip() will return "abc", remove the trailing spaces
        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/22898595/4084039
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	proj
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 thei
r second or third languages. We are a melting pot of refugees, immig
rants, and native-born Americans bringing the gift of language to ou
r school. \r\n\r\n We have over 24 languages represented in our Engl
ish Learner program with students at every level of mastery. We als
o have over 40 countries represented with the families within our sc
hool. Each student brings a wealth of knowledge and experiences to
us that open our eyes to new cultures, beliefs, and respect.\"The li
mits of your language are the limits of your world.\"-Ludwig Wittgen
stein Our English learner's have a strong support system at home th
at begs for more resources. Many times our parents are learning to
read and speak English along side of their children. Sometimes this
creates barriers for parents to be able to help their child learn ph
onetics, letter recognition, and other reading skills.\r\n\r\nBy pro
viding these dvd's and players, students are able to continue their
mastery of the English language even if no one at home is able to as
sist. All families with students within the Level 1 proficiency sta
tus, will be a offered to be a part of this program. These educatio
nal videos will be specially chosen by the English Learner Teacher a
nd will be sent home regularly to watch. 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 opportunity to check out a dvd
player to use for the year. The plan is to use these videos and edu
cational dvd's for the years to come for other EL students.\r\nnanna
n

==========

The 51 fifth grade students that will cycle through my classroom thi
s 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 56
0 students, 97.3% are minority students. \r\nThe school has a vibran
t community that loves to get together and celebrate. Around Hallowe
en there is a whole school parade to show off the beautiful costumes
that students wear. On Cinco de Mayo we put on a big festival with c
rafts made by the students, dances, and games. At the end of the yea
r the school hosts a carnival to celebrate the hard work put in duri
ng the school year, with a dunk tank being the most popular activit
y.My students will use these five brightly colored Hokki stools in p
lace of regular, stationary, 4-legged chairs. As I will only have a
total of ten in the classroom and not enough for each student to hav
e an individual one, they will be used in a variety of ways. During
independent reading time they will be used as special chairs student
s will each use on occasion. I will utilize them in place of chairs
at my small group tables during math and reading times. The rest of
the day they will be used by the students who need the highest amoun
t 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 their 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 the same time doing the
ir work. Anytime the students get to pick where they can sit, the Ho
kki Stools are the first to be taken. There are always students who
head over to the kidney table to get one of the stools who are disap
pointed as there are not enough of them. \r\n\r\nWe ask a lot of stu
dents to sit for 7 hours a day. The Hokki stools will be a compromis
e that allow my students to do desk work and move at the same time.
These stools will help students to meet their 60 minutes a day of mo
vement by allowing them to activate their core muscles for balance w
hile they sit. For many of my students, these chairs will take away
the barrier that exists in schools for a child who can't sit still.n
annan

==========

How do you remember your days of school? Was it in a sterile environ
ment with plain walls, rows of desks, and a teacher in front of the
room? A typical day in our room is nothing like that. I work hard to
create a warm inviting themed room for my students look forward to c
oming to each day.\r\n\r\nMy class is made up of 28 wonderfully uniq
ue 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-price lunch to qualify. Our school is an \"open classroom\"
concept, which is very unique as there are no walls separating the c
lassrooms. These 9 and 10 year-old students are very eager learners;
they are like sponges, 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 able to help create the mood in our classroom s
etting to be one of a themed nautical environment. Creating a classr
oom environment is very important in the success in each and every c
hild's education. The nautical photo props will be used with each ch
ild as they step foot into our classroom for the first time on Meet
the Teacher evening. I'll take pictures of each child with them, hav
e them developed, and then hung in our classroom ready for their fir
st day of 4th grade. This kind gesture will set the tone before eve
n the first day of school! The nautical thank you cards will be used
throughout the year by the students as they create thank you cards t
o their team groups.\r\n\r\nYour generous donations will help me to
help make our classroom a fun, inviting, learning environment from d
ay one.\r\n\r\nIt costs lost of money out of my own pocket on resour
ces to get our classroom ready. Please consider helping with this pr
oject to make our new school year a very successful one. Thank you!n
annan

==

My kindergarten students have varied disabilities ranging from speec
h and language delays, cognitive delays, gross/fine motor delays, to
autism. They are eager beavers and always strive to work their harde
st working past their limitations. \r\n\r\nThe materials we have are
the ones I seek out for my students. I teach in a Title I school whe
re most of the students receive free or reduced price lunch. Despit
e their disabilities and limitations, my students love coming to sch
ool and come eager to learn and explore.Have you ever felt like you
had ants in your pants and you needed to groove and move as you were
in a meeting? This is how my kids feel all the time. The want to be
able to move as they learn or so they say.Wobble chairs are the answ
er and I love then because they develop their core, which enhances g
ross motor and in Turn fine motor skills. \r\nThey also want to lear
n through games, my kids don't want to sit and do worksheets. They w
ant to learn to count by jumping 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 ju
st have the fun a 6 year old deserves.nannan

==

The mediocre teacher tells. The good teacher explains. The superior
teacher demonstrates. The great teacher inspires. -William A. Ward\r
\n\r\nMy school has 803 students which is makeup is 97.6% African-Am
erican, 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 students are on free or reduced lunch. We aren't receiving do
ctors, lawyers, or engineers children from rich backgrounds or neigh
borhoods. As an educator I am inspiring minds of young children and
we focus not only on academics but one smart, effective, efficient,
and disciplined students with good character.In our classroom we can
utilize the Bluetooth for swift transitions during class. I use a sp
eaker 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 boo
ks clearly and it isn't making the lessons as meaningful. But with t
he bluetooth speaker my students will be able to hear and I can sto
p, pause and replay it at any time.\r\nThe cart will allow me to hav
e more room for storage of things that are needed for the day and ha
s an extra part to it I can use.  The table top chart has all of the
letter, words and pictures for students to learn about different let
ters and it is more accessible.nannan
==================================================
```

In [12]:

```
# 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 speec
h and language delays, cognitive delays, gross/fine motor delays, to
autism. They are eager beavers and always strive to work their harde
st working past their limitations. \r\n\r\nThe materials we have are
the ones I seek out for my students. I teach in a Title I school whe
re most of the students receive free or reduced price lunch.  Despit
e their disabilities and limitations, my students love coming to sch
ool and come eager to learn and explore.Have you ever felt like you
had ants in your pants and you needed to groove and move as you were
in a meeting? This is how my kids feel all the time. The want to be
able to move as they learn or so they say.Wobble chairs are the answ
er and I love then because they develop their core, which enhances g
ross motor and in Turn fine motor skills. \r\nThey also want to lear
n through games, my kids do not want to sit and do worksheets. They
want to learn to count by jumping and playing. Physical engagement i
s the key to our success. The number toss and color and shape mats c
an make that happen. My students will forget they are doing work and
just have the fun a 6 year old deserves.nannan
==================================================
```

In [14]:

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

```
My kindergarten students have varied disabilities ranging from speec
h and language delays, cognitive delays, gross/fine motor delays, to
autism. They are eager beavers and always strive to work their harde
st working past their limitations.     The materials we have are the
ones I seek out for my students. I teach in a Title I school where m
ost of the students receive free or reduced price lunch.  Despite th
eir disabilities and limitations, 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 needed to groove and move as you were in
a meeting? This is how my kids feel all the time. The want to be abl
e to move as they learn or so they say.Wobble chairs are the answer
and I love then because they develop their core, which enhances gros
s motor and in Turn fine motor skills.   They also want to learn thr
ough games, my kids do not want to sit and do worksheets. They want
to learn to count by jumping and playing. Physical engagement is the
key to our success. The number toss and color and shape mats can mak
e that happen. My students will forget they are doing work and just
have the fun a 6 year old deserves.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 speec
h and language delays cognitive delays gross fine motor delays to au
tism 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 for my students I teach in a Title I school where most of t
he students receive free or reduced price lunch Despite their disabi
lities and limitations my students love coming to school and come ea
ger 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 T
his is how my kids feel all the time The want to be able to move as
they learn or so they say Wobble chairs are the answer and I love th
en because they develop their core which enhances gross motor and in
Turn fine motor skills They also want to learn through games my kids
do not want to sit and do worksheets They want to learn to count by
jumping and playing Physical engagement is the key to our success Th
e number toss and color and shape mats can make that happen My stude
nts will forget they are doing work and just have the fun a 6 year o
ld 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',
"you're", "you've",\
            "you'll", "you'd", 'your', 'yours', 'yourself', 'yourselves', 'he',
'him', 'his', 'himself', \
            'she', "she's", 'her', 'hers', 'herself', 'it', "it's", 'its', 'itse
lf', 'they', 'them', 'their',\
            'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'tha
t', "that'll", 'these', 'those', \
            'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'ha
s', 'had', 'having', 'do', 'does', \
            'did', 'doing', 'a', 'an', 'the', 'and', 'but', 'if', 'or', 'becaus
e', 'as', 'until', 'while', 'of', \
            'at', 'by', 'for', 'with', 'about', 'against', 'between', 'into', 't
hrough', 'during', 'before', 'after',\
            'above', 'below', 'to', 'from', 'up', 'down', 'in', 'out', 'on', 'of
f', 'over', 'under', 'again', 'further',\
            'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'al
l', 'any', 'both', 'each', 'few', 'more',\
            'most', 'other', 'some', 'such', 'only', 'own', 'same', 'so', 'than'
, 'too', 'very', \
            's', 't', 'can', 'will', 'just', 'don', "don't", 'should', "should'v
e", 'now', 'd', 'll', 'm', 'o', 're', \
            've', 'y', 'ain', 'aren', "aren't", 'couldn', "couldn't", 'didn', "d
idn't", 'doesn', "doesn't", 'hadn',\
            "hadn't", 'hasn', "hasn't", 'haven', "haven't", 'isn', "isn't", 'ma'
, 'mightn', "mightn't", 'mustn',\
            "mustn't", 'needn', "needn't", 'shan', "shan't", 'shouldn', "should
n't", 'wasn', "wasn't", 'weren', "weren'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, 7475.72it/s]

In [18]:

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

Out[18]:

```
'kindergarten students varied disabilities ranging speech language d
elays cognitive delays gross fine motor delays autism eager beavers
always strive work hardest working past limitations the materials on
es seek students teach title school students receive free reduced pr
ice lunch despite disabilities limitations students love coming scho
ol come eager learn explore have ever felt like ants pants needed gr
oove move meeting kids feel time want able move learn say wobble cha
irs answer love develop core enhances gross motor turn fine motor sk
ills they also want learn games kids want sit worksheets want learn
count jumping playing physical engagement key success number toss co
lor shape mats make happen students forget work fun 6 year old deser
ves nannan'
```

In [19]:

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

In [20]:

```
project_data.drop(['project_essay_1','project_essay_2','project_essay_3','projec
t_essay_4'],axis=1,inplace=True)
```

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, 66467.06it/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-numpy
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_p
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', 'qua
ntity',
       'clean_categories', 'clean_subcategories', 'essay', 'clean_es
say',
       'clean_title', 'clean_teacher_prefix', 'clean_grade_categor
y'],
      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()), l
owercase=False, binary=True)
vectorizer_category.fit(X_train['clean_categories'].values)

X_train_category_ohe = vectorizer_category.transform(X_train['clean_categories']
.values)
X_test_category_ohe = vectorizer_category.transform(X_test['clean_categories'].v
alues)
```

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', 'AppliedLe
arning', 'SpecialNeeds', 'Health_Sports', 'Math_Science', 'Literacy_
Language']
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 1 0 0]]
[[0 0 0 0 0 0 1 0 0]]
```

One hot encoding: clean_subcategories

In [35]:

```
# count of all the words in corpus python: https://stackoverflow.com/a/22898595/
4084039
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.key
s()), lowercase=False, binary=True)
vectorizer_subcategory.fit(X_train['clean_subcategories'].values)

X_train_subcategory_ohe = vectorizer_subcategory.transform(X_train['clean_subcat
egories'].values)
X_test_subcategory_ohe = vectorizer_subcategory.transform(X_test['clean_subcateg
ories'].values)
```

In [37]:

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

```
['Economics', 'CommunityService', 'FinancialLiteracy', 'ParentInvolvement', 'Civics_Government', 'Extracurricular', 'ForeignLanguages', 'NutritionEducation', 'Warmth', 'Care_Hunger', 'SocialSciences', 'PerformingArts', 'CharacterEducation', 'TeamSports', 'Other', 'College_CareerPrep', 'Music', 'History_Geography', 'Health_LifeScience', 'EarlyDevelopment', 'ESL', 'Gym_Fitness', 'EnvironmentalScience', 'VisualArts', 'Health_Wellness', 'AppliedSciences', 'SpecialNeeds', 'Literature_Writing', '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 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 1 0 0 1 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=True)
vectorizer_state.fit(X_train['school_state'].values)

X_train_school_state_ohe = vectorizer_state.transform(X_train['school_state'].values)
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_stat
e_ohe.shape)
print("Shape of X_test school_state after one hot encodig ",X_test_school_state_
ohe.shape)
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',
'HI', 'IA', 'ID', 'IL', 'IN', 'KS', 'KY', 'LA', 'MA', 'MD', 'ME', 'M
I', 'MN', 'MO', 'MS', 'MT', 'NC', 'ND', 'NE', 'NH', 'NJ', 'NM', 'N
V', 'NY', 'OH', 'OK', 'OR', 'PA', 'RI', 'SC', 'SD', 'TN', 'TX', 'U
T', '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 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 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]]
```

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,low
ercase=False,binary=True)
vectorizer_teacher_prefix.fit(X_train['clean_teacher_prefix'].values)

X_train_teacher_prefix_ohe = vectorizer_teacher_prefix.transform(X_train['clean_
teacher_prefix'].values)
X_test_teacher_prefix_ohe = vectorizer_teacher_prefix.transform(X_test['clean_te
acher_prefix'].values)
```

In [41]:

```
print(vectorizer_teacher_prefix.get_feature_names())
print("Shape of X_train clean_teacher_prefix after one hot encodig ",X_train_tea
cher_prefix_ohe.shape)
print("Shape of X_test clean_teacher_prefix after one hot encodig ",X_test_teach
er_prefix_ohe.shape)
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 0 1 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,bina
ry=True)
vectorizer_grade.fit(X_train['clean_grade_category'].values)


X_train_grade_category_ohe = vectorizer_grade.transform(X_train['clean_grade_cat
egory'].values)
X_test_grade_category_ohe = vectorizer_grade.transform(X_test['clean_grade_categ
ory'].values)
```

In [43]:

```
print(vectorizer_grade.get_feature_names())
print("Shape of X_train clean_grade_category after one hot encodig ",X_train_gra
de_category_ohe.shape)
print("Shape of X_test clean_grade_category after one hot encodig ",X_test_grade
_category_ohe.shape)
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,-1))
```

In [45]:

```
X_train_price_normalized = price_vectorizer.transform(X_train['price'].values.reshape(1,-1))
X_test_price_normalized = price_vectorizer.transform(X_test['price'].values.reshape(1, -1))
```

In [46]:

```
X_train_price_normalized
```

Out[46]:

```
array([[8.17538335e-04, 4.00903816e-05, 4.88652116e-03, ...,
        3.89220334e-04, 3.06718146e-03, 1.57765197e-03]])
```

In [47]:

```
X_test_price_normalized
```

Out[47]:

```
array([[0.00099303, 0.00217137, 0.00291126, ..., 0.00264468, 0.00416
806,
        0.00052604]])
```

Normalize teacher_number_of_previously_posted_projects

In [48]:

```
project_vectorizer = preprocessing.Normalizer().fit(X_train['teacher_number_of_previously_posted_projects'].values.reshape(1,-1))
```

In [49]:

```
X_train_normal_previous_project = project_vectorizer.transform(X_train['teacher_number_of_previously_posted_projects'].values.reshape(1, -1))
X_test_normal_previous_project = project_vectorizer.transform(X_test['teacher_number_of_previously_posted_projects'].values.reshape(1, -1))
```

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 projects).
vectorizer_essay_bow = CountVectorizer(min_df=10,ngram_range=(1,2), max_features=5000)
vectorizer_essay_bow.fit(X_train['clean_essay'])
```

Out[50]:

```
CountVectorizer(analyzer='word', binary=False, decode_error='stric
t',
        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=5000)
vectorizer_title_bow.fit(X_train['clean_title'])
```

Out[52]:

```
CountVectorizer(analyzer='word', binary=False, decode_error='stric
t',
        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, 4837)
Shape of X_test_title_bow  (32775, 4837)
```

2.3.3 TFIDF vectorizer: Essay

In [54]:

```
vectorizer_essay_tfidf = TfidfVectorizer(min_df=10,ngram_range=(1,2), max_featur
es=5000)
vectorizer_essay_tfidf.fit(X_train['clean_essay'])
```

Out[54]:

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

In [56]:

```
vectorizer_title_tfidf = TfidfVectorizer(min_df=10,ngram_range=(1,2), max_featur
es=5000)
vectorizer_title_tfidf.fit(X_train['clean_title'])
```

Out[56]:

```
TfidfVectorizer(analyzer='word', binary=False, decode_error='stric
t',
        dtype=<class 'numpy.float64'>, encoding='utf-8', input='cont
ent',
        lowercase=True, max_df=1.0, max_features=5000, min_df=10,
        ngram_range=(1, 2), norm='l2', preprocessor=None, smooth_idf
=True,
        stop_words=None, strip_accents=None, sublinear_tf=False,
        token_pattern='(?u)\\b\\w\\w+\\b', tokenizer=None, use_idf=T
rue,
        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, 4837)
Shape of X_test_title_tfidf (32775, 4837)
```

2.3.5 Using Pretrained Models: Avg W2V : Essay

In [58]:

```
# stronging variables into pickle files python: http://www.jessicayung.com/how-t
o-use-pickle-to-save-and-load-variables-in-python/
# 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 [00:25<00:00, 2992.63it/s]
100%|██████████| 32775/32775 [00:10<00:00, 3041.38it/s]
```

In [60]:

```
print("Shape of X_train_essay_avg_w2v_vectors",len(X_train_essay_avg_w2v_vectors
),len(X_train_essay_avg_w2v_vectors[0]))
print("Shape of X_test_essay_avg_w2v_vectors ",len(X_test_essay_avg_w2v_vectors
),len(X_test_essay_avg_w2v_vectors[0]))
```

```
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, 57663.95it/s]
100%|██████████| 32775/32775 [00:00<00:00, 58311.30it/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
 this list
    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/rev
iew
        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
value((sentence.count(word)/len(sentence.split())))
                tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.spl
it())) # getting the tfidf value for each word
                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(vectorize
r_essay_tfidf.idf_)))
tfidf_words = set(vectorizer_essay_tfidf.get_feature_names())

X_train_essay_tfidf_w2v_vectors = get_tfidf_weighted_w2v(X_train['clean_essay'].
values,dictionary,tfidf_words)
X_test_essay_tfidf_w2v_vectors = get_tfidf_weighted_w2v(X_test['clean_essay'].va
lues,dictionary,tfidf_words)
```

```
100%|██████████| 76473/76473 [02:13<00:00, 573.96it/s]
100%|██████████| 32775/32775 [00:56<00:00, 578.26it/s]
```

In [64]:

```
print("Shape of X_train_essay_tfidf_w2v_vectors",len(X_train_essay_tfidf_w2v_vec
tors),len(X_train_essay_tfidf_w2v_vectors[0]))
print("Shape of X_test_essay_tfidf_w2v_vectors ",len(X_test_essay_tfidf_w2v_vect
ors),len(X_test_essay_tfidf_w2v_vectors[0]))
```

```
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(vectorize
r_title_tfidf.idf_)))
tfidf_words = set(vectorizer_title_tfidf.get_feature_names())

X_train_title_tfidf_w2v_vectors = get_tfidf_weighted_w2v(X_train['clean_title'],
dictionary,tfidf_words)
X_test_title_tfidf_w2v_vectors = get_tfidf_weighted_w2v(X_test['clean_title'],di
ctionary,tfidf_words)

print("Shape of X_train_title_tfidf_w2v_vectors",len(X_train_title_tfidf_w2v_vec
tors),len(X_train_title_tfidf_w2v_vectors[0]))
print("Shape of X_title_title_tfidf_w2v_vectors ",len(X_test_title_tfidf_w2v_vec
tors),len(X_test_title_tfidf_w2v_vectors[0]))
```

```
100%|██████████| 76473/76473 [00:02<00:00, 28034.24it/s]
100%|██████████| 32775/32775 [00:01<00:00, 31593.30it/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 [71]:

```
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[71]:

```
(76473, 9939)
```

In [72]:

```
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[72]:

```
(32775, 9939)
```

Hyperparameter Tuning

In [114]:

```
tune_parameters = {'max_depth':[1, 5, 10, 50, 100, 500, 1000], 'min_samples_spli
t': [5, 10, 100, 500]}

#Using GridSearchCV
model = GridSearchCV(DecisionTreeClassifier(class_weight='balanced'), tune_param
eters, scoring = 'roc_auc', cv=3, return_train_score=True,n_jobs=-1, verbose=Tru
e)
model.fit(X_train_dt, Y_train)
```

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

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent
workers.
[Parallel(n_jobs=-1)]: Done  18 tasks      | elapsed:    6.9s
[Parallel(n_jobs=-1)]: Done  84 out of  84 | elapsed:  7.9min finish
ed
```

Out[114]:

```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=DecisionTreeClassifier(class_weight='balanced', cri
terion='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_stat
e=None,
            splitter='best'),
       fit_params=None, iid='warn', n_jobs=-1,
       param_grid={'max_depth': [1, 5, 10, 50, 100, 500, 1000], 'min
_samples_split': [5, 10, 100, 500]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
       scoring='roc_auc', verbose=True)
```

In [134]:

```
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_
score']):
    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)
```

In [136]:

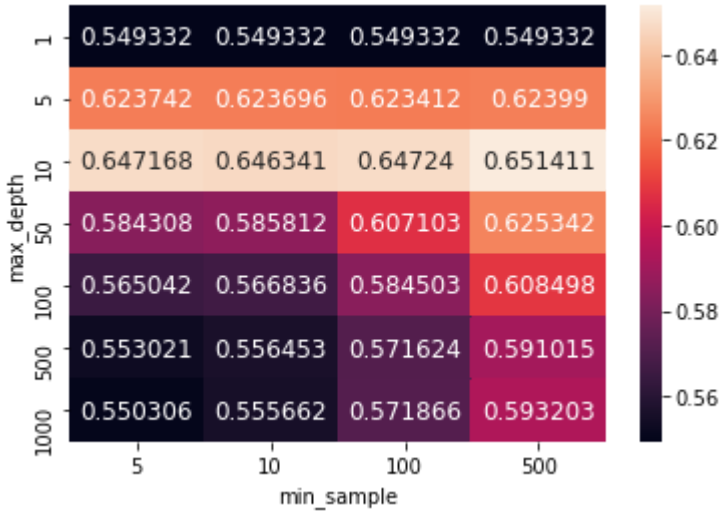
```
df = pd.DataFrame({'max_depth':max_depths,'min_sample':min_samples,'mean_test_sc
ore':mean_cv_scores})
pivot = df.pivot(index = "max_depth", columns = "min_sample", values="mean_test_
score")
```

In [141]:

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

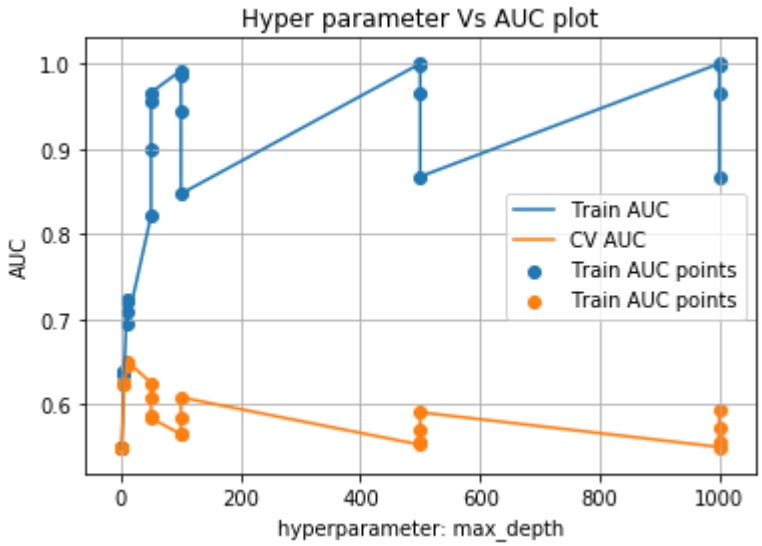
Out[141]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff15720fba8>
```



In [146]:

```
auc_df_train = pd.DataFrame({'max_depth':max_depths,'train_auc':mean_train_score
s})
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 A
UC points')
plt.scatter(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='Train AUC point
s')


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

results.head()
```



Out[146]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_max_depth	param_r
0	0.945838	0.102339	0.150862	0.027691	1	
1	0.944985	0.050369	0.169049	0.007639	1	
2	0.960690	0.050474	0.165803	0.009275	1	
3	0.983229	0.056244	0.153194	0.001948	1	
4	3.275126	0.050876	0.176872	0.006112	5	

In [147]:

```
model.best_estimator_
```

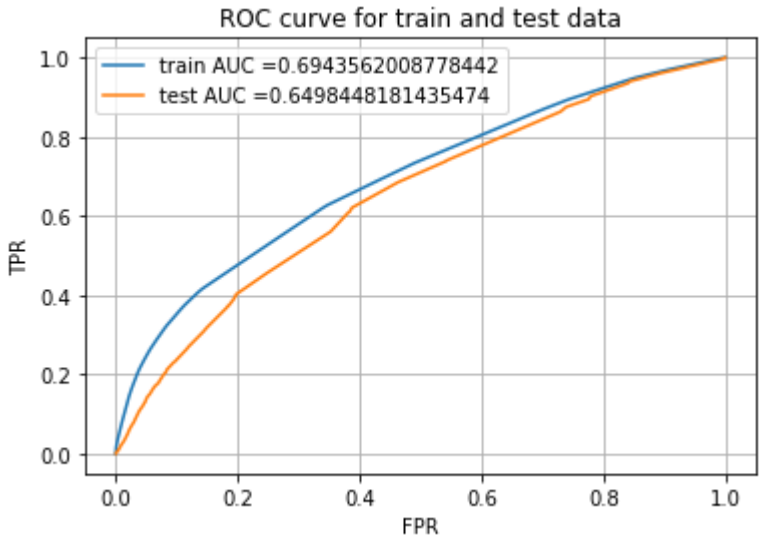
Out[147]:

```
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_stat
e=None,
            splitter='best')
```

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

In [148]:

```
dt_bow = DecisionTreeClassifier(class_weight='balanced',max_depth=10,min_samples
_split=500)
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 estimat
es of the positive class
# 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()
```



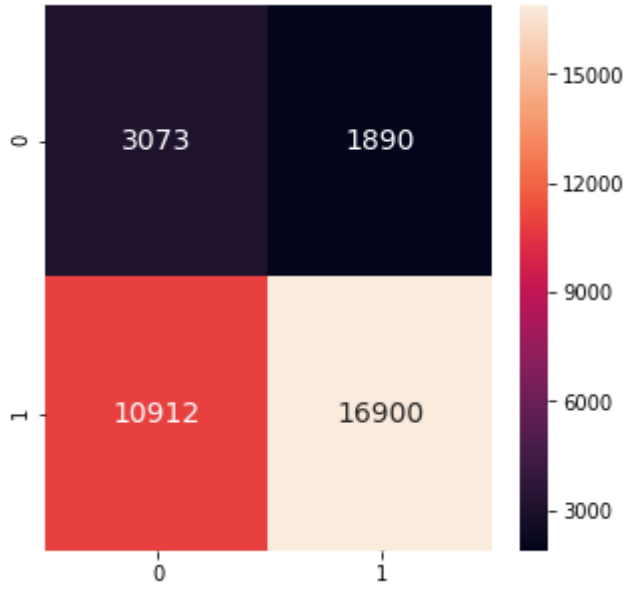
Confusion Matrix

In [192]:

```
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[192]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff14d7ed710>
```



Analysis of False Positive Data points

In [223]:

```
from wordcloud import WordCloud
```

In [213]:

```
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)]
```

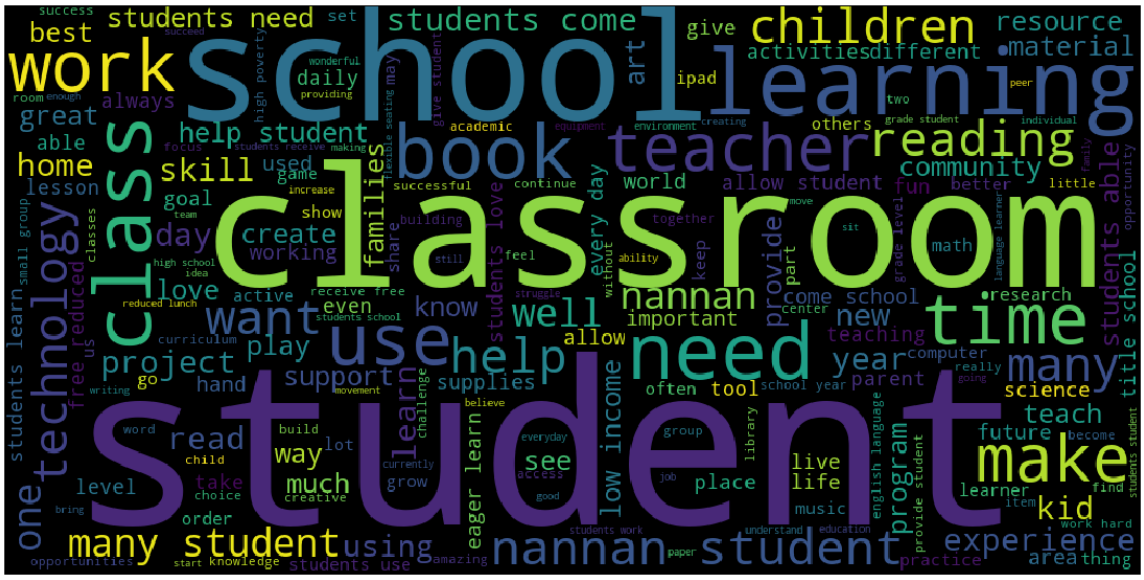
In [221]:

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

Creating a word cloud of essays

In [226]:

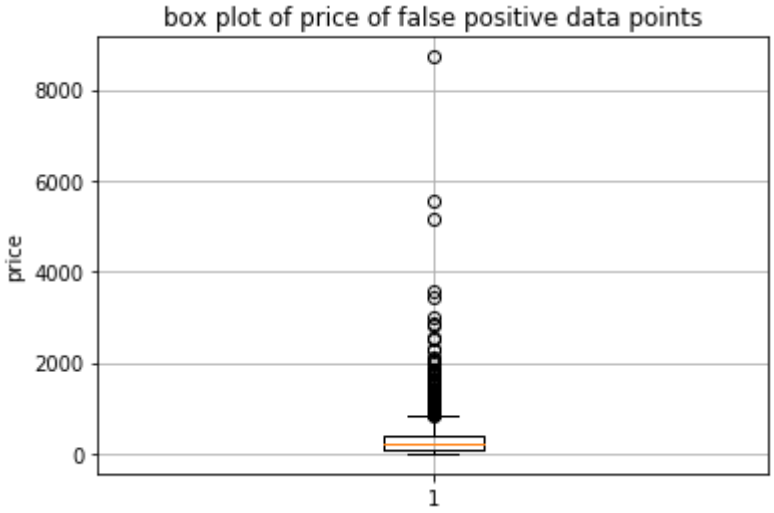
```
unique_string=(" ").join(fp_bow_essays)
wordcloud = WordCloud(width = 1000, height = 500).generate(unique_string)
plt.figure(figsize=(25,10))
plt.imshow(wordcloud)
plt.axis("off")
plt.show()
plt.close()
```



Boxplot of price

In [241]:

```
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()
```



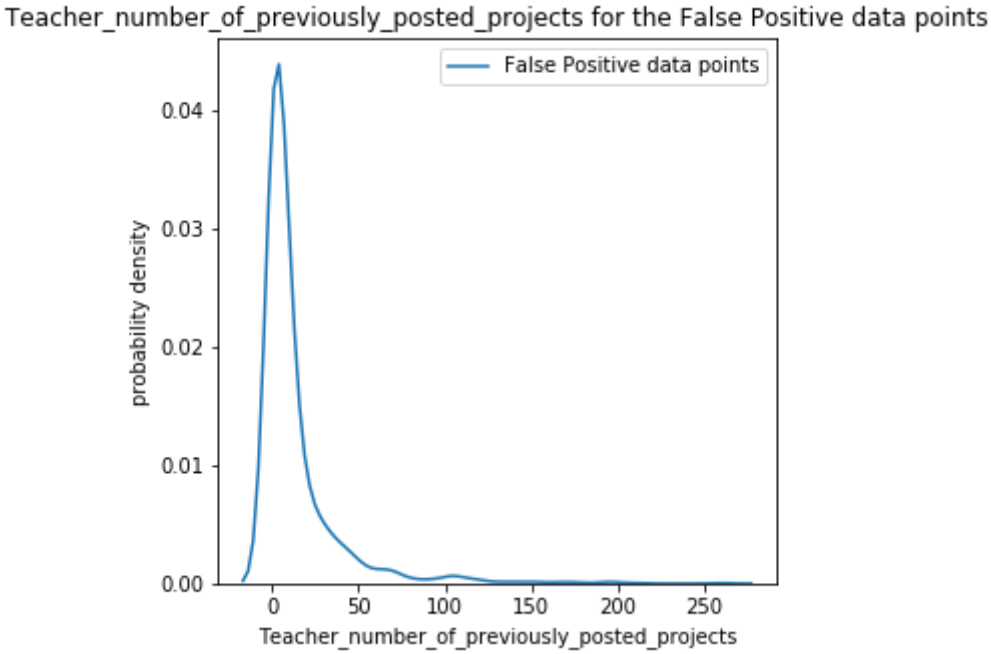
Conclusion

- 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 [242]:

```
plt.figure(figsize=(5,5))
sns.distplot(fp_df['teacher_number_of_previously_posted_projects'].values, hist=
False, label="False Positive data points")
plt.title('Teacher_number_of_previously_posted_projects for the False Positive d
ata points')
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.

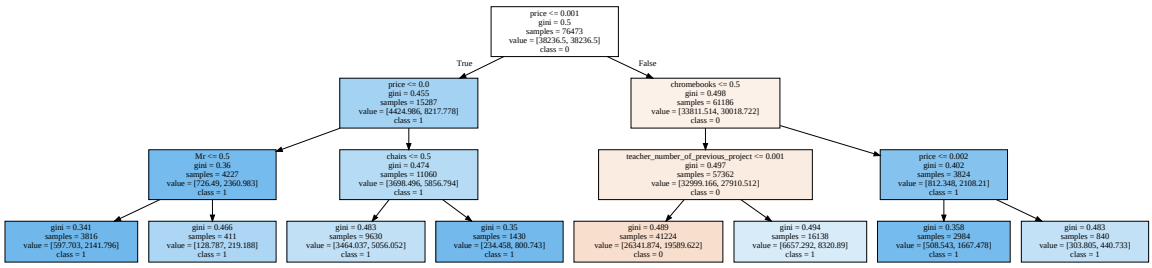
2.4.1.1 Graphviz visualization of Decision Tree on BOW, SET 1

In [166]:

```
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 [178]:

```
dt_bow_viz = DecisionTreeClassifier(class_weight='balanced',max_depth=3,min_samp
les_split=500)
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 [179]:

```
# 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 [227]:

```
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_t
fidf))
X_train_tfidf.shape
```

Out[227]:

```
(76473, 9939)
```

In [228]:

```
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_tfid
f))
X_test_tfidf.shape
```

Out[228]:

```
(32775, 9939)
```

Hyperparameter Tuning

In [229]:

```
tune_parameters = {'max_depth':[1, 5, 10, 50, 100, 500, 1000], 'min_samples_spli
t': [5, 10, 100, 500]}

#Using GridSearchCV
model = GridSearchCV(DecisionTreeClassifier(class_weight='balanced'), tune_param
eters, scoring = 'roc_auc', cv=3, return_train_score=True,n_jobs=-1, verbose=Tru
e)
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
workers.
[Parallel(n_jobs=-1)]: Done  18 tasks      | elapsed:   14.2s
[Parallel(n_jobs=-1)]: Done  84 out of  84 | elapsed:  7.9min finish
ed
```

Out[229]:

```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=DecisionTreeClassifier(class_weight='balanced', cri
terion='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_stat
e=None,
            splitter='best'),
       fit_params=None, iid='warn', n_jobs=-1,
       param_grid={'max_depth': [1, 5, 10, 50, 100, 500, 1000], 'min
_samples_split': [5, 10, 100, 500]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
       scoring='roc_auc', verbose=True)
```

In [230]:

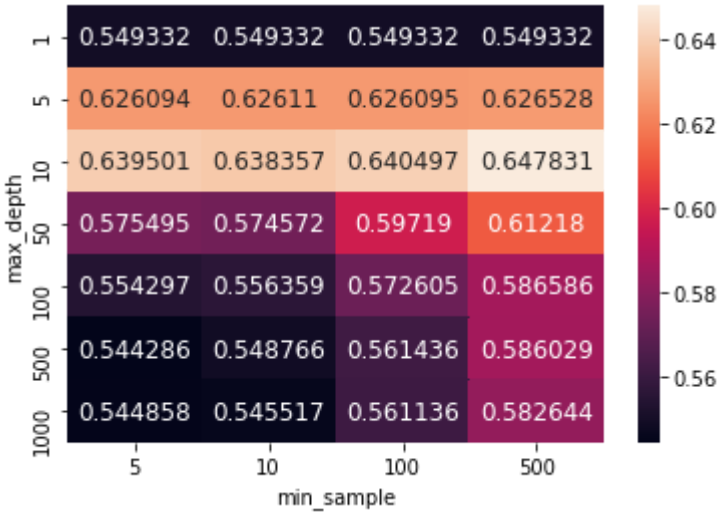
```
results = pd.DataFrame.from_dict(model.cv_results_)
max_depths = []
min_samples = []
mean_cv_scores = []
mean_train_scores = []
for p in zip(results['params'], results['mean_test_score'], results['mean_train_
score']):
    param_dict, score_test, score_train = p
    max_depth,min_sample = param_dict.values()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

In [231]:

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

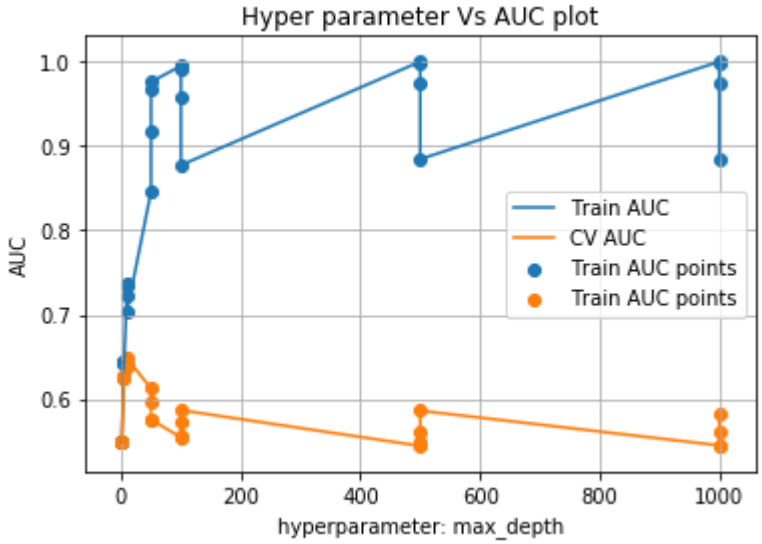
Out[231]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff14c3cc3c8>
```



In [232]:

```
auc_df_train = pd.DataFrame({'max_depth':max_depths,'train_auc':mean_train_score
s})
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 A
UC points')
plt.scatter(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='Train AUC point
s')


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

results.head()
```



Out[232]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_max_depth	param_r
0	2.185698	0.219209	0.167770	0.010508	1	
1	2.307535	0.050574	0.163200	0.011208	1	
2	2.322602	0.029638	0.168274	0.006337	1	
3	2.313034	0.137224	0.166023	0.007770	1	
4	9.346741	0.201844	0.180907	0.006573	5	

In [233]:

```
model.best_estimator_
```

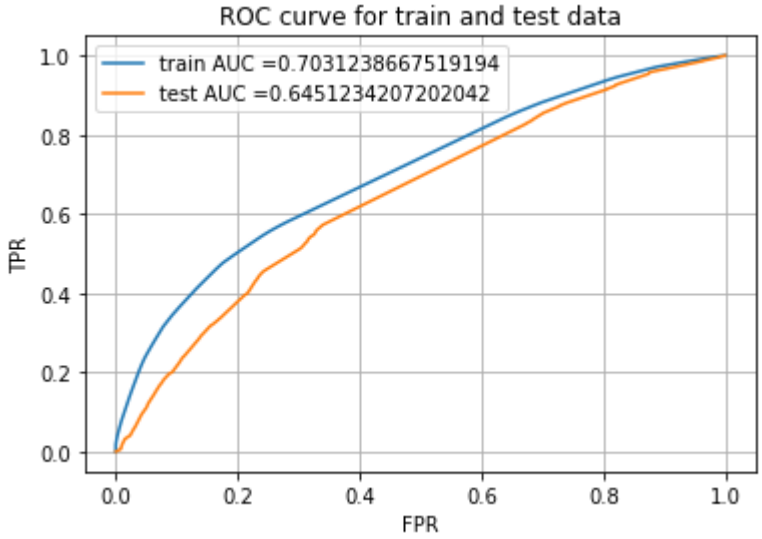
Out[233]:

```
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_stat
e=None,
            splitter='best')
```

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

In [234]:

```
dt_tfidf = DecisionTreeClassifier(class_weight='balanced',max_depth=10,min_sampl
es_split=500)
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 estimat
es of the positive class
# 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()
```



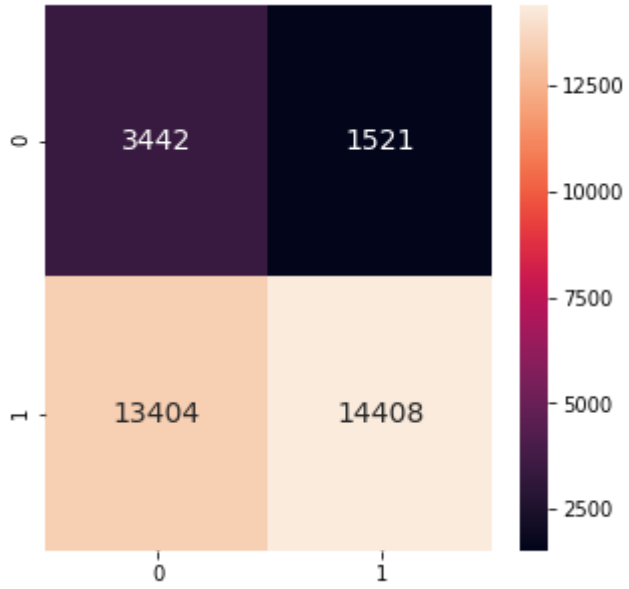
Confusion Matrix

In [235]:

```
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[235]:

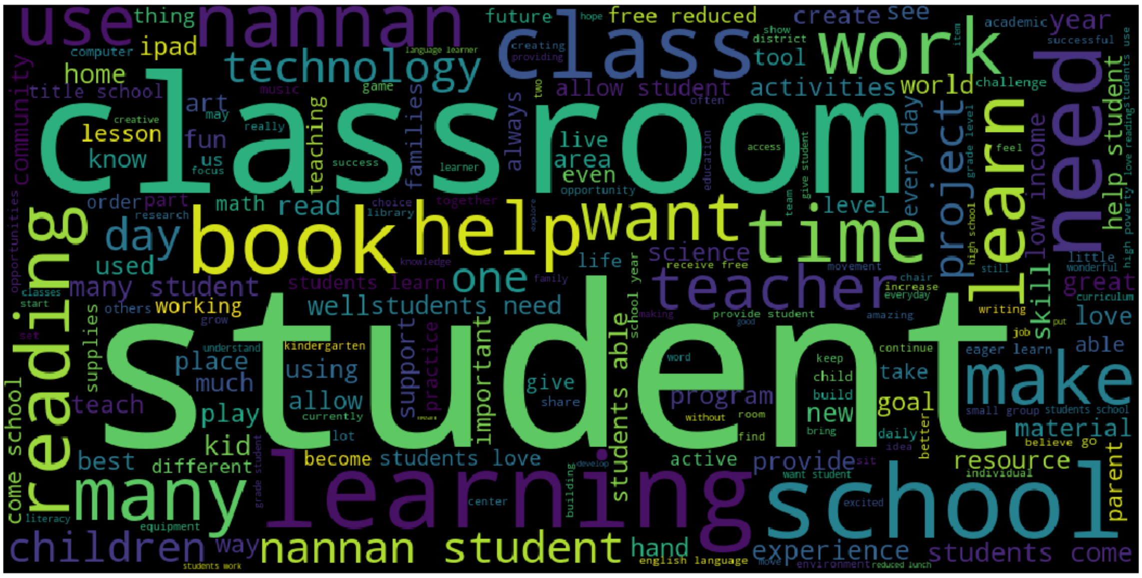
```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff14d4d9048>
```



Analysis of False Positive

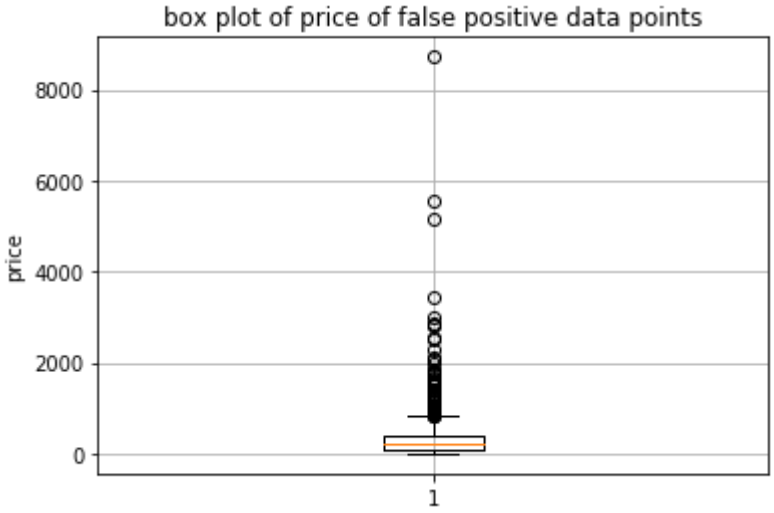
In [244]:

```
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 [246]:

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

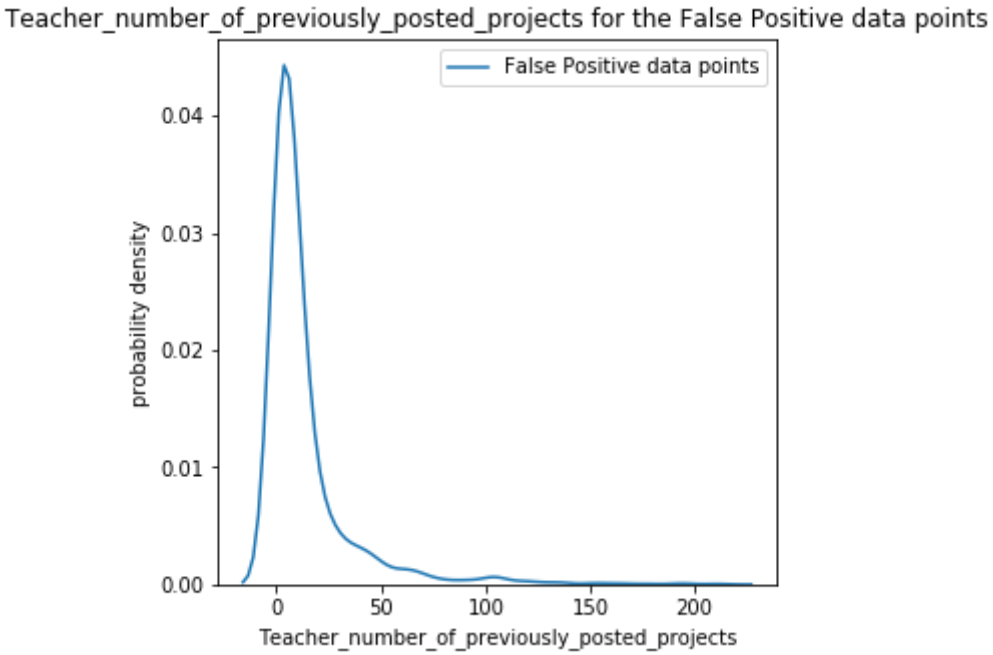


Conclusion:

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

In [247]:

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



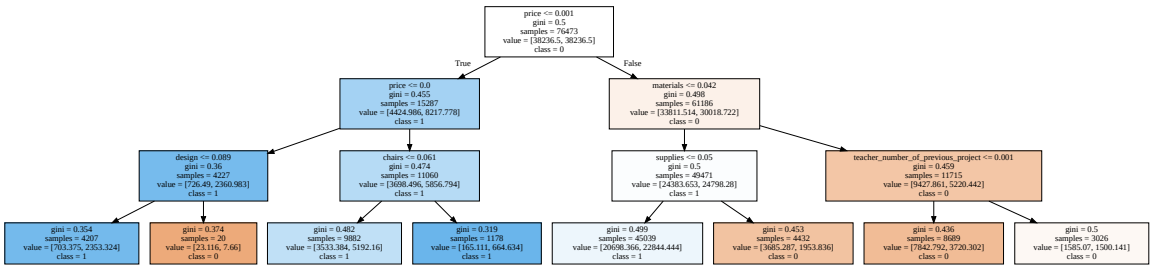
Conclusion:

- 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 [248]:

```
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_sa
mples_split=500)
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 [249]:

```
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
_title_avg_w2v_vectors))
X_train_w2v.shape
```

Out[249]:

```
(76473, 702)
```

In [250]:

```
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_avg_w2v_vectors))
X_test_w2v.shape
```

Out[250]:

```
(32775, 702)
```

Hyperparameter Tuning

In [251]:

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

#Using GridSearchCV
model = GridSearchCV(DecisionTreeClassifier(class_weight='balanced'), tune_parameters, scoring = 'roc_auc', cv=3, return_train_score=True,n_jobs=-1, verbose=True)
model.fit(X_train_w2v, Y_train)
```

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

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent
workers.
[Parallel(n_jobs=-1)]: Done  18 tasks      | elapsed:  1.1min
[Parallel(n_jobs=-1)]: Done  84 out of  84 | elapsed: 15.2min finish
ed
```

Out[251]:

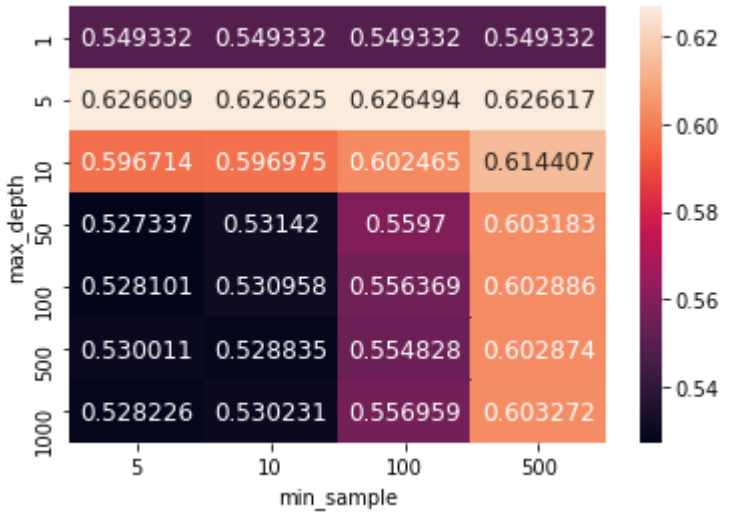
```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=DecisionTreeClassifier(class_weight='balanced', cri
terion='gini',
            max_depth=None, max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1,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

In [252]:

```
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_
score']):
    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)

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

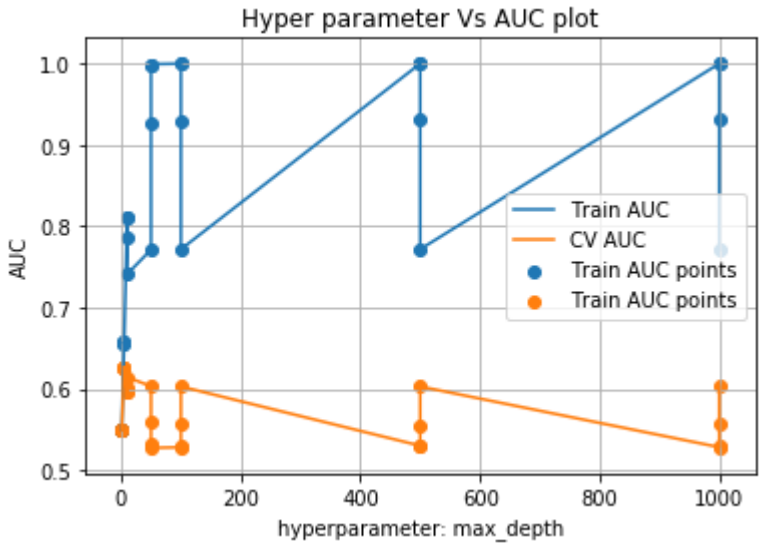
Out[252]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff14d145668>
```



In [253]:

```
auc_df_train = pd.DataFrame({'max_depth':max_depths,'train_auc':mean_train_score
s})
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 A
UC points')
plt.scatter(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='Train AUC point
s')


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

results.head()
```



Out[253]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_max_depth	param_r
0	19.405422	0.154280	0.810844	0.004654	1	
1	19.499704	0.317155	0.826448	0.017091	1	
2	19.533478	0.118607	0.820223	0.005071	1	
3	19.440878	0.432694	0.829825	0.020909	1	
4	51.240497	0.215427	0.814442	0.007202	5	

In [254]:

```
model.best_estimator_
```

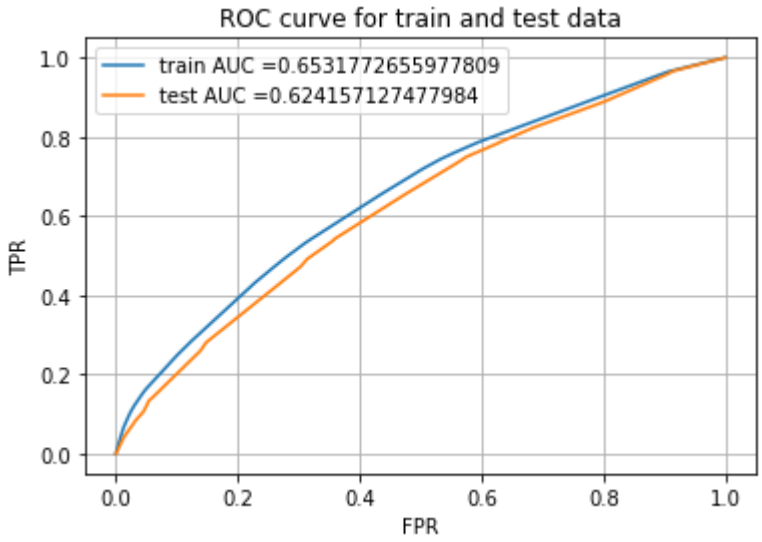
Out[254]:

```
DecisionTreeClassifier(class_weight='balanced', criterion='gini', ma
x_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_stat
e=None,
            splitter='best')
```

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

In [255]:

```
dt_w2v = DecisionTreeClassifier(class_weight='balanced',max_depth=5,min_samples_
split=10)
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 estimat
es of the positive class
# 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()
```



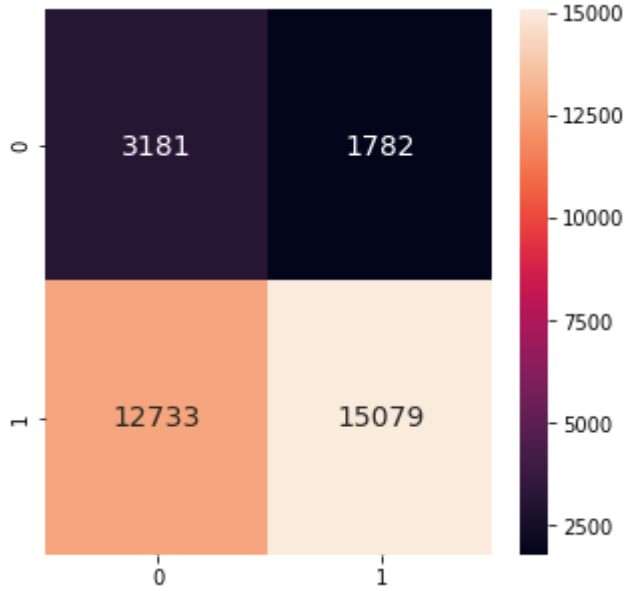
Confusion Matrix

In [256]:

```
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[256]:

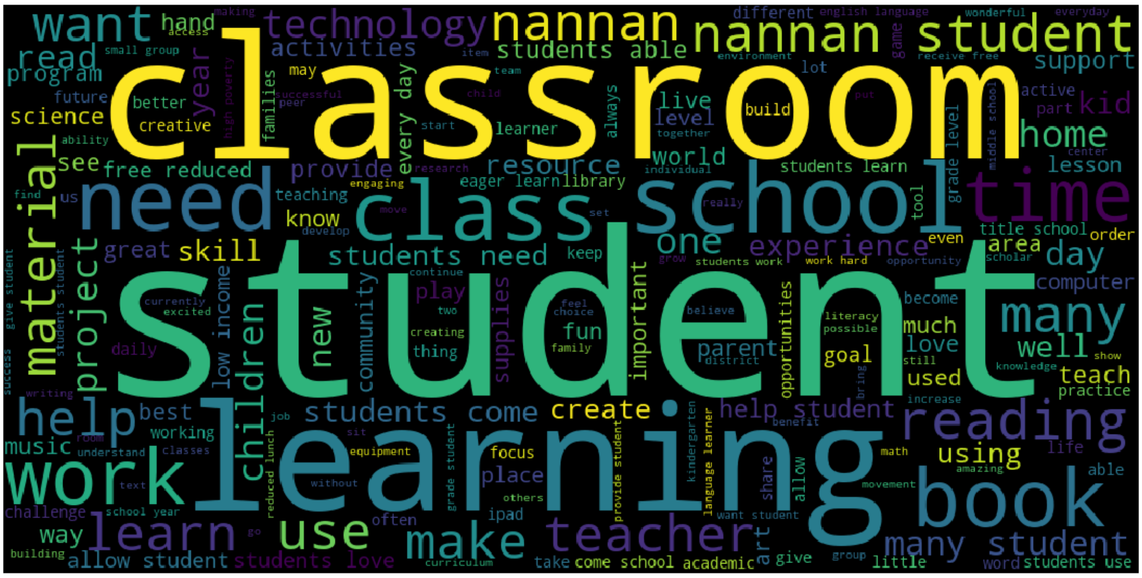
```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff14c6444e0>
```



Analysis of False Positive

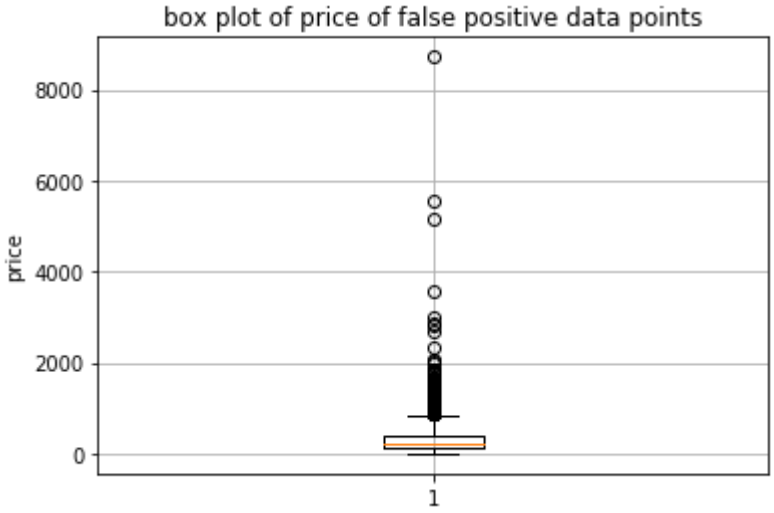
In [257]:

```
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()
```



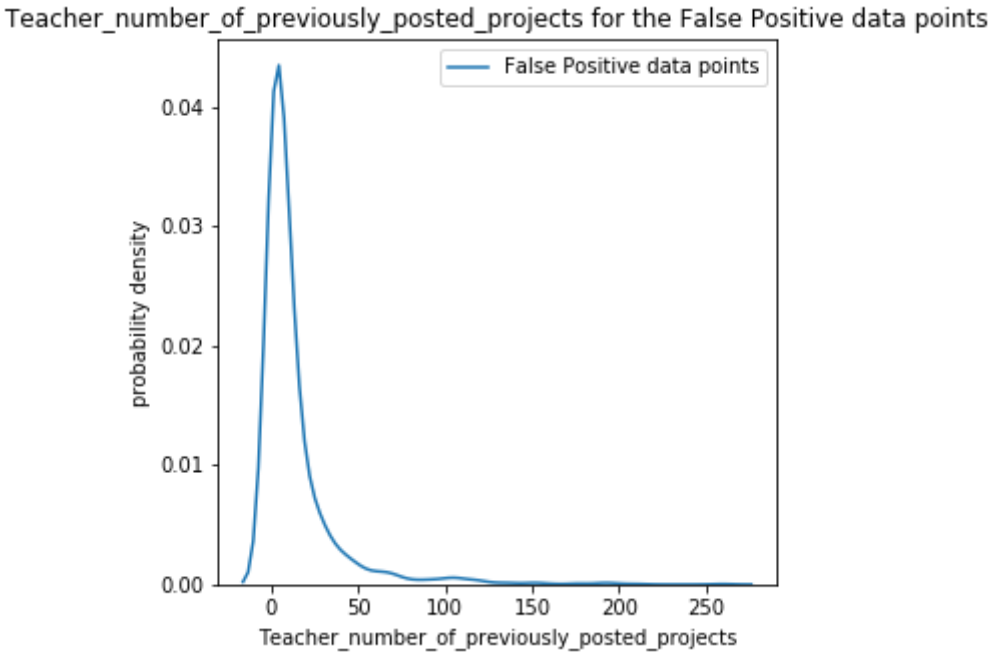
In [258]:

```
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 [259]:

```
plt.figure(figsize=(5,5))
sns.distplot(fp_df_w2v['teacher_number_of_previously_posted_projects'].values, h
ist=False, label="False Positive data points")
plt.title('Teacher_number_of_previously_posted_projects for the False Positive d
ata points')
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 [260]:

```
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_train_title_tfidf_w2v_vectors))
X_train_tfidf_w2v.shape
```

Out[260]:

```
(76473, 702)
```

In [261]:

```
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
_test_title_tfidf_w2v_vectors))
X_test_tfidf_w2v.shape
```

Out[261]:

```
(32775, 702)
```

In [262]:

```
tune_parameters = {'max_depth':[1, 5, 10, 50, 100, 500, 1000], 'min_samples_spli
t': [5, 10, 100, 500]}

#Using GridSearchCV
model = GridSearchCV(DecisionTreeClassifier(class_weight='balanced'), tune_param
eters, scoring = 'roc_auc', cv=3, return_train_score=True,n_jobs=-1, verbose=Tru
e)
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
workers.
[Parallel(n_jobs=-1)]: Done  18 tasks      | elapsed:  1.0min
[Parallel(n_jobs=-1)]: Done  84 out of  84 | elapsed: 14.7min finish
ed
```

Out[262]:

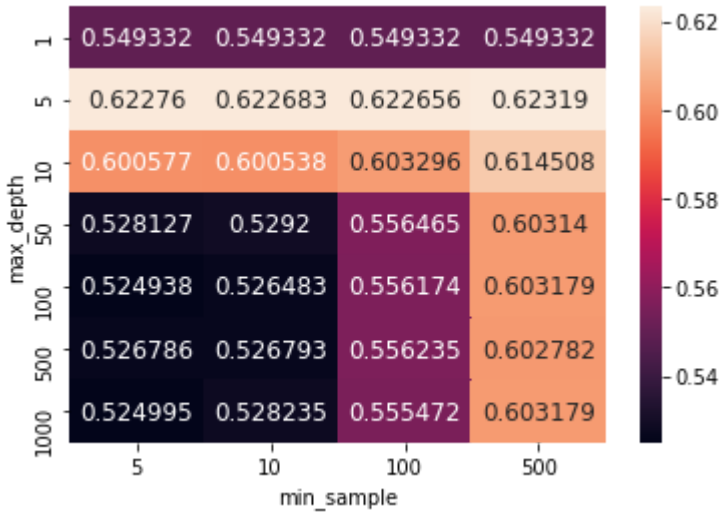
```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=DecisionTreeClassifier(class_weight='balanced', cri
terion='gini',
            max_depth=None, max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1,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

In [263]:

```
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_
score']):
    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)

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

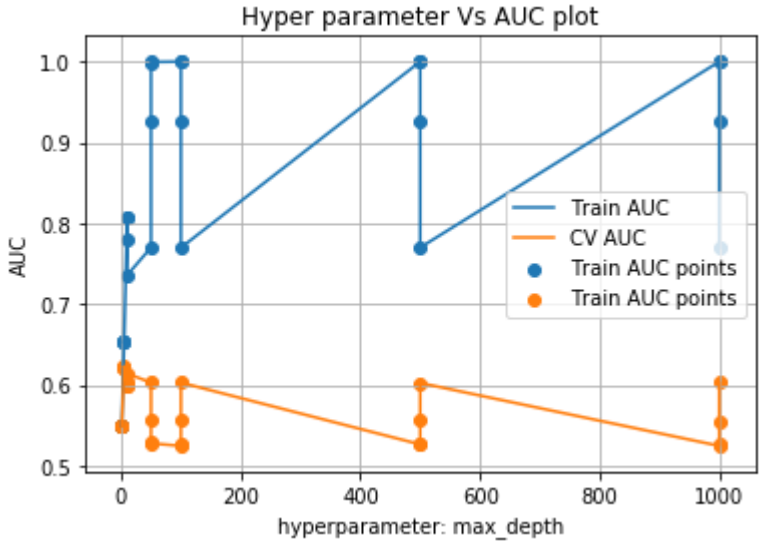
Out[263]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff14af3b940>
```



In [264]:

```
auc_df_train = pd.DataFrame({'max_depth':max_depths,'train_auc':mean_train_score
s})
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 A
UC points')
plt.scatter(auc_df_cv['max_depth'], auc_df_cv['cv_auc'], label='Train AUC point
s')


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

results.head()
```



Out[264]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_max_depth	param_r
0	11.529969	0.239466	0.804597	0.001948	1	
1	11.232384	0.225829	0.803551	0.008368	1	
2	11.421203	0.032625	0.805257	0.004952	1	
3	11.413182	0.086289	0.810021	0.005595	1	
4	42.424900	0.206719	0.802968	0.002618	5	

In [265]:

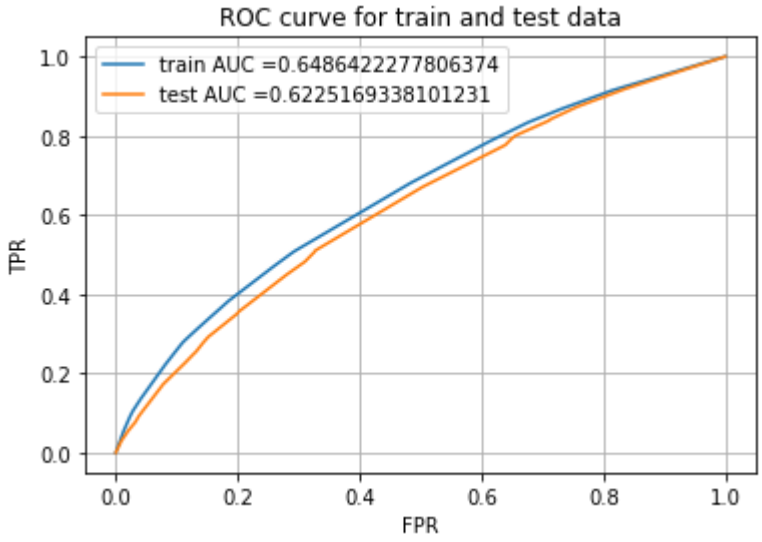
```
model.best_estimator_
```

Out[265]:

```
DecisionTreeClassifier(class_weight='balanced', criterion='gini', ma
x_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_stat
e=None,
            splitter='best')
```

In [266]:

```
dt_tfidf_w2v = DecisionTreeClassifier(class_weight='balanced',max_depth=5,min_sa
mples_split=500)
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 estimat
es of the positive class
# 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()
```



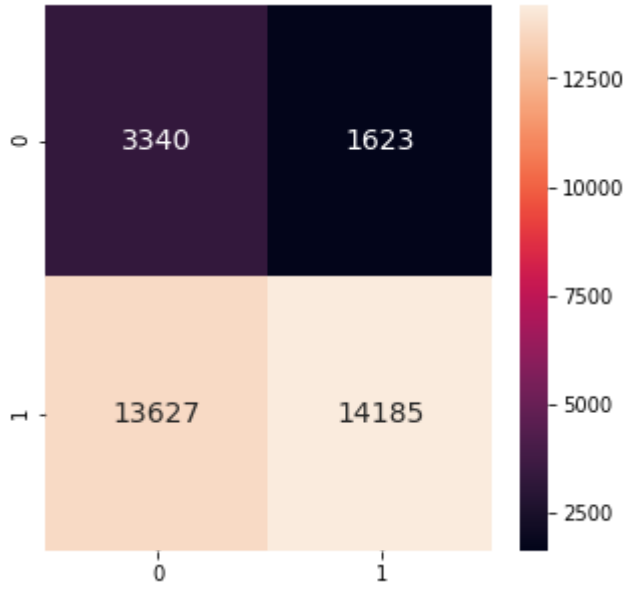
Confusion Matrix

In [267]:

```
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[267]:

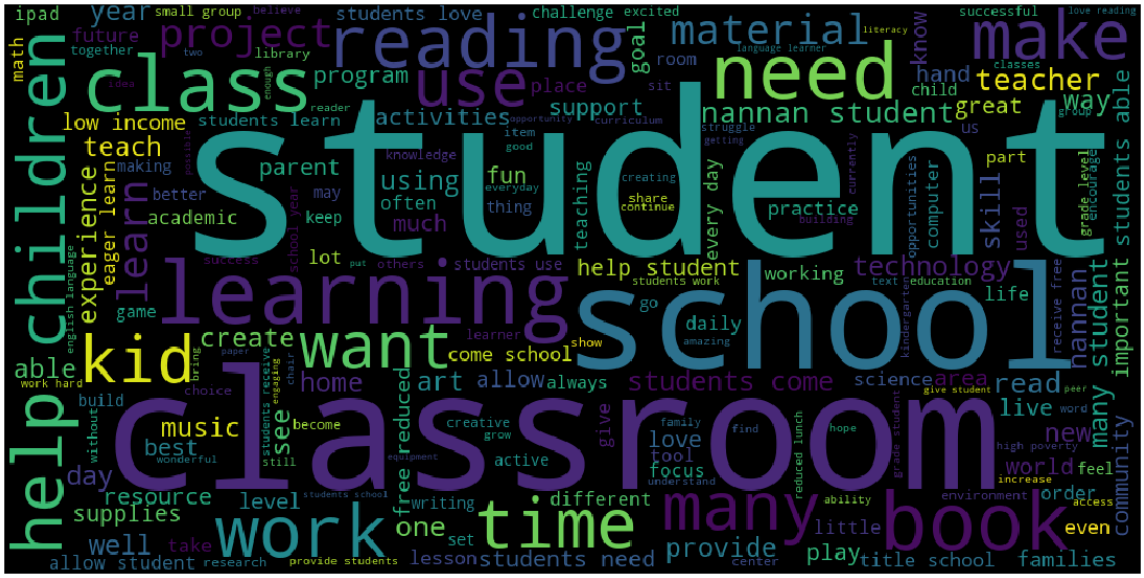
```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff14af40ef0>
```



Analysis of False Positive data

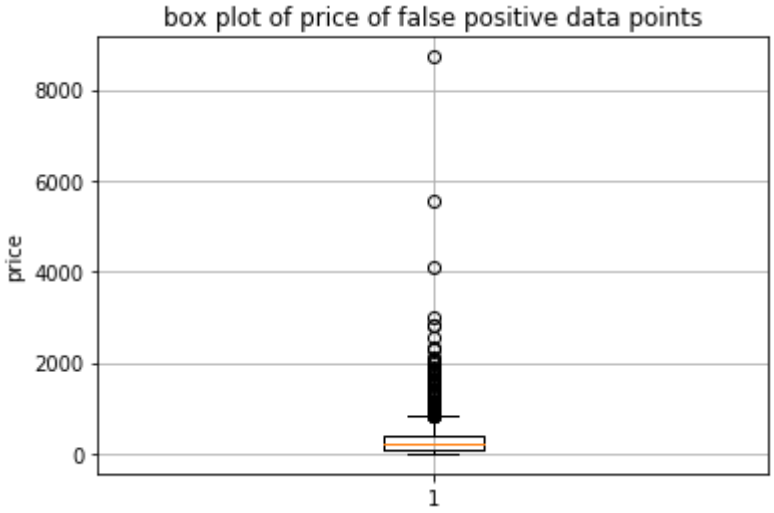
In [268]:

```
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_i
df_w2v['y_hat']==1)]

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()
```



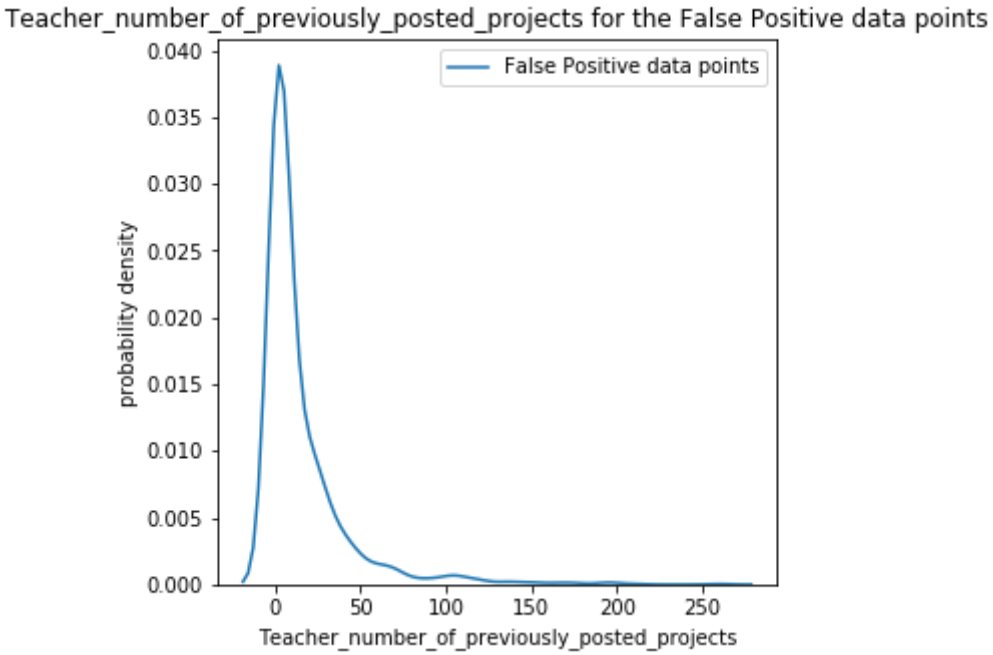
In [269]:

```
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 [270]:

```
plt.figure(figsize=(5,5))
sns.distplot(fp_df_tf_idf_w2v['teacher_number_of_previously_posted_projects'].values, hist=False, label="False Positive data points")
plt.title('Teacher_number_of_previously_posted_projects for the False Positive data points')
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 [331]:

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

Out[331]:

```
DecisionTreeClassifier(class_weight=None, criterion='gini', max_dept
h=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_stat
e=None,
            splitter='best')
```

In [365]:

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

Out[365]:

	0	1	2	3	4	5	6	7	8	9	...	9929	9930	9931	9
0	0.0	0.00007	0.0	0.0	0.000081	0.000013	0.0	0.0	0.0	0.0	...	0.0	0.0	0.000026	

1 rows × 9939 columns

Remove all the features with importance zero

In [366]:

```
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 [382]:

```
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 [383]:

```
tfidf_df_train.shape
```

Out[383]:

```
(76473, 3507)
```

Training a MultinomialNB classifier on the transformed dataset

In [397]:

```
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, 0.0
5, 0.1, 0.5, 1, 5, 10, 50, 100, 500, 1000, 2500, 5000, 10000]}
# Use GridSearchCV to search for the optimal value of alpha
# Here, we are using roc_auc as our scoring metric since we have imbalanced data
set
clf = GridSearchCV(estimator = multinomial_nb, param_grid = parameters, cv=3, sc
oring='roc_auc', return_train_score=True, n_jobs=8, verbose = True)
#pass X_train and Y_train as data to search alpha. Here grid search will automat
ically split the data
#into stratified samples.
clf.fit(tfidf_df_train.values, Y_train)
```

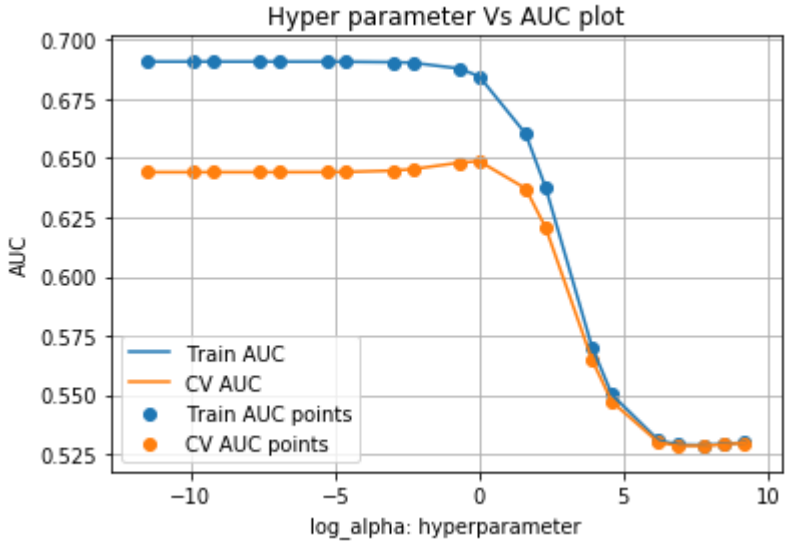
```
Fitting 3 folds for each of 20 candidates, totalling 60 fits

[Parallel(n_jobs=8)]: Using backend LokyBackend with 8 concurrent wo
rkers.
[Parallel(n_jobs=8)]: Done  34 tasks      | elapsed:   51.0s
[Parallel(n_jobs=8)]: Done  60 out of  60 | elapsed:  1.3min finishe
d
```

Out[397]:

```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=MultinomialNB(alpha=1.0, class_prior=[0.5, 0.5], fi
t_prior=True),
       fit_params=None, iid='warn', n_jobs=8,
       param_grid={'alpha': [1e-05, 5e-05, 0.0001, 0.0005, 0.001, 0.
005, 0.01, 0.05, 0.1, 0.5, 1, 5, 10, 50, 100, 500, 1000, 2500, 5000,
10000]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
       scoring='roc_auc', verbose=True)
```

In [398]:

```
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[398]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_alpha	params	split
0	6.711862	0.127199	0.312209	0.019024	1e-05	{'alpha': 1e-05}	
1	7.297321	0.367258	0.325055	0.031615	5e-05	{'alpha': 5e-05}	
2	6.618534	0.139563	0.319039	0.083929	0.0001	{'alpha': 0.0001}	
3	7.379565	0.661302	0.265951	0.015358	0.0005	{'alpha': 0.0005}	
4	7.193194	0.122408	0.289029	0.025618	0.001	{'alpha': 0.001}	

In [399]:

```
clf.best_estimator_
```

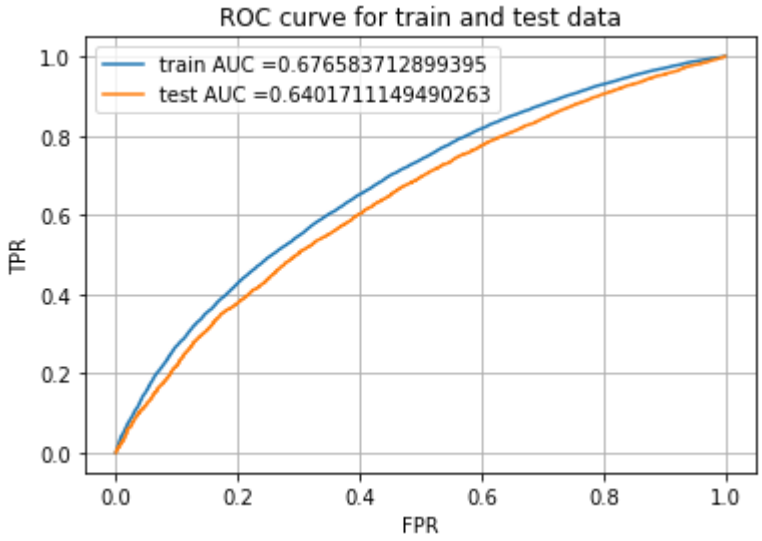
Out[399]:

```
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 estimat
es of the positive class
# 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()
```



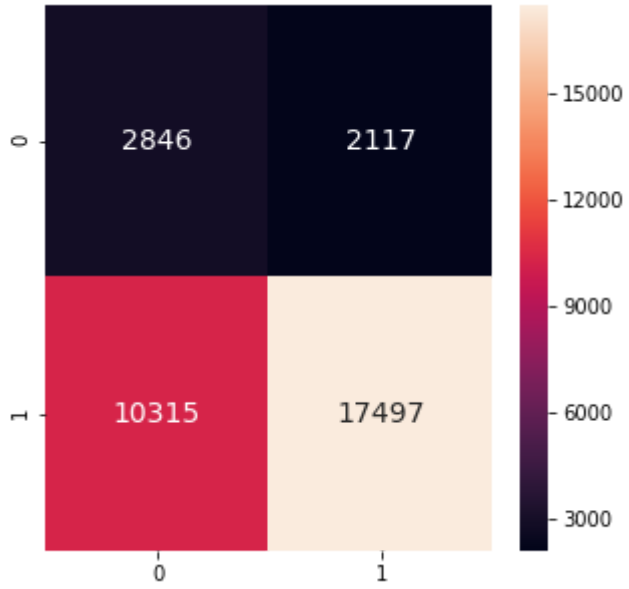
Confusion Matrix

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 [408]:

```
x = PrettyTable()
x.field_names = ["Vectorizer", "Model", "max_depth:(DT)/aplha(NB)","min_samples_
split","AUC"]

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) |
min_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 |
+---------------------+----------------+--------------------------+-
-----------------+------+
```