In [3]:

```
# -*- coding: utf-8 -*-
"""
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"""
import numpy as np
from requiredFunctions.trainMLP import trainMLP
from requiredFunctions.MLP import MLP
from requiredFunctions.doubleMoon import doubleMoon
import matplotlib as mpl
import matplotlib.pyplot as plt
import matplotlib.ticker as mtick

height = 10
width = 10

mpl.rcParams['figure.figsize'] = (width, height)
mpl.rcParams['font.size'] = 20
mpl.rcParams['figure.titlesize'] = 'small'
mpl.rcParams['legend.fontsize'] = 'small'
mpl.rcParams['xtick.major.size'] = 12
mpl.rcParams['xtick.minor.size'] = 8
mpl.rcParams['xtick.labelsize'] = 18
mpl.rcParams['ytick.major.size'] = 12
mpl.rcParams['ytick.minor.size'] = 8
mpl.rcParams['ytick.labelsize'] = 18

cmap = plt.get_cmap('Paired')
cmap_scatter = mpl.colors.ListedColormap(cmap((1, 3, 5)))
cmap_contour = mpl.colors.ListedColormap(cmap((0, 2)))
titles = (('a', 'b'), ('c', 'd'), ('e', 'f'))

# Data parameters
N = 300
r = 1
w = 0.6
d = -0.5

# Model parameters
learning_rate = 1e-4
alpha = 0
epochs = 1000
```
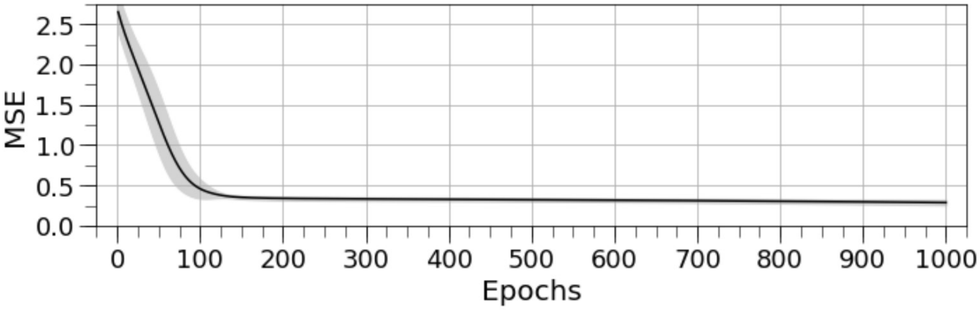
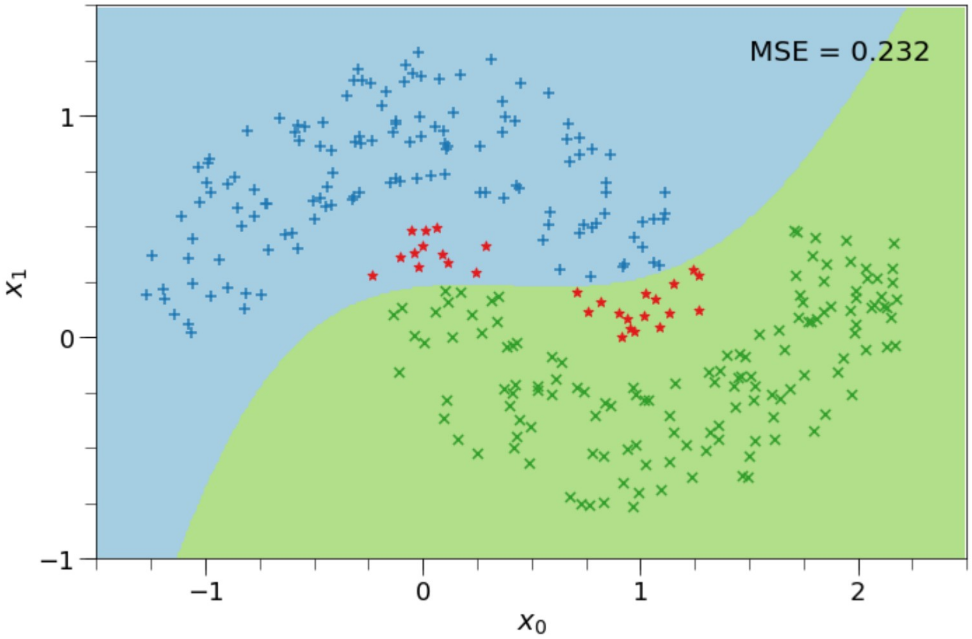
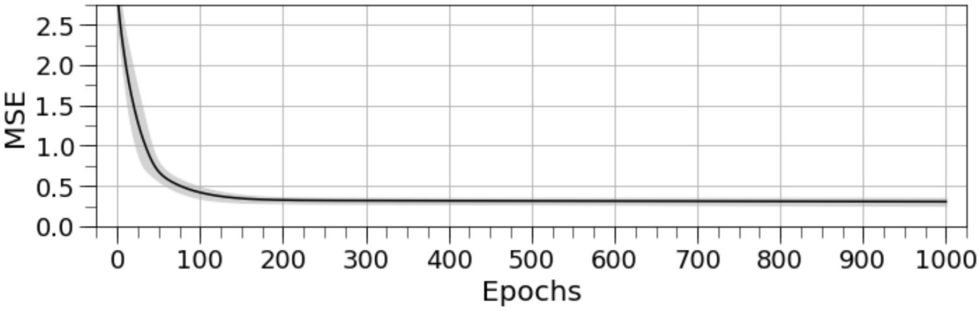

In [4]:

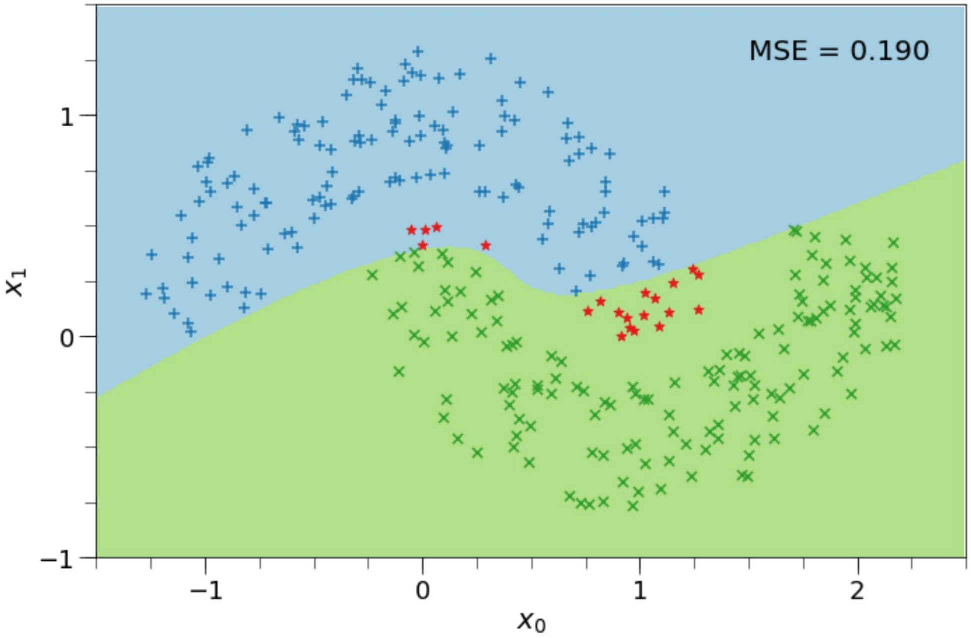
```
layers = {0:[10,], 1:[6,4], 2:[5,3,2]}
best_mse = np.inf
for i in range(3):
    # Part 1
    trials = 10
    trial_mse = np.zeros((trials, epochs))
    for t in range(trials):
        data = doubleMoon(N, w, r, d, seed=t)
        x_train, y_train = data[:,:2], data[:,2]
        x_train, y_train = x_train.T, y_train.reshape(1, len(y_train))
        wh, wo, mse = trainMLP(x_train, y_train, layers[i], learning_rate, alpha, epochs, verbose=False)
        trial_mse[t] = mse.flatten()
        if mse.flatten()[-1] < best_mse:
            best_wh, best_wo, best_mse = wh, wo, mse.flatten()[-1]

    mse_avg = trial_mse.mean(axis=0)
    mse_std = trial_mse.std(axis=0)
    print(len(layers[i]), 'Layers, Best Final MSE:', best_mse)

    epoch_grid = np.arange(1, epochs+1, 1)

    fig = plt.figure()
    ax = [plt.subplot2grid((3,1), (0,0), colspan=1, rowspan = 1, fig=fig),
          plt.subplot2grid((3,1), (1,0), colspan=1, rowspan = 2, fig=fig)]

    ax[0].plot(epoch_grid, mse_avg, color='black')
    ax[0].fill_between(epoch_grid, mse_avg - mse_std, mse_avg + mse_std, color='lightgray')
    ax[0].xaxis.set_major_locator(mtick.MultipleLocator(100))
    ax[0].xaxis.set_minor_locator(mtick.MultipleLocator(25))
    ax[0].yaxis.set_major_locator(mtick.MultipleLocator(0.5))
    ax[0].yaxis.set_minor_locator(mtick.MultipleLocator(0.25))
    ax[0].set_xlim(-25, epochs+25)
    ax[0].set_ylim(0, 2.75)
    ax[0].set_xlabel('Epochs')
    ax[0].set_ylabel('MSE')
    ax[0].grid()

    # Part 2
    test_data = doubleMoon(N, w, r, d, seed=100)
    x_test, y_test = test_data[:,:2], test_data[:,2]
    x_test, y_test = x_test.T, y_test.reshape(1, len(y_test))

    #x_test, y_test = x_train, y_train

    y_pred = MLP(x_test, best_wh, best_wo).flatten()
    y_test = y_test.flatten()
    x_test = x_test.T
    y_pred[y_pred > 0] = 1
    y_pred[y_pred < 0] = -1

    y_right = np.where(y_pred == y_test)[0]
    y_wrong = np.where(y_pred != y_test)[0]
    blue_ind = y_right[np.where(y_test[y_right]==-1)]
    green_ind = y_right[np.where(y_test[y_right]==1)]

    x0_min, x0_max = -1.5, 2.5
    x1_min, x1_max = -1, 1.5
    xx0, xx1 = np.meshgrid(np.arange(x0_min, x0_max, 0.01),
                           np.arange(x1_min, x1_max, 0.01))
    cc = MLP(np.c_[xx0.ravel(), xx1.ravel()].T, best_wh, best_wo)
    cc[cc > 0] = 1
    cc[cc < 0] = -1
    cc = cc.reshape(xx0.shape)

    ax[1].contourf(xx0, xx1, cc, cmap=cmap_contour)
    ax[1].scatter(x_test[:,0][blue_ind], x_test[:,1][blue_ind], 50,
                  c=[cmap_scatter(0)], marker='+')
    ax[1].scatter(x_test[:,0][green_ind], x_test[:,1][green_ind], 50,
                  c=[cmap_scatter(1)], marker='x')
    ax[1].scatter(x_test[:,0][y_wrong], x_test[:,1][y_wrong], 50,
                  c=[cmap_scatter(2)], marker='*')
    ax[1].set_xlim(x0_min, x0_max)
    ax[1].set_ylim(x1_min, x1_max)
    ax[1].xaxis.set_major_locator(mtick.MultipleLocator(1))
    ax[1].xaxis.set_minor_locator(mtick.MultipleLocator(0.25))
    ax[1].yaxis.set_major_locator(mtick.MultipleLocator(1))
    ax[1].yaxis.set_minor_locator(mtick.MultipleLocator(0.25))
    ax[1].set_xlabel(r'$x_0$')
    ax[1].set_ylabel(r'$x_1$')
    ax[1].text(1.5, 1.25, 'MSE = {:.3f}'.format(best_mse))
    fig.tight_layout(pad=0.5)
    #fig.savefig('../prob1' + str(titles[i][0]) + str(titles[i][1]) + '.eps', dpi=500)
```

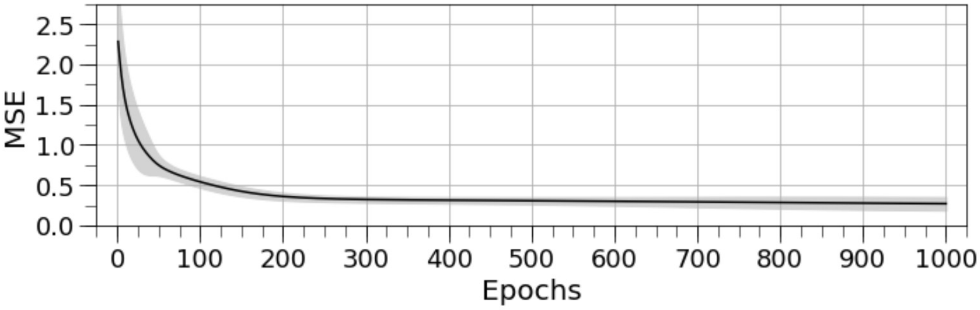
```
1 Layers, Best Final MSE: 0.23182632470268116
2 Layers, Best Final MSE: 0.18986019943346888
3 Layers, Best Final MSE: 0.10508344094404794
```

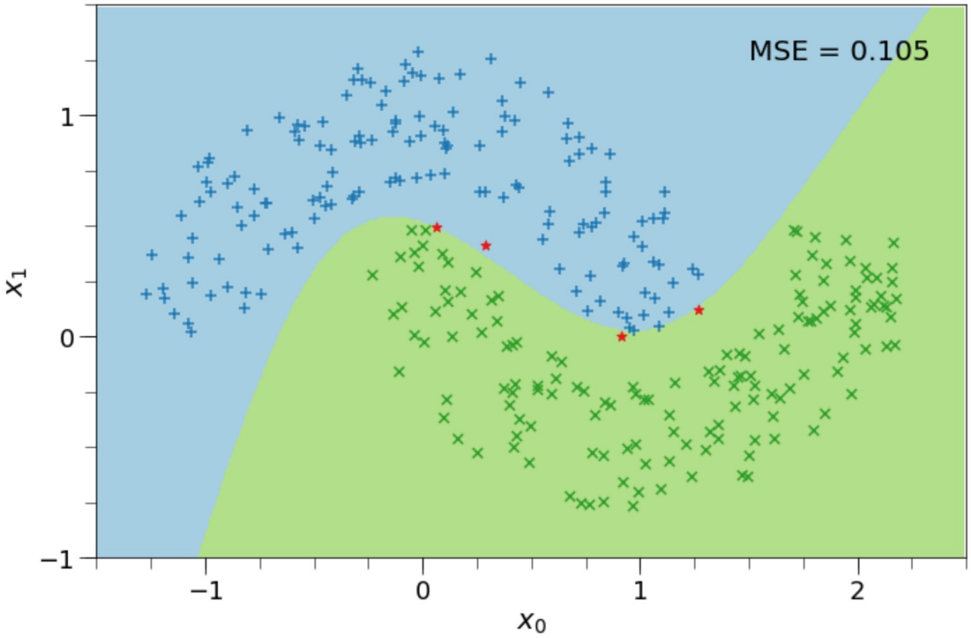





MSE
2.5
2.0
1.5
1.0
0.5
0.0
0
100
200
300
400
500
600
700
800
900
1000
Epochs


MSE = 0.190
x_1
1
0
−1
−1
0
1
2
x_0


MSE
2.5
2.0
1.5
1.0
0.5
0.0
0
100
200
300
400
500
600
700
800
900
1000
Epochs


MSE = 0.105
x_1
1
0
−1
−1
0
1
2
x_0