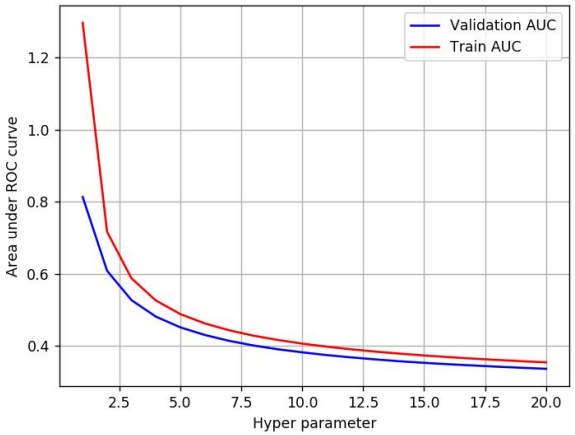
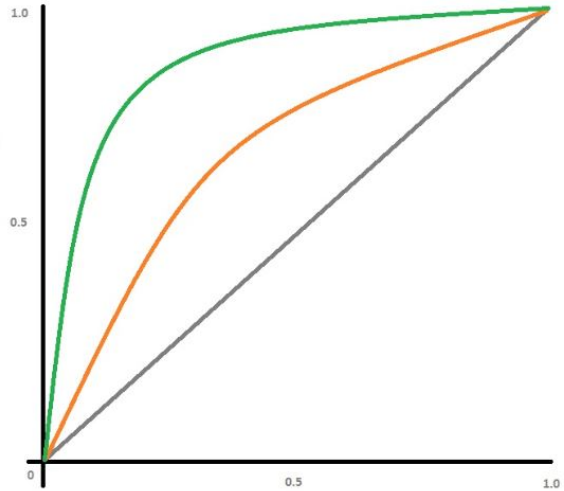
Assignment 6: Apply NB

1. **Apply Multinomial NB on these feature sets**
    - Set 1: categorical, numerical features + preprocessed_eassay (BOW)
    - Set 2: categorical, numerical features + preprocessed_eassay (TFIDF)
2. **The hyper paramter tuning(find best alpha:smoothing parameter)**
    - 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(use GridsearchCV or RandomsearchCV)/simple cross validation data (write for loop to iterate over hyper parameter values)
    -
3. **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/)](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

	Predicted: NO	Predicted: YES
Actual: NO	TN = ??	FP = ??
Actual: YES	FN = ??	TP = ??

4. fine the top 20 features from either from feature Set 1 or feature Set 2 using absolute values of `feature_log_prob_ ` parameter of `MultinomialNB` (https://scikit-learn.org/stable/modules/generated/sklearn.naive_bayes.MultinomialNB.html) and print their corresponding feature names
5. You need to summarize the results at the end of the notebook, summarize it in the table format

Vectorizer	Model	Hyper parameter	AUC
BOW	Brute	7	0.78
TFIDF	Brute	12	0.79
W2V	Brute	10	0.78
TFIDFW2V	Brute	6	0.78

In [1]:
```
import numpy as np
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import pickle
from tqdm import tqdm_notebook

from scipy.sparse import hstack
from sklearn.feature_extraction.text import TfidfTransformer, TfidfVectorizer, CountVectorizer

from sklearn.preprocessing import MinMaxScaler, OneHotEncoder
from sklearn.compose import ColumnTransformer
from sklearn.pipeline import Pipeline, make_pipeline
import joblib
from sklearn.metrics import roc_curve, auc, accuracy_score, confusion_matrix,  roc_auc_score
from sklearn import tree
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import train_test_split, GridSearchCV, KFold

from scipy.stats import randint as sp_randint
from sklearn.model_selection import RandomizedSearchCV, cross_val_predict
from sklearn.naive_bayes import MultinomialNB

%matplotlib inline
import warnings
warnings.filterwarnings("ignore")
```

In [2]:
```
# from google.colab import drive
# drive.mount('/content/drive/')
```

In [3]:
```
%cd /demo-mount/donors choose data/
```

```
/demo-mount/donors choose data
```

In [4]:
```
data = pd.read_csv('preprocessed_final.csv',nrows = 50000,index_col = 0) #reading locally using pandas
data = data.drop(['teacher_id','std_price','nrm_price'], axis =1)
```

Feature Set 1 - BOW

In [5]:
```
data.head()
```

Out[5]:

	teacher_prefix	school_state	project_grade_category	project_subject_categories	project_subject_subcategories	project_title	project_resource
0	mrs	in	grades_prek_2	literacy_language	esl_literacy	Educational Support for English Learners at Home	My stu opportunities
1	mr	fl	grades_6_8	history_civics_health_sports	civics_government_teamsports	Wanted: Projector for Hungry Learners	My students need to help
2	ms	az	grades_6_8	health_sports	health_wellness_teamsports	Soccer Equipment for AWESOME Middle School Stu...	My students guards, athle
3	mrs	ky	grades_prek_2	literacy_language_math_science	literacy_mathematics	Techie Kindergarteners	My students nee in Reading
4	mrs	tx	grades_prek_2	math_science	mathematics	Interactive Math Tools	My students nee practice in

In [6]:
```
#https://scikit-learn.org/stable/auto_examples/compose/plot_column_transformer_mixed_types.html
#https://stackoverflow.com/a/54704747/9292995
#https://stackoverflow.com/q/24169238/9292995 If valueError: If any column is negative

text_transformer = CountVectorizer(min_df=10,ngram_range=(1,4), max_features=5000)

numeric_features = ['teacher_number_of_previously_posted_projects', 'price', 'quantity']
numeric_transformer = Pipeline(steps=[
  ('scaler', MinMaxScaler())])

categorical_features = ['school_state', 'teacher_prefix', 'project_grade_category','project_subject_categories',\
                        'project_subject_subcategories']
categorical_transformer = Pipeline(steps=[
  ('onehot', OneHotEncoder(handle_unknown='ignore'))])


text_transformer = Pipeline(steps=[
  ('trans', text_transformer)])

preprocessor = ColumnTransformer(
  transformers=[('num', numeric_transformer, numeric_features),
      ('cat', categorical_transformer, categorical_features),
      ('essay', text_transformer, "essay"),
      ('title', text_transformer, "project_title"),
      ('resource', text_transformer, "project_resource_summary")]
  ,n_jobs=-1, verbose=True, remainder = 'drop'
          )
```

In [7]:
```
y = data['project_is_approved'].values
X = data.drop(['project_is_approved'], axis=1)
```

In [8]:
```
%%time
preprocessed_X_BOW =  preprocessor.fit_transform(X)
```

```
CPU times: user 10.5 s, sys: 2.49 s, total: 13 s
Wall time: 3min 41s
```

In [9]:
```
%%time
model = MultinomialNB()

pipeline = Pipeline(steps=[('classifier',  model)])

X_train, X_test, y_train, y_test = train_test_split(preprocessed_X_BOW, y, test_size=0.25, stratify=y, random_state = 42

pipeline.fit(X_train, y_train)
print("model score: %.3f" % pipeline.score(X_test, y_test))
```

```
model score: 0.703
CPU times: user 197 ms, sys: 41.1 ms, total: 238 ms
Wall time: 172 ms
```

In [10]:
```
print("model score: %.3f" % pipeline.score(X_train, y_train))
```

```
model score: 0.721
```

In [11]:

```
def searchplot(gs, alpha, title):
  print(("best from search: %.3f"
        % gs.score(X_test, y_test)))

  results = pd.DataFrame.from_dict(gs.cv_results_)

  results = results.sort_values(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']

  K =  results[alpha]

  plt.plot(K, train_auc, label='Train AUC')
  # https://stackoverflow.com/a/48803361/4084039
  # plt.gca().fill_between(K, train_auc - train_auc_std,train_auc + train_auc_std,alpha=0.2,color='darkblue')

  plt.plot(K, cv_auc, label='CV AUC')

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


  plt.legend()
  plt.xscale('log')
  plt.xlabel("Alpha")
  plt.ylabel("AUC")
  plt.title(title)
  plt.grid()
  plt.show()

  results.head()
```

In [12]:

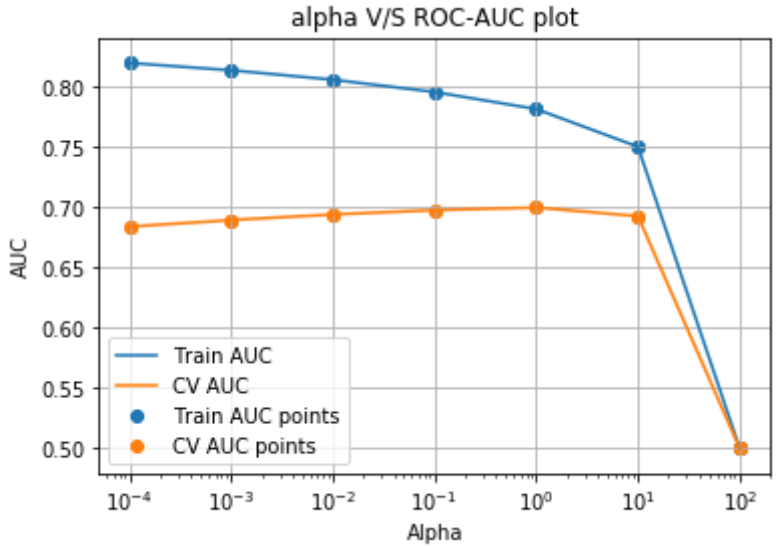
```
# https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve

def roc_auc_pipe(clf, X_train, X_test, y_train, y_test, title):
  y_train_pred = clf.predict_proba(X_train)[:,1]
  y_test_pred = clf.predict_proba(X_test)[:,1]

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

  plt.close
  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.plot([0, 1], [0, 1],'g--')
  plt.xlim([0, 1])
  plt.ylim([0, 1])
  plt.xlabel("False Positive Rate(FPR)")
  plt.ylabel("True Positive Rate(TPR)")
  plt.title(title)
  plt.grid()
  plt.show()
```

In [13]:
```
%%time
cv = KFold(3)

param_grid = {
    'classifier__alpha': [0.0001, 0.001, 0.01, 0.1, 1, 10, 100],
    'classifier__fit_prior': [True, False]
}

gs = GridSearchCV(pipeline, param_grid, cv = cv, n_jobs = -1, verbose = 2, return_train_score = True, scoring = "roc_auc

gs.fit(X_train, y_train)
print("Mean cross-validated score(AUC) of the best_estimator : {0}".format(gs.best_score_))
```

```
Fitting 3 folds for each of 14 candidates, totalling 42 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent workers.
[Parallel(n_jobs=-1)]: Done   9 tasks      | elapsed:    0.8s

Mean cross-validated score(AUC) of the best_estimator : 0.6992968471282798
CPU times: user 485 ms, sys: 88.6 ms, total: 574 ms
Wall time: 1.6 s

[Parallel(n_jobs=-1)]: Done  33 out of  42 | elapsed:    1.5s remaining:    0.4s
[Parallel(n_jobs=-1)]: Done  42 out of  42 | elapsed:    1.5s finished
```

In [14]:
```
searchplot(gs, alpha = 'param_classifier__alpha', title = 'alpha V/S ROC-AUC plot')
```

```
best from search: 0.704
```

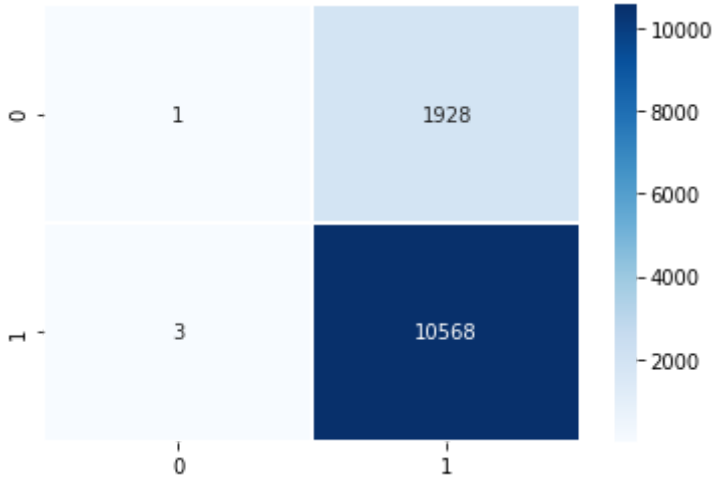


The best hyper parameter which seems be the best fit is c = 10 Because the difference between train and test AUC is minimal

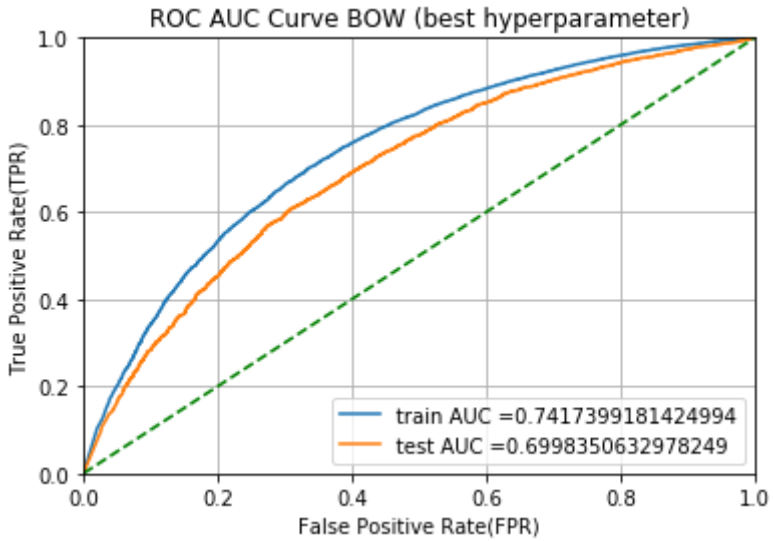
In [15]:
```
%%time
model = MultinomialNB(alpha = 10)

best_pipeline_BOW = Pipeline(steps=[('classifier',  model)])

X_train, X_test, y_train, y_test = train_test_split(preprocessed_X_BOW, y, test_size=0.25, stratify=y, random_state = 42

best_pipeline_BOW.fit(X_train, y_train)
print("model score: %.3f" % best_pipeline_BOW.score(X_test, y_test))
```

```
model score: 0.795
CPU times: user 192 ms, sys: 36.7 ms, total: 228 ms
Wall time: 165 ms
```

In [16]:
```
y_pred = cross_val_predict(best_pipeline_BOW, X_test, y_test, cv=3)
conf_mat = confusion_matrix(y_test, y_pred)
sns.heatmap(conf_mat,  annot=True,  cmap = 'Blues', fmt = 'g', linewidths=.5);
```



In [17]:
```
#Trained on Best hyperparameter alpha = 10
roc_auc_pipe(best_pipeline_BOW, X_train, X_test, y_train, y_test, "ROC AUC Curve BOW (best hyperparameter)")
```



Top 20 features

In [18]:
```
#Most important features in Naive Bayes : https://stackoverflow.com/questions/26976362/how-to-get-most-informative-featu
def most_informative_feature_for_binary_classification(vectorizer, classifier, n=20):
    class_labels = classifier.classes_
    feature_names = vectorizer.get_feature_names()
    topn_class1 = sorted(zip(abs(classifier.feature_log_prob_[0]), feature_names))[:n]
    topn_class2 = sorted(zip(abs(classifier.coef_[0]), feature_names))[-n:]
    print("Top 20 features for class 0")
    print("")
    for coef, feat in topn_class1:
        print(class_labels[0], coef, feat)

    print('='*50)
    print("Top 20 features for class 1")
    print("")
    for coef, feat in reversed(topn_class2):
        print (class_labels[1], coef, feat)
```

In [19]:
```
cat_features = preprocessor.named_transformers_['cat'][0].get_feature_names()
title_features = preprocessor.named_transformers_['title'][0].get_feature_names()
essay_features = preprocessor.named_transformers_['essay'][0].get_feature_names()
resource_features = preprocessor.named_transformers_['resource'][0].get_feature_names()
```

In [20]:
```
all_features = [cat_features , essay_features , title_features , resource_features, ['teacher_number_of_previously_poste
feat_list = [item for sublist in all_features for item in sublist]
```

In [21]:
```
preprocessed_X_BOW.toarray().shape
```

Out[21]:
```
(50000, 15497)
```

In [22]:
```
df = pd.DataFrame(data = preprocessed_X_BOW.toarray(), columns = feat_list) #Converting the csr to numpy array and creat
```

In [23]:
```
df.head()
```

Out[23]:

	x0_ak	x0_al	x0_ar	x0_az	x0_ca	x0_co	x0_ct	x0_dc	x0_de	x0_fl	...	yoga ball	yoga balls	yoga mats	yoga mats and	you	young	your	teacher_numbe
0	0.000000	0.015397	0.023681	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	0.016355	0.029839	0.000000	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	
2	0.002336	0.051628	0.022605	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	
3	0.009346	0.023228	0.003229	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	
4	0.002336	0.006733	0.003229	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	

5 rows × 15497 columns

In [24]:
```
word_vectorizer = CountVectorizer(min_df = 10, ngram_range=(1,4))
word_vectorizer.fit_transform(df)
most_informative_feature_for_binary_classification(word_vectorizer, best_pipeline_BOW.named_steps['classifier'])
```

```
Top 20 features for class 0

0 6.035724163398765 working
0 6.492990511627772 things
0 6.502837418324775 thinking
0 6.648457608268302 to get
0 6.720977017736885 basics
0 6.946259607299845 bean
0 7.0376801453042255 be
0 7.149264693188695 be able to
0 7.15610862619352 variety of
0 7.469293641225228 to the
0 7.6287570599431325 year
0 7.644128839990986 to provide
0 7.658866861414502 can be
0 7.761804308283204 challenges
0 7.800289570746268 to work
0 7.849784208350965 be successful
0 7.9769931352359995 used
0 8.067393419541157 able
0 8.165335179811539 they can
0 8.209786942382372 center
==================================================
Top 20 features for class 1

1 14.089526821716202 succeed
1 14.089526821716202 some
1 14.089526821716202 snacks
1 14.089526821716202 sensory
1 14.089526821716202 reading
1 14.089526821716202 of my students
1 14.089526821716202 need ipads
1 14.089526821716202 mind
1 14.089526821716202 lunch
1 14.089526821716202 literacy
1 14.089526821716202 kindle
1 14.089526821716202 it
```

```
1 14.089526821716202 is the
1 14.089526821716202 is
1 14.089526821716202 how
1 14.089526821716202 hear
1 14.089526821716202 healthy
1 14.089526821716202 health
1 14.089526821716202 hard
1 14.089526821716202 group
```

Feature Set 2 - TFIDF

In [25]:
```
#https://scikit-learn.org/stable/auto_examples/compose/plot_column_transformer_mixed_types.html
#https://stackoverflow.com/a/54704747/9292995
# #https://stackoverflow.com/q/24169238/9292995 If valueError: If any column is negative

numeric_features = ['teacher_number_of_previously_posted_projects', 'price', 'quantity']
numeric_transformer = Pipeline(steps=[('scaler', MinMaxScaler())])

categorical_features = ['school_state', 'teacher_prefix', 'project_grade_category','project_subject_categories',\
                        'project_subject_subcategories']
categorical_transformer = Pipeline(steps=[
    ('onehot', OneHotEncoder(handle_unknown='ignore'))])

# text_features = ['essay','project_title']
text_transformer = Pipeline(steps=[
    ('tfidf', TfidfVectorizer(stop_words = 'english', min_df=10, ngram_range=(1,4), max_features=5000))])

preprocessor = ColumnTransformer(
    transformers=[('num', numeric_transformer, numeric_features),
        ('cat', categorical_transformer, categorical_features),
        ('essay', text_transformer, "essay"),
        ('title', text_transformer, "project_title"),
        ('resource', text_transformer, "project_resource_summary")]
    ,n_jobs=-1, verbose=True, remainder = 'passthrough'
            )
```

In [*]:
```
%%time
preprocessor.fit(X)
preprocessed_X_TFIDF =  preprocessor.fit_transform(X)
```

```
CPU times: user 17.1 s, sys: 4.64 s, total: 21.7 s
Wall time: 5min 17s
```

In [*]:
```
%%time

# Append classifier to preprocessing pipeline.
# Now we have a full prediction pipeline.
pipeline = Pipeline(steps=[('classifier',  MultinomialNB())])

y = data['project_is_approved'].values
X = data.drop(['project_is_approved'], axis=1)

X_train, X_test, y_train, y_test = train_test_split(preprocessed_X_TFIDF, y, test_size=0.25, stratify=y)

pipeline.fit(X_train, y_train)
print("model score: %.3f" % pipeline.score(X_test, y_test))

#Note - we're including the preprocessing step in the pipeline too as it will fit the vocab for the Tfidfvectorizer
```

In [*]:
```
print("model score: %.3f" % pipeline.score(X_train, y_train))
```

In [*]:
```
%%time
cv = KFold(3)

param_grid = {
    'classifier__alpha': [0.0001, 0.001, 0.01, 0.1, 1, 10, 100],
    'classifier__fit_prior': [True, False]
}

gs = GridSearchCV(pipeline, param_grid, cv = cv, n_jobs = -1, verbose = 2, return_train_score = True, scoring = "roc_auc
                  refit = True)

gs.fit(X_train, y_train)
print("Mean cross-validated score(AUC) of the best_estimator : {0}".format(gs.best_score_))
```

In [*]:
```
gs.best_params_
```

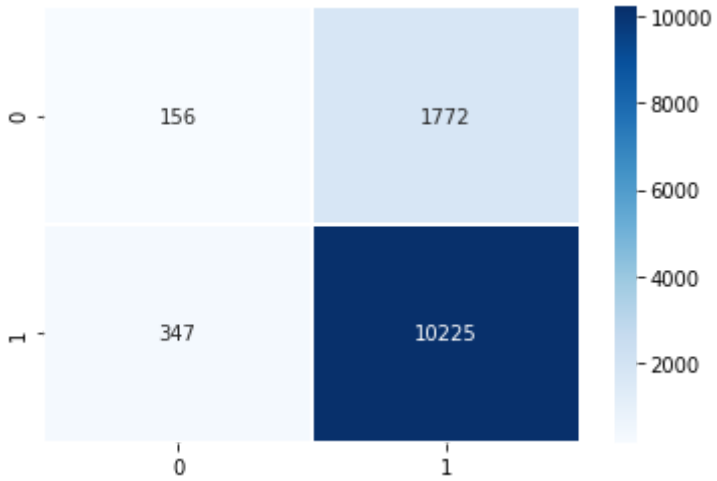
In [*]:
```
searchplot(gs, alpha = 'param_classifier__alpha', title = 'alpha V/S ROC-AUC plot')
```

Best hyperparameter seems to be 1 as the test AUC isn't too low and the difference between train AUC and train AUC is less

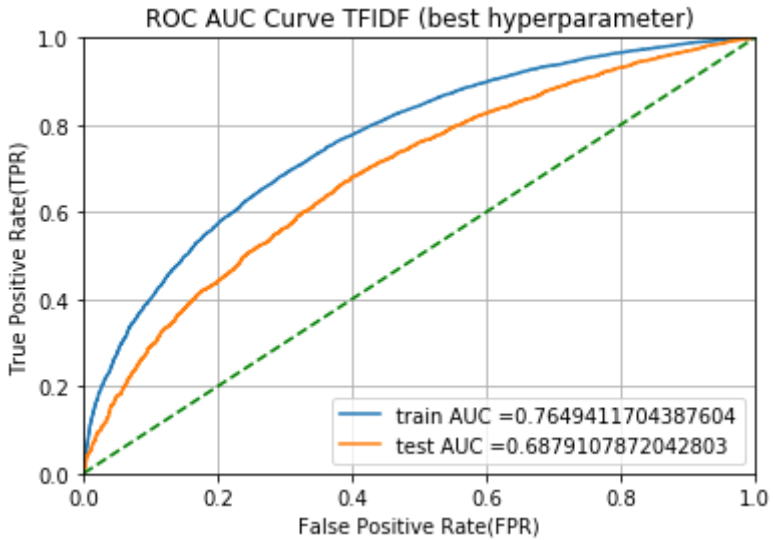
In [33]:
```
%%time
best_pipeline_tfidf = Pipeline(steps=[('classifier',  MultinomialNB(alpha = 1))])

y = data['project_is_approved'].values
X = data.drop(['project_is_approved'], axis=1)

X_train, X_test, y_train, y_test = train_test_split(preprocessed_X_TFIDF, y, test_size=0.25, stratify=y)

best_pipeline_tfidf.fit(X_train, y_train)
print("model score: %.3f" % best_pipeline_tfidf.score(X_test, y_test))
```

```
model score: 0.819
CPU times: user 44.3 s, sys: 2.93 s, total: 47.2 s
Wall time: 2min 44s
```

In [34]:
```
y_pred = cross_val_predict(best_pipeline_tfidf, X_test, y_test, cv=3)
conf_mat = confusion_matrix(y_test, y_pred)
sns.heatmap(conf_mat,  annot=True, cmap = 'Blues', fmt = 'g', linewidths=.5);
```



In [35]:
```
roc_auc_pipe(best_pipeline_tfidf, X_train, X_test, y_train, y_test, "ROC AUC Curve TFIDF (best hyperparameter)")
```



In [37]:
```
from prettytable import PrettyTable
t = PrettyTable(['Vectorizer', 'Model','Hyperparameter','AUC'])
t.add_row(['BOW', 'Brute', 10, 0.699])
t.add_row(['TFIDF', 'Brute', 1, 0.687])
print(t)
```

```
+------------+-------+----------------+-------+
| Vectorizer | Model | Hyperparameter |  AUC  |
+------------+-------+----------------+-------+
|    BOW     | Brute |       10       | 0.699 |
|   TFIDF    | Brute |       1        | 0.687 |
+------------+-------+----------------+-------+
```

In [ ]: