Assignment 1, Deep Learning Fundamentals

Import libraries

In [1]:
```
# Import libraries
import pandas as pd
import numpy as np
from scipy.sparse import hstack
import matplotlib.pyplot as plt
import seaborn as sns
import time

from sklearn.datasets import load_svmlight_file
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score
from sklearn.metrics import recall_score
```

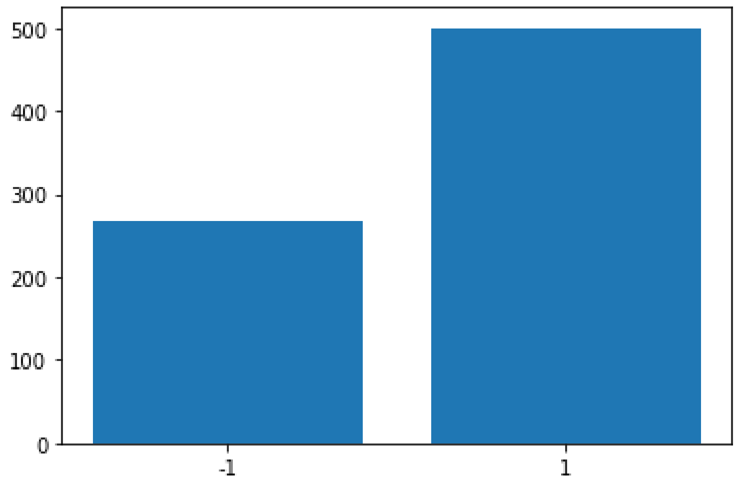
Import and proprocess of the dataset

In [2]:
```
# Import dataset
X, y = load_svmlight_file("/Users/fuchuenli/Desktop/Year 1/Trimester 3/COMP
```

In [3]:
```
# Check number of -1 and 1 distribution in the dataset
y_1 = y.tolist().count(1)
y_m1 = y.tolist().count(-1)
print(f"Number of healthy entity: {y_m1}")
print(f"Number of diabetic patients: {y_1}")
plt.bar(["-1",'1'], [y_m1,y_1])
```

```
Number of healthy entity: 268
Number of diabetic patients: 500
```

Out[3]:
```
<BarContainer object of 2 artists>
```



In [4]:
```
# Combine in one dataset for further processing
dataset = hstack((y.reshape(768,1), X)).toarray()
```

In [5]:
```
# A peak of the whole dataset
dataset
```

Out[5]:
```
array([[-1.        , -0.294118  ,  0.487437  , ...,  0.00149028,
        -0.53117   , -0.0333333 ],
       [ 1.        , -0.882353  , -0.145729  , ..., -0.207153  ,
        -0.766866  , -0.666667  ],
       [-1.        , -0.0588235 ,  0.839196  , ..., -0.305514  ,
        -0.492741  , -0.633333  ],
       ...,
       [ 1.        , -0.411765  ,  0.21608   , ..., -0.219076  ,
        -0.857387  , -0.7       ],
       [-1.        , -0.882353  ,  0.266332  , ..., -0.102832  ,
        -0.768574  , -0.133333  ],
       [ 1.        , -0.882353  , -0.0653266 , ..., -0.0938897 ,
        -0.797609  , -0.933333  ]])
```

In [6]:
```
# Split the whole dataset into training, validation and testing set in a rat
training_set_whole, testing_set = train_test_split(dataset, train_size=0.85,
                                             stratify=dataset[:,0], random_s
training_set, validation_set = train_test_split(training_set_whole, train_si
                                               stratify=training_set_whole[:
```

In [7]:
```
# Split into X(features) and y(label)
X_train = training_set[:,1:]
y_train = training_set[:,0:1]
X_valid = validation_set[:,1:]
y_valid = validation_set[:,0:1]
X_test = testing_set[:,1:]
y_test = testing_set[:,0:1]
```

In [8]:
```
# Check the shape of the datasets
print(f"Shape of X_train: {X_train.shape}")
print(f"Shape of y_train: {y_train.shape}")
print(f"Shape of X_valid: {X_valid.shape}")
print(f"Shape of y_valid: {y_valid.shape}")
print(f"Shape of X_test: {X_test.shape}")
print(f"Shape of y_test: {y_test.shape}")
```

```
Shape of X_train: (534, 8)
Shape of y_train: (534, 1)
Shape of X_valid: (118, 8)
Shape of y_valid: (118, 1)
Shape of X_test: (116, 8)
Shape of y_test: (116, 1)
```

Perceptron building

In [9]:
```
# A perceptron class to perform training, plotting etc functions
class Perceptron:
    def __init__(self):
        # Dataset
        self._X = None
        self._y = None
        self._X_valid = None
        self._y_valid = None
        # Learning rate
        self._learning_rate = 0
        # Weight
        np.random.seed(0)
        self._weight = None
        self._best_weight = None
        # Early stopping
        self._early_stopping_cycle = 0
```

```
        self._stop_counter = 0
        self._max_iteration = 0
        self._iteration = 1
        # Cost function
        self._gradient = None
        self._loss = 0
        self._accuracy = 0
        self._best_loss = np.inf
        self._best_accuracy = 0
        self._loss_list = []
        self._accuracy_list = []
        self._valid_accuracy = 0
        self._valid_accuarcy_list = []
        # Batch Size
        self._batch_size = 0
        self._execution_time = 0

    # Train the preceptron
    def train(self, X=None, y=None, max_iteration=1000, learning_rate=0.1,
              early_stopping_cycle=10, verbose=0, batch_size = None):
        # Instantiate variables from parameters
        self._X = np.vstack((np.ones((1,X.shape[0])), X.T)).T
        self._y = y
        self._max_iteration = max_iteration
        self._learning_rate = learning_rate
        self._early_stopping_cycle = early_stopping_cycle
        self._weight = np.random.uniform(low=-100, high=100, size=self._X[0,
        if batch_size == None:
                self._batch_size = self._y.shape[0]
        else:
            self._batch_size = batch_size
        # Training loop
        start_time = time.time()
        while self._iteration < self._max_iteration :
            # Cost function calculation
            self._gradient = np.zeros(self._X[0,:].shape[0])
            self._loss = 0
            row_count = 0
            while True:
                try:
                    for row in range(self._batch_size):
                        if self._y[row_count+row]*(self._X[row_count+row].dc
                            self._gradient += self._y[row_count+row]*self._X
                            self._loss += -self._y[row_count+row]*(self._X[r
                    row_count += row +1
                except:
                    break

                self._weight = self._weight + self._learning_rate*self._grad

            # Early Stopping
            self._accuracy = 0
            in_loop_predication = []
            for i in range(self._X.shape[0]):
                if self._X[i].dot(self._weight) <= 0:
                    in_loop_predication.append(-1)
                else:
                    in_loop_predication.append(1)
            self._accuracy = accuracy_score(y_pred= in_loop_predication, y_t

            if self._accuracy > self._best_accuracy:
                self._best_accuracy = self._accuracy
                self._best_weight = self._weight
                self._stop_counter = 0
```

```
            else:
                self._stop_counter += 1

            if  self._stop_counter > self._early_stopping_cycle:
                break

            # Mismatch and accuracy list for plotting graph
            self._loss_list.append(self._loss)
            self._accuracy_list.append(self._accuracy)

            # Showing training details
            if verbose == 1:
                print(f"iteration: {self._iteration}")
                print(f"loss: {self._gradient}")
                print(f"weight: {self._weight}")
                print("")

            # Count for finishing an iteration
            self._iteration += 1

        # Final error and weight
        if verbose == 1:
            print(f"Best weight: {self._best_weight}")
            print("")
        self._execution_time = time.time() - start_time
        print(f"execution time: {self._execution_time}")
    # Plot the learning curve
    def learning_curve(self, save=False):
        fig, ax = plt.subplots(1,1, figsize=[6,6])
        ax.scatter([i for i in range(len(self._accuracy_list))], self._accur
        ax.scatter([i for i in range(len(self._loss_list))], [i/max(self._lo
        ax.legend()
        ax.set_title(f"Learning curve of the perceptron: batch_size={self._b
        ax.set_xlabel("Epoch")
        ax.set_ylabel("Accuracy/Loss")

        if save == True:
            fig.savefig(f"/Users/fuchuenli/Desktop/Year 1/Trimester 3/COMP S

    # Predict new data
    def predict(self, df):
        prediction = []
        df = np.vstack((np.ones((1,df.shape[0])), df.T)).T
        for i in range(df.shape[0]):
            if df[i].dot(self._best_weight) < 0:
                prediction.append(-1)
            else:
                prediction.append(1)
        return prediction
```

Artificial Linearly Separable Dataset

In [10]:

```
# Create artificial data
np.random.seed(0)
artificial_data_x = np.concatenate([np.random.normal(0,2,500), np.random.nor
artificial_data_y = np.concatenate([np.random.normal(0,2,500), np.random.nor
artificial_data_label = np.concatenate([np.full((1,500), -1)[0], np.ones((1,
```

In [11]:

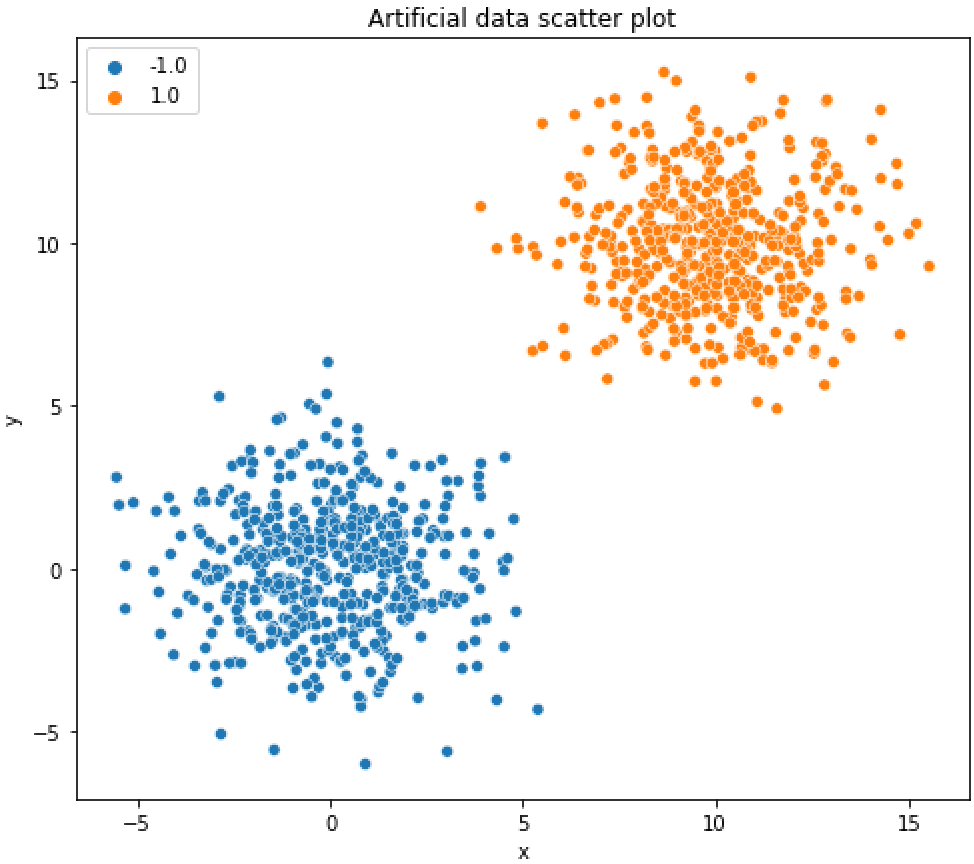
```
# Add bias to artificial data
artificial_dataset = np.vstack([np.vstack([artificial_data_x.T, artificial_d
```

```
artificial_dataset
```

Out[11]:
```
array([[ 3.52810469,  1.11192536, -1.        ],
       [ 0.80031442,  1.78494777, -1.        ],
       [ 1.95747597, -0.84462965, -1.        ],
       ...,
       [10.1883846 , 10.31686769,  1.        ],
       [ 7.70477811,  7.71619716,  1.        ],
       [ 9.28377185,  7.37805926,  1.        ]])
```

In [12]:
```
# Scatter plot of the artificial data
fig, ax = plt.subplots(1,1,figsize=[8,7])
sns.scatterplot(data=artificial_dataset, x=artificial_dataset[:,0], y=artifi
ax.set_xlabel("x")
ax.set_ylabel("y")
ax.set_title("Artificial data scatter plot")
#fig.savefig("/Users/fuchuenli/Desktop/Year 1/Trimester 3/COMP SCI 7318/Week
```

Out[12]:
```
Text(0.5, 1.0, 'Artificial data scatter plot')
```



In [13]:
```
# Split dataset in artificial data
art_training_set, art_testing_set = train_test_split(artificial_dataset, tra
```

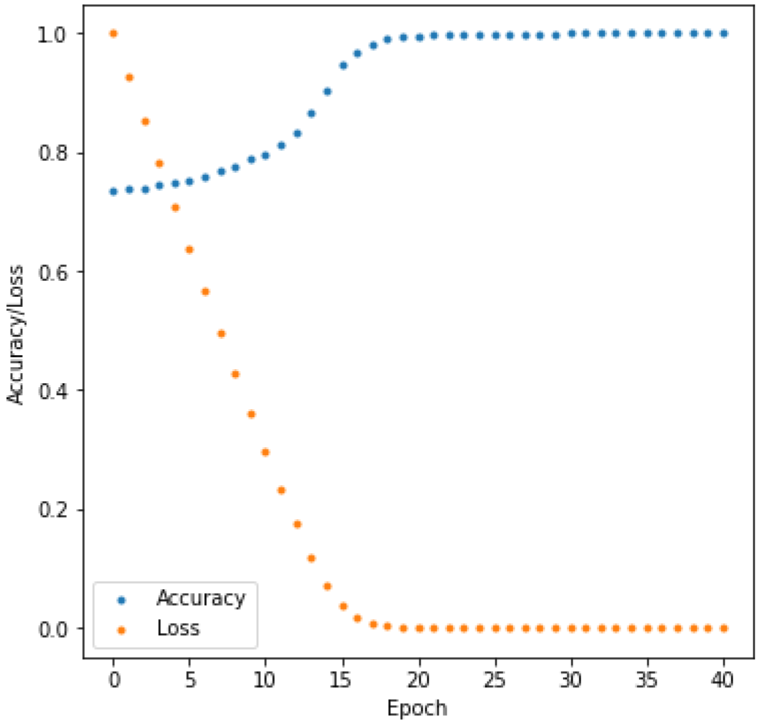
In [14]:
```
# features and a label of artificial data
art_train_X = art_training_set[:, 0:2]
art_train_y = art_training_set[:,2]
art_test_X = art_testing_set[:, 0:2]
art_test_y = art_testing_set[:, 2]
```

In [15]:
```
# Build, train and plot the perceptron model for artificial dataset
# Instantiate a perceptron object
art_perceptron = Perceptron()
# Train the perceptron
art_perceptron.train(X=art_train_X, y=art_train_y, max_iteration=1000,
        early_stopping_cycle=10, learning_rate=0.01, verbose=0)
```

```
# Plot the learning curve
art_perceptron.learning_curve()
```

```
execution time: 0.04526090621948242
```

Learning curve of the perceptron: batch_size=700 learning_rate=0.01



In [16]:
```
# Accuracy of perceptron model in artificial data testing set
accuracy_score(y_pred=art_perceptron.predict(art_test_X), y_true=art_test_y)
```

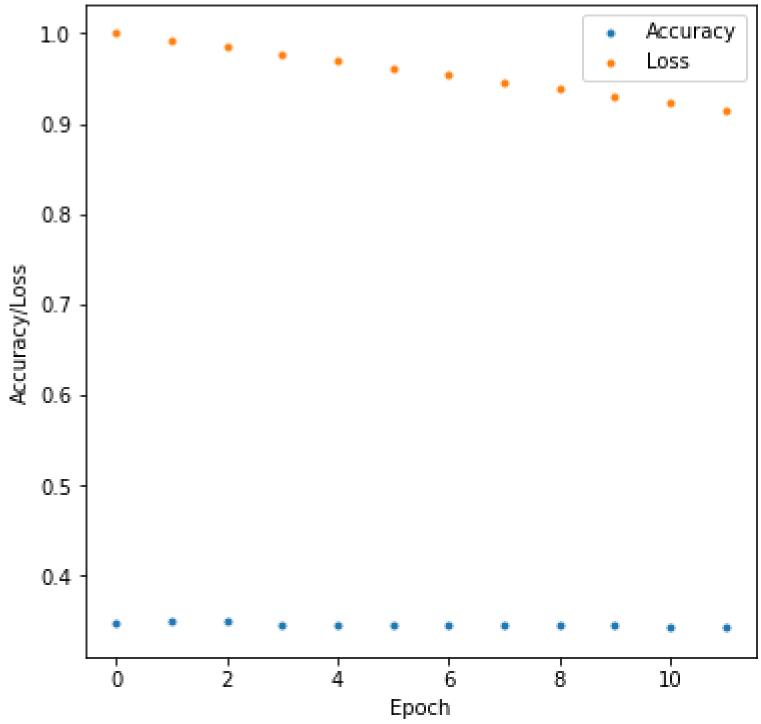
Out[16]: `1.0`

Diabetes Dataset

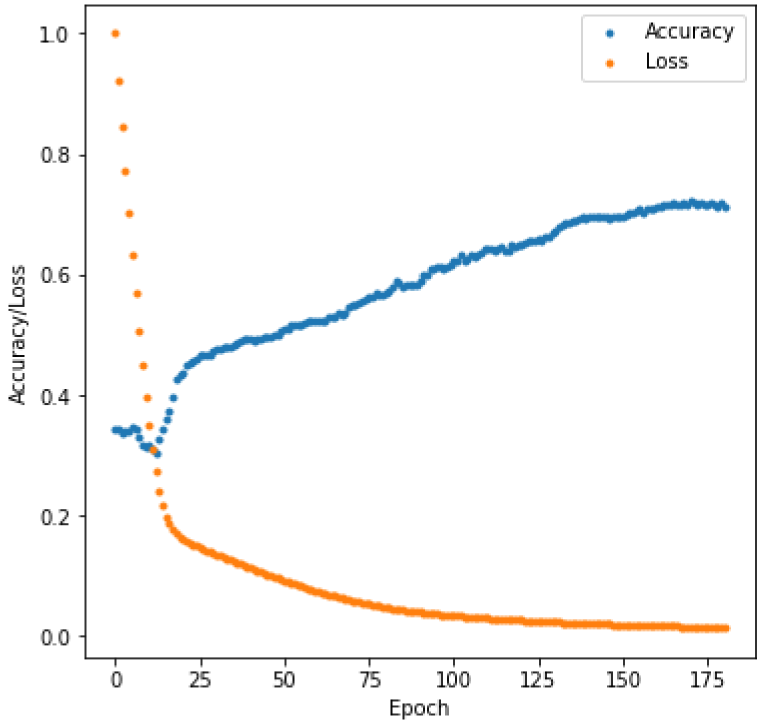
In [17]:
```
#comprehensive learning rate comparsion
learning_rate = [1e-3, 1e-2, 1e-1, 1]
for lr in learning_rate:
    # Instantiate a perceptron object
    perceptron = Perceptron()
    # Train the perceptron
    perceptron.train(X=X_train, y=y_train, max_iteration=1000,
                     early_stopping_cycle=10, learning_rate=lr, verbose=0)
    # Plot the learning curve
    perceptron.learning_curve()
```

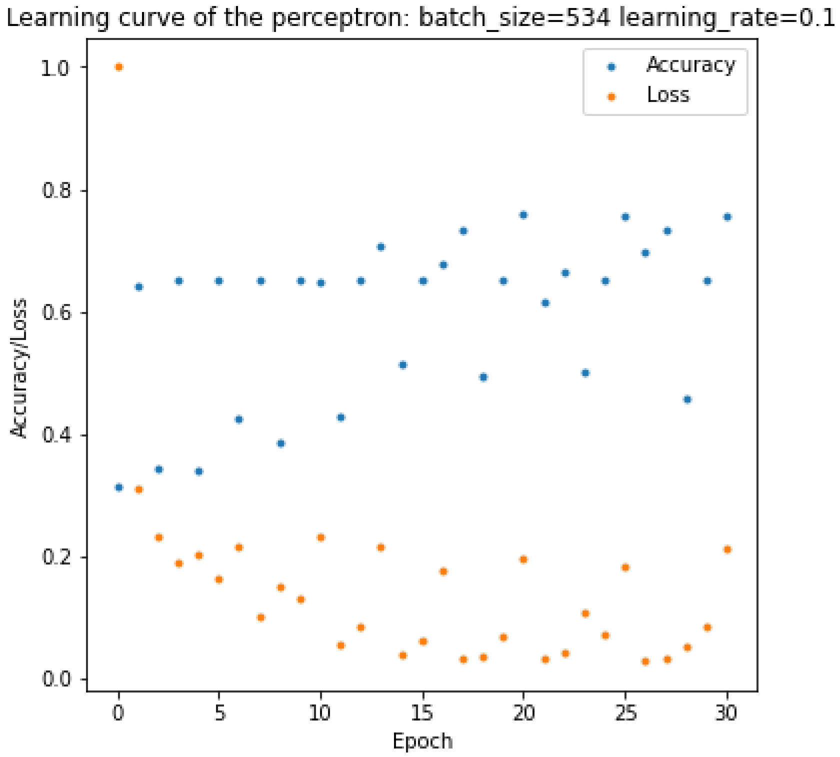
```
execution time: 0.036656856536865234
execution time: 0.3325519561767578
execution time: 0.05727124214172363
execution time: 0.06219196319580078
```

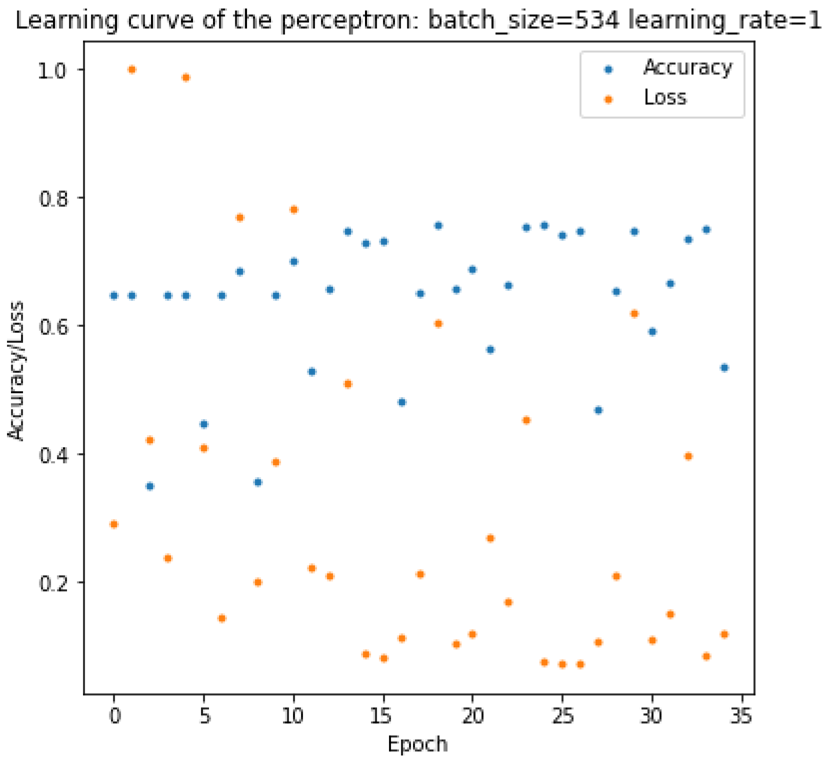
Learning curve of the perceptron: batch_size=534 learning_rate=0.001



Learning curve of the perceptron: batch_size=534 learning_rate=0.01



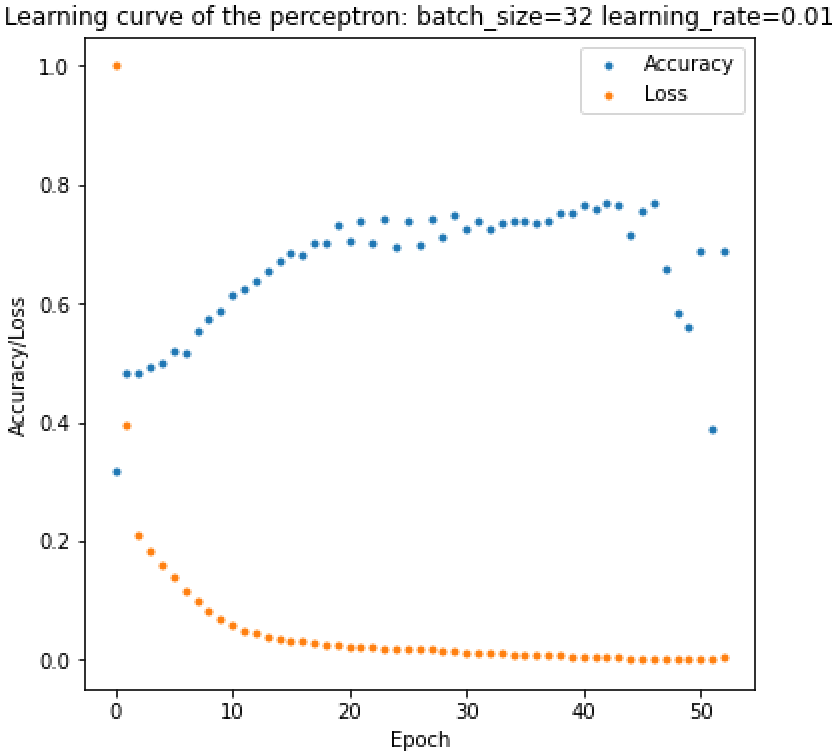


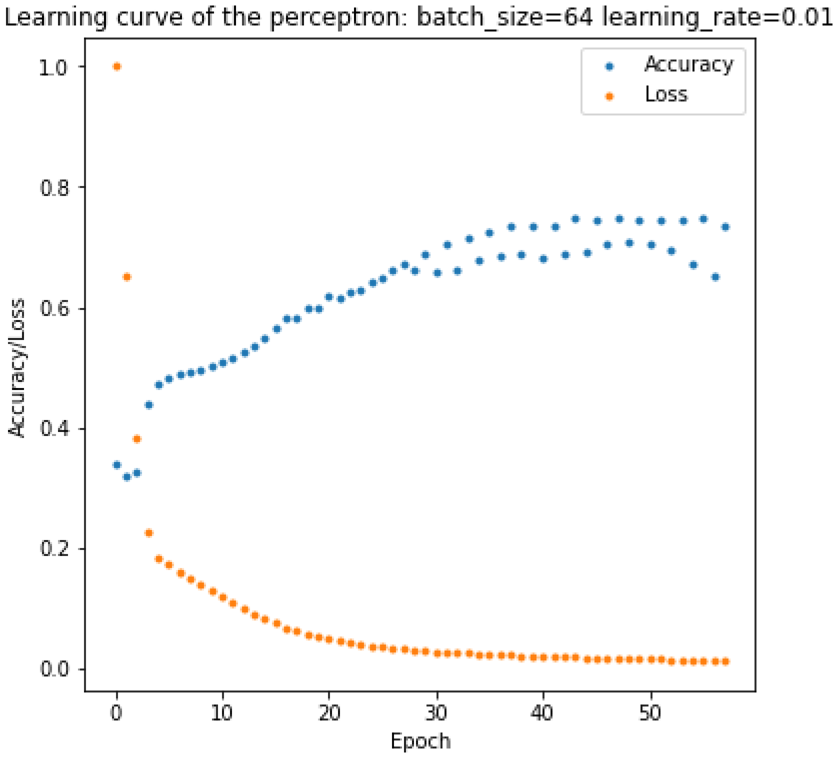


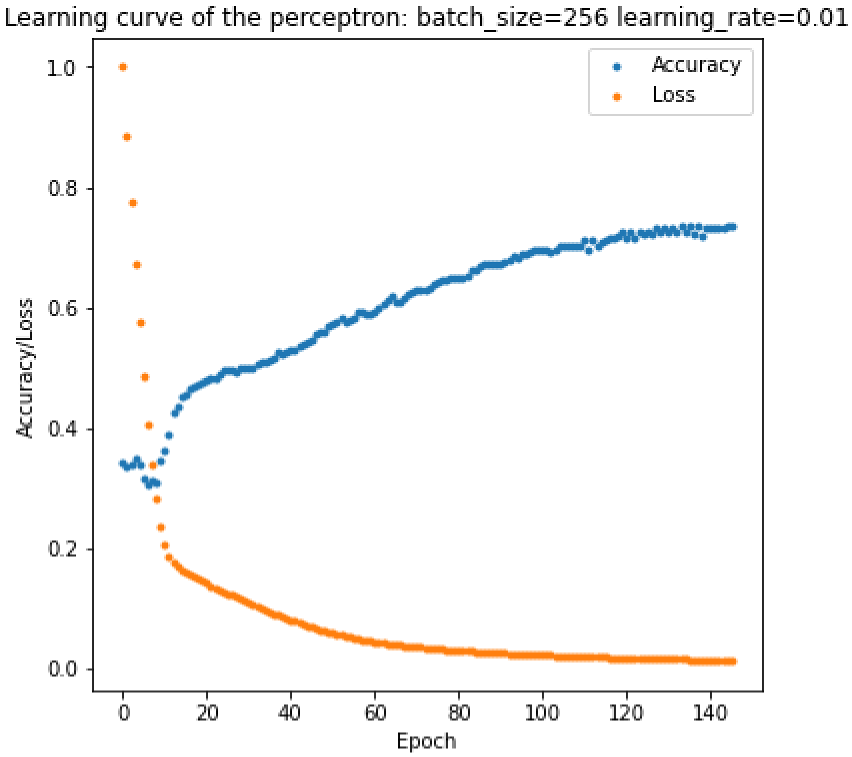
In [18]:

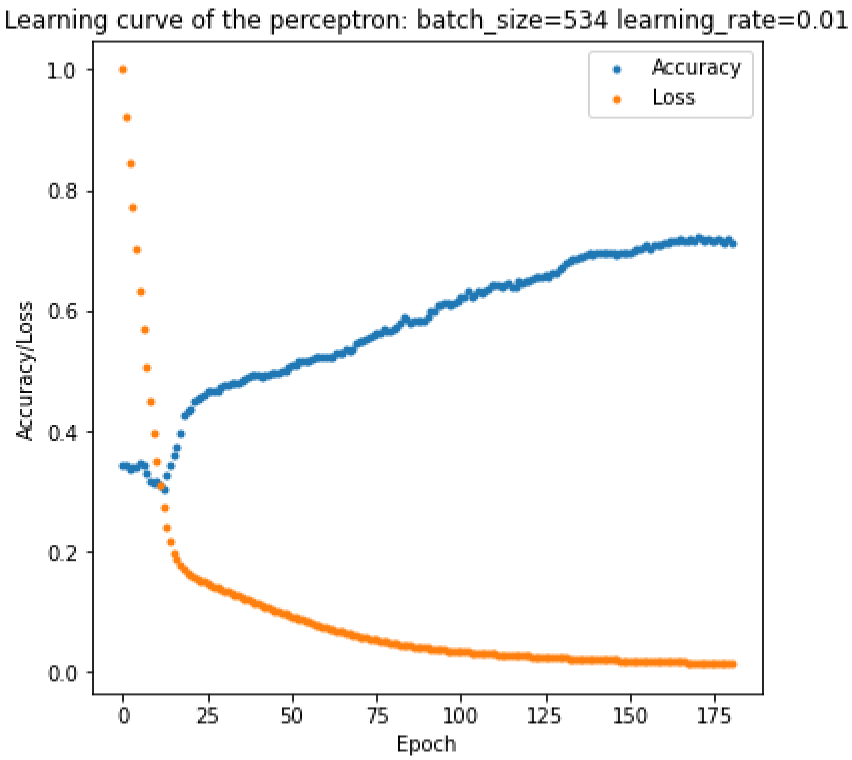
```
# Comprehensive batch size comparsion
batch_sizes = [32, 64, 256, None]
for batch_size in batch_sizes:
    # Instantiate a perceptron object
    perceptron = Perceptron()
    # Train the perceptron
    perceptron.train(X=X_train, y=y_train, max_iteration=1000,
            early_stopping_cycle=10, learning_rate=0.01, verbose=0, batch_si
    # Plot the learning curve
    perceptron.learning_curve()
    print(f"Validation accuracy: {accuracy_score(y_pred=perceptron.predict(X
```

```
execution time: 0.09664583206176758
Validation accuracy: 0.7966101694915254
execution time: 0.10820293426513672
Validation accuracy: 0.788135593220339
execution time: 0.2575252056121826
Validation accuracy: 0.7457627118644068
execution time: 0.3237271308898926
Validation accuracy: 0.7457627118644068
```









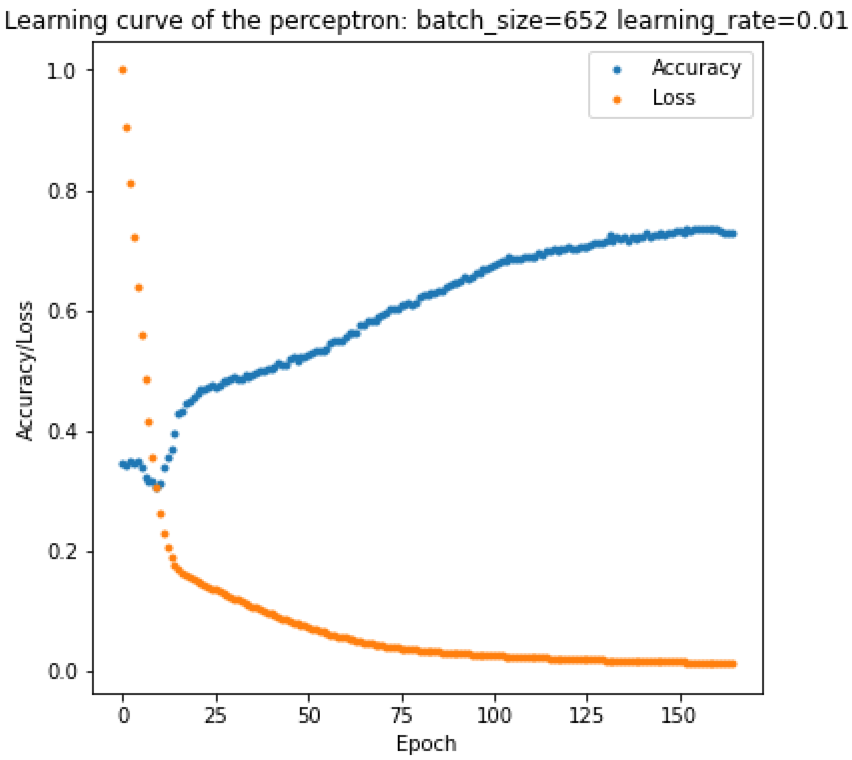
Final Model Evaluation

In [19]:
```
# Split the whole training set(including training and validation set)into X(
X_train_whole = training_set_whole[:,1:]
y_train_whole = training_set_whole[:,0:1]
```

In [20]:
```
# Instantiate a perceptron object
perceptron = Perceptron()
# Train the perceptron
perceptron.train(X=X_train_whole, y=y_train_whole, max_iteration=1000,
        early_stopping_cycle=10, learning_rate=1e-2, verbose=0, batch_size=N
```

```python
# Plot the learning curve
perceptron.learning_curve()
```

```
execution time: 0.365537166595459
```



In [21]:
```python
# Accuracy of the test set
accuracy_score(y_pred=perceptron.predict(X_test), y_true=y_test)
```

Out[21]:
```
0.6982758620689655
```

In [22]:
```python
# Recall rate of test set
recall_score(y_pred=perceptron.predict(X_test), y_true=y_test)
```

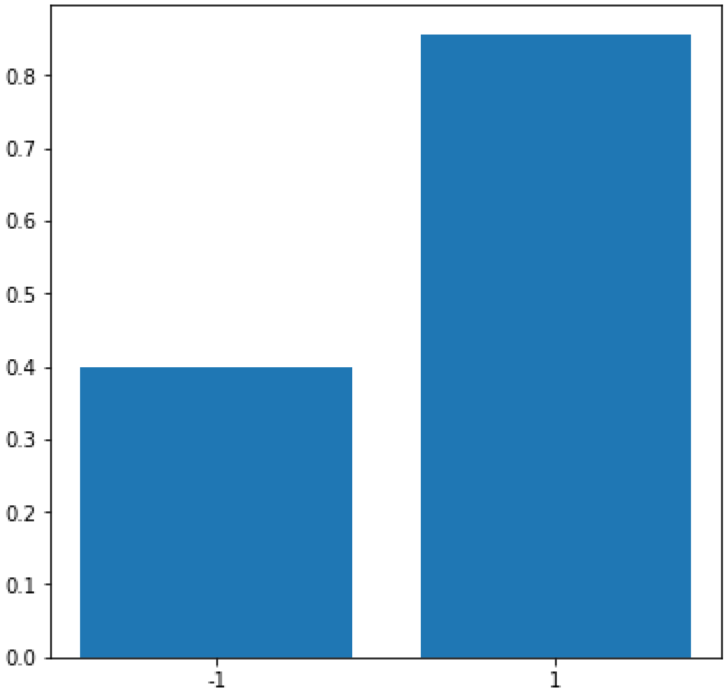
Out[22]:
```
0.8552631578947368
```

In [23]:
```python
# Calculate the accuracy of predicting -1 and 1
y_pred = perceptron.predict(X_test)
acc_m1 = 0
acc_1 = 0
for i in range(len(y_pred)):
    if y_pred[i] == -1 and y_test.ravel()[i] == -1:
        acc_m1 += 1
    if y_pred[i] == 1 and y_test.ravel()[i] == 1:
        acc_1 += 1
print(f"Accuracy of 1: {acc_1/y_test.ravel().tolist().count(1)}")
print(f"Accuracy of -1: {acc_m1/y_test.ravel().tolist().count(-1)}")
```

```
Accuracy of 1: 0.8552631578947368
Accuracy of -1: 0.4
```

In [24]:
```python
# Plot the distribution of accuracy of -1 and 1
fig, ax = plt.subplots(1,1, figsize=[6,6])
plt.bar(["-1","1"], [acc_m1/y_test.ravel().tolist().count(-1), acc_1/y_test.
#fig.savefig("/Users/fuchuenli/Desktop/Year 1/Trimester 3/COMP SCI 7318/Week
```

Out[24]:
```
<BarContainer object of 2 artists>
```



In [ ]: