

**Wine Dataset**

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## Dataset Assign

```
from google.colab import drive
drive.mount('/content/drive')

Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/content/drive", force_remount)

import os, sys
file_id = "1gJ0729q2mUayPsff6Q9iH3PE931meG-d"
downloaded_name = "dataset_downloaded"

import subprocess, shlex
try:
    !gdown --id {file_id} -O {downloaded_name} || true
except Exception as e:
    print("gdown attempt failed:", e)

candidates = [f for f in os.listdir('.') if f.startswith(downloaded_name)]
print("Downloaded candidates:", candidates)

if len(candidates) == 0:
    print("No file was downloaded.")
DATASET_PATH = None

if len(candidates) > 0:
    DATASET_PATH = candidates[0]
    print("Using downloaded file:", DATASET_PATH)

if DATASET_PATH is None:
    DATASET_PATH = "/content/drive/MyDrive/dataset.csv"
    print("Fallback DATASET_PATH:", DATASET_PATH)

/usr/local/lib/python3.12/dist-packages/gdown/__main__.py:140: FutureWarning: Option `--id` was deprecated in version 2.0.0. Use `id` instead.
  warnings.warn(
Downloading...
From: https://drive.google.com/uc?id=1gJ0729q2mUayPsff6Q9iH3PE931meG-d
To: /content/dataset_downloaded
100% 390k/390k [00:00<00:00, 98.3MB/s]
Downloaded candidates: ['dataset_downloaded']
Using downloaded file: dataset_downloaded
```

## 2. Imports

```
import warnings
warnings.filterwarnings("ignore")
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
sns.set(style="whitegrid")
from sklearn.model_selection import train_test_split, learning_curve
from sklearn.preprocessing import StandardScaler, LabelEncoder, OneHotEncoder,
from sklearn.compose import ColumnTransformer
```

```
from sklearn.impute import SimpleImputer
from sklearn.pipeline import Pipeline
from sklearn.utils import shuffle
from sklearn.metrics import (confusion_matrix, classification_report, roc_curve,
                             roc_auc_score, precision_recall_fscore_support, accuracy_score)
from sklearn.metrics import ConfusionMatrixDisplay
from sklearn.linear_model import LogisticRegression
from sklearn.neighbors import KNeighborsClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC
```

### 3. Load dataset (automatically detect CSV)

```
def load_dataset(path):
    if not os.path.exists(path):
        raise FileNotFoundError(f"Dataset not found at: {path}")
    try:
        df = pd.read_csv(path)
        print("Loaded CSV with shape:", df.shape)
        return df
    except Exception as e_csv:
        try:
            df = pd.read_excel(path, engine='openpyxl')
            print("Loaded Excel with shape:", df.shape)
            return df
        except Exception as e_xls:
            raise ValueError(f"Failed to read dataset as CSV or Excel. CSV error: {e_csv}, Excel error: {e_xls}")
    try:
        df = load_dataset(DATASET_PATH)
    except Exception as e:
        print("Error loading dataset:", e)
        raise
    print("\nFirst five rows:")
    display(df.head())
    print("\nDataset info:")
    display(df.info())
    print("\nMissing values per column:")
    display(df.isnull().sum())
```

Loaded CSV with shape: (6497, 13)

First five rows:

	type	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	density	pH	sulphates	alcohol	quality
0	white	7.0	0.27	0.36	20.7	0.045	45.0	170.0	1.0010	3.00	0.45	8.8	6
1	white	6.3	0.30	0.34	1.6	0.049	14.0	132.0	0.9940	3.30	0.49	9.5	6
2	white	8.1	0.28	0.40	6.9	0.050	30.0	97.0	0.9951	3.26	0.44	10.1	6
3	white	7.2	0.23	0.32	8.5	0.058	47.0	186.0	0.9956	3.19	0.40	9.9	6
4	white	7.2	0.23	0.32	8.5	0.058	47.0	186.0	0.9956	3.19	0.40	9.9	6

Dataset info:

<class 'pandas.core.frame.DataFrame'>

RangeIndex: 6497 entries, 0 to 6496

Data columns (total 13 columns):

#	Column	Non-Null Count	Dtype
0	type	6497 non-null	object
1	fixed acidity	6487 non-null	float64
2	volatile acidity	6489 non-null	float64
3	citric acid	6494 non-null	float64
4	residual sugar	6495 non-null	float64
5	chlorides	6495 non-null	float64
6	free sulfur dioxide	6497 non-null	float64
7	total sulfur dioxide	6497 non-null	float64
8	density	6497 non-null	float64
9	pH	6488 non-null	float64
10	sulphates	6493 non-null	float64
11	alcohol	6497 non-null	float64
12	quality	6497 non-null	int64

dtypes: float64(11), int64(1), object(1)

memory usage: 660.0+ KB

None

Missing values per column:

	0
type	0
fixed acidity	10
volatile acidity	8
citric acid	3
residual sugar	2
chlorides	2
free sulfur dioxide	0
total sulfur dioxide	0
density	0

## 4. Detect target column

sulphates 4

```
possible_targets = ['target', 'label', 'class', 'Class', 'y', 'Y', 'Outcome', 'outcomes']
target_col = None
for name in possible_targets:
    if name in df.columns:
        target_col = name
        break
if target_col is None:
    target_col = df.columns[-1]
print("Auto-detected target column:", target_col)
print("Unique values (up to 20):", df[target_col].unique()[:20])
print("Number of unique labels:", df[target_col].nunique())
```

Auto-detected target column: quality

Unique values (up to 20): [6 5 7 8 4 3 9]

Number of unique labels: 7

## 5. Data cleaning and preprocessing

## 5.1 Remove exact duplicates

```
before = df.shape[0]
df = df.drop_duplicates()
after = df.shape[0]
print(f"Removed {before-after} duplicate rows. New shape: {df.shape}")
```

Removed 1168 duplicate rows. New shape: (5329, 13)

## 5.2 Attempt numeric coercion on object columns (except target)

```
for col in df.columns:
    if col == target_col:
        continue
    if df[col].dtype == object:
        # try to coerce to numeric where possible
        df[col] = pd.to_numeric(df[col].str.replace(',', ''), errors='ignore')
```

## 5.3 Report missing values and handle them

```
print("Missing values before imputation:")
display(df.isnull().sum())
```

Missing values before imputation:

	0
type	0
fixed acidity	10
volatile acidity	8
citric acid	3
residual sugar	2
chlorides	2
free sulfur dioxide	0
total sulfur dioxide	0
density	0
pH	9
sulphates	4
alcohol	0
quality	0

dtype: int64

## Identify numeric and categorical feature columns

```
numeric_cols = df.select_dtypes(include=['number']).columns.tolist()
if target_col in numeric_cols:
    numeric_cols = [c for c in numeric_cols if c != target_col]
categorical_cols = [c for c in df.columns if c not in numeric_cols + [target_col]]

print("Numeric columns:", numeric_cols)
print("Categorical columns:", categorical_cols)
```

Numeric columns: ['fixed acidity', 'volatile acidity', 'citric acid', 'residual sugar', 'chlorides', 'free sulfur dioxide', 'density', 'pH', 'sulphates', 'alcohol', 'quality']  
Categorical columns: ['type']

Impute numeric -> mean, categorical -> most frequent

```

num_imputer = SimpleImputer(strategy='mean')
cat_imputer = SimpleImputer(strategy='most_frequent')

if numeric_cols:
    df[numeric_cols] = num_imputer.fit_transform(df[numeric_cols])
if categorical_cols:
    df[categorical_cols] = cat_imputer.fit_transform(df[categorical_cols])

```

## ▼ Drop rows with missing target if any.

```

if df[target_col].isnull().sum() > 0:
    df = df.dropna(subset=[target_col])
    print("Dropped rows with missing target. New shape:", df.shape)

print("Missing values after imputation:")
display(df.isnull().sum())

```

Missing values after imputation:

	0
type	0
fixed acidity	0
volatile acidity	0
citric acid	0
residual sugar	0
chlorides	0
free sulfur dioxide	0
total sulfur dioxide	0
density	0
pH	0
sulphates	0
alcohol	0
quality	0

dtype: int64

## ▼ 6. Encode target and features

```

le_target = LabelEncoder()
if df[target_col].dtype == object or df[target_col].nunique() <= 50:
    y = le_target.fit_transform(df[target_col].astype(str))
    print("Target label-encoded. Classes:", list(le_target.classes_))
else:

    y = df[target_col].values
    print("Target appears numeric/continuous. If you intended classification, ")
    X = df.drop(columns=[target_col]).copy()
    cat_features = X.select_dtypes(include=['object','category','bool']).columns.to_list()
    int_like = [c for c in X.select_dtypes(include=['int','int64','Int64']).columns]
    for c in int_like:
        if c not in cat_features:
            cat_features.append(c)
    binary_cols = [c for c in cat_features if X[c].nunique() == 2]
    multi_cols = [c for c in cat_features if X[c].nunique() > 2]
    print("Binary categorical columns:", binary_cols)
    print("Multi-class categorical columns:", multi_cols)

transformers = []

```

```

if binary_cols:
    transformers.append(('bin', OrdinalEncoder(), binary_cols))
if multi_cols:
    transformers.append(('ohe', OneHotEncoder(handle_unknown='ignore', sparse=1,
                                             drop='if_binary'), multi_cols))

remainder_cols = [c for c in X.columns if c not in binary_cols + multi_cols]
if transformers:
    ct = ColumnTransformer(transformers=transformers, remainder='passthrough')
    X_trans = ct.fit_transform(X)
    feature_names = []
    if multi_cols:
        ohe = ct.named_transformers_['ohe']
        ohe_names = ohe.get_feature_names_out(multi_cols).tolist()
        feature_names.extend(ohe_names)
    if binary_cols:
        feature_names.extend(binary_cols)
    feature_names.extend(remainder_cols)
    X = pd.DataFrame(X_trans, columns=feature_names)
else:
    X = X.reset_index(drop=True)

print("Feature matrix shape after encoding:", X.shape)

```

Target label-encoded. Classes: ['3', '4', '5', '6', '7', '8', '9']  
 Binary categorical columns: ['type']  
 Multi-class categorical columns: []  
 Feature matrix shape after encoding: (5329, 12)

## ▼ 7. Feature scaling

```

scaler = StandardScaler()
X_scaled = pd.DataFrame(scaler.fit_transform(X), columns=X.columns)
X = X_scaled.copy()
print("Features scaled with StandardScaler.")

Features scaled with StandardScaler.

```

## ▼ 8. Train-test split (80/20)

```

stratify_param = y if (isinstance(y, np.ndarray) and len(np.unique(y)) <= 50) else None
X, y = shuffle(X, y, random_state=42)
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.20, random_state=42, stratify=stratify_param)
print("Train shape:", X_train.shape, "Test shape:", X_test.shape)

Train shape: (4263, 12) Test shape: (1066, 12)

```

## ▼ 9. Define models five classifiers models and train

```

models = {
    "Logistic Regression": LogisticRegression(max_iter=2000),
    "K-Nearest Neighbors": KNeighborsClassifier(n_neighbors=5),
    "Decision Tree": DecisionTreeClassifier(random_state=42),
    "Random Forest": RandomForestClassifier(n_estimators=200, random_state=42),
    "Support Vector Machine": SVC(probability=True, random_state=42)
}

fitted_models = {}
predictions = {}
probabilities = {}

for name, clf in models.items():

```

```

print(f"Training model: {name} ...")
clf.fit(X_train, y_train)
fitted_models[name] = clf
predictions[name] = clf.predict(X_test)
try:
    proba = clf.predict_proba(X_test)
    probabilities[name] = proba
except Exception:
    try:
        dfun = clf.decision_function(X_test)
        if dfun.ndim == 1:
            dfun_scaled = (dfun - dfun.min()) / (dfun.max() - dfun.min() + 1)
            probabilities[name] = np.vstack([1-dfun_scaled, dfun_scaled]).T
        else:
            from scipy.special import softmax
            probabilities[name] = softmax(dfun, axis=1)
    except Exception:
        probabilities[name] = None
print(f"{name} trained.")

print("All models trained.")

Training model: Logistic Regression ...
Logistic Regression trained.
Training model: K-Nearest Neighbors ...
K-Nearest Neighbors trained.
Training model: Decision Tree ...
Decision Tree trained.
Training model: Random Forest ...
Random Forest trained.
Training model: Support Vector Machine ...
Support Vector Machine trained.
All models trained.

```

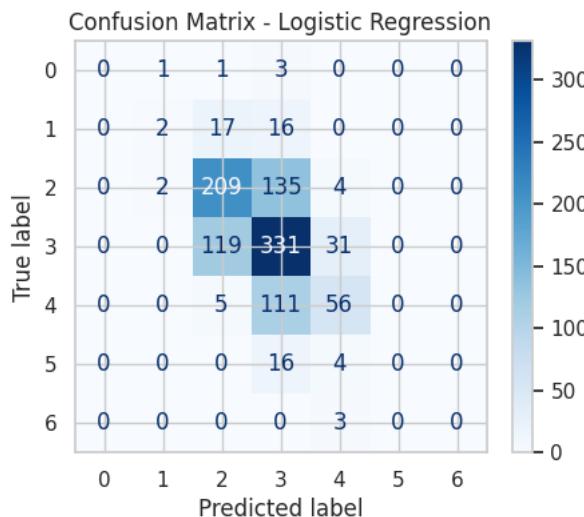
## ▼ 10. Evaluate models: classification report and confusion matrix

```

for name in models.keys():
    print("\n" + "="*40)
    print("Model:", name)
    print(classification_report(y_test, predictions[name], digits=4))
    cm = confusion_matrix(y_test, predictions[name])
    disp = ConfusionMatrixDisplay(confusion_matrix=cm)
    fig, ax = plt.subplots(figsize=(5,4))
    disp.plot(ax=ax, cmap='Blues', values_format='d')
    ax.set_title(f'Confusion Matrix - {name}')
    plt.show()

```

Model: Logistic Regression					
	precision	recall	f1-score	support	
0	0.0000	0.0000	0.0000	5	
1	0.4000	0.0571	0.1000	35	
2	0.5954	0.5971	0.5963	350	
3	0.5408	0.6881	0.6057	481	
4	0.5714	0.3256	0.4148	172	
5	0.0000	0.0000	0.0000	20	
6	0.0000	0.0000	0.0000	3	
accuracy			0.5610	1066	
macro avg	0.3011	0.2383	0.2453	1066	
weighted avg	0.5449	0.5610	0.5393	1066	



Model: K-Nearest Neighbors					
	precision	recall	f1-score	support	
0	0.0000	0.0000	0.0000	5	
1	0.3333	0.2000	0.2500	35	
2	0.5254	0.5914	0.5565	350	
3	0.5573	0.5967	0.5763	481	
4	0.4882	0.3605	0.4147	172	
5	0.1250	0.0500	0.0714	20	
6	0.0000	0.0000	0.0000	3	
accuracy			0.5291	1066	
macro avg	0.2899	0.2569	0.2670	1066	
weighted avg	0.5160	0.5291	0.5192	1066	

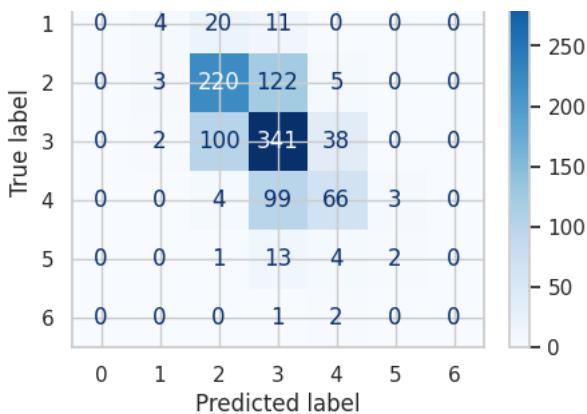
## 11. ROC Curves (binary and multiclass handling)

```
def plot_roc_curve(y_true, y_score, model_name):
    classes = np.unique(y_true)
    if len(classes) == 2:
        if y_score is None:
            print(f"Skipping ROC for {model_name} (no score/probabilities).")
            return
        if y_score.ndim == 2 and y_score.shape[1] == 2:
            pos_score = y_score[:,1]
        elif y_score.ndim == 1:
            pos_score = y_score
        else:
            pos_score = y_score[:,1]
        fpr, tpr, _ = roc_curve(y_true, pos_score)
        roc_auc = auc(fpr, tpr)
        plt.figure()
        plt.plot(fpr, tpr, label=f'{model_name} (AUC = {roc_auc:.4f})')
        plt.plot([0,1],[0,1],'k--')
        plt.xlabel('False Positive Rate')
        plt.ylabel('True Positive Rate')
```

```

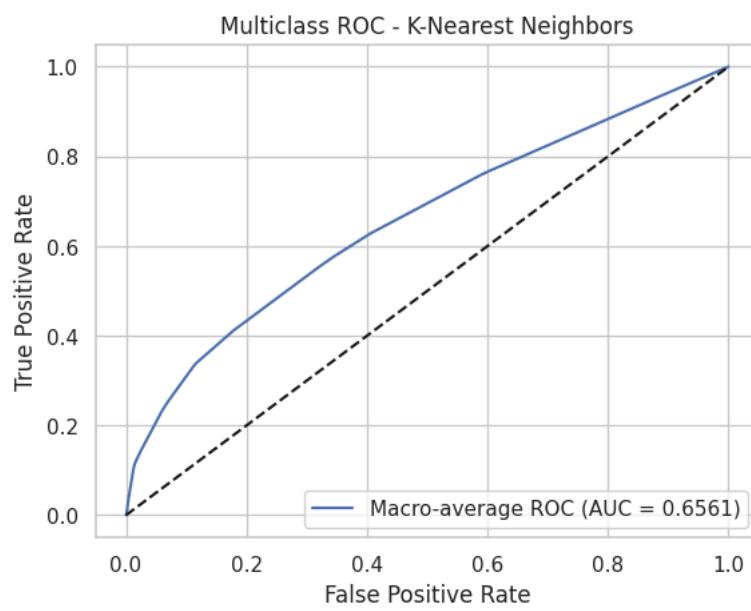
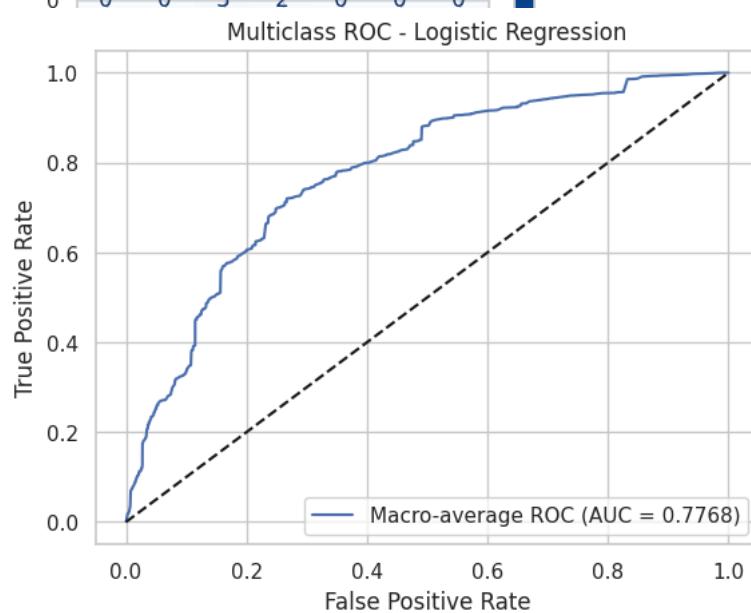
        plt.title(f'ROC Curve - {model_name}')
        plt.legend(loc='lower right')
        plt.show()
    else:
        if y_score is None:
            print(f"Skipping multiclass ROC for {model_name} (no probability output available).")
            return
        try:
            from sklearn.preprocessing import label_binarize
            y_bin = label_binarize(y_true, classes=classes)
            n_classes = y_bin.shape[1]
            if y_score.ndim == 1:
                print(f"Unexpected shape for y_score for multiclass model {model_name}.")
                return
            fpr = dict(); tpr = dict(); roc_auc = dict()
            for i in range(n_classes):
                fpr[i], tpr[i], _ = roc_curve(y_bin[:, i], y_score[:, i])
                roc_auc[i] = auc(fpr[i], tpr[i])
            all_fpr = np.unique(np.concatenate([fpr[i] for i in range(n_classes)]))
            mean_tpr = np.zeros_like(all_fpr)
            for i in range(n_classes):
                mean_tpr += np.interp(all_fpr, fpr[i], tpr[i])
            mean_tpr /= n_classes
            roc_auc["macro"] = auc(all_fpr, mean_tpr)
            plt.figure()
            plt.plot(all_fpr, mean_tpr, label=f'Macro-average ROC (AUC = {roc_auc["macro"]})')
            plt.plot([0,1],[0,1],'k--')
            plt.xlabel('False Positive Rate')
            plt.ylabel('True Positive Rate')
            plt.title(f'Multiclass ROC - {model_name}')
            plt.legend(loc='lower right')
            plt.show()
        except Exception as e:
            print("Failed to compute multiclass ROC for", model_name, ":", e)
    for name in models.keys():
        plot_roc_curve(y_test, probabilities.get(name, None), name)

```

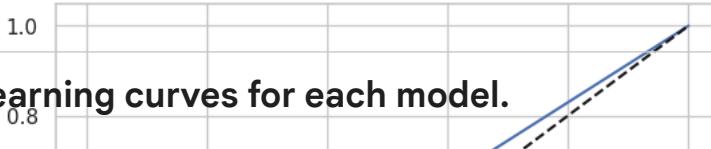


Model: Support Vector Machine				
	precision	recall	f1-score	support
0	0.0000	0.0000	0.0000	5
1	0.0000	0.0000	0.0000	35
2	0.5918	0.6171	0.6042	350
3	0.5417	0.7152	0.6165	481
4	0.0000	0.0000	0.0000	11
5	0.0000	0.0000	0.0000	20
6	0.0000	0.0000	0.0000	3
accuracy			0.5638	1066
macro avg	0.2507	0.2244	0.2236	1066
weighted avg	0.5390	0.5638	0.5321	1066

Confusion Matrix - Support Vector Machine



Multiclass ROC - Decision Tree



▼ **12. Learning curves for each model.**

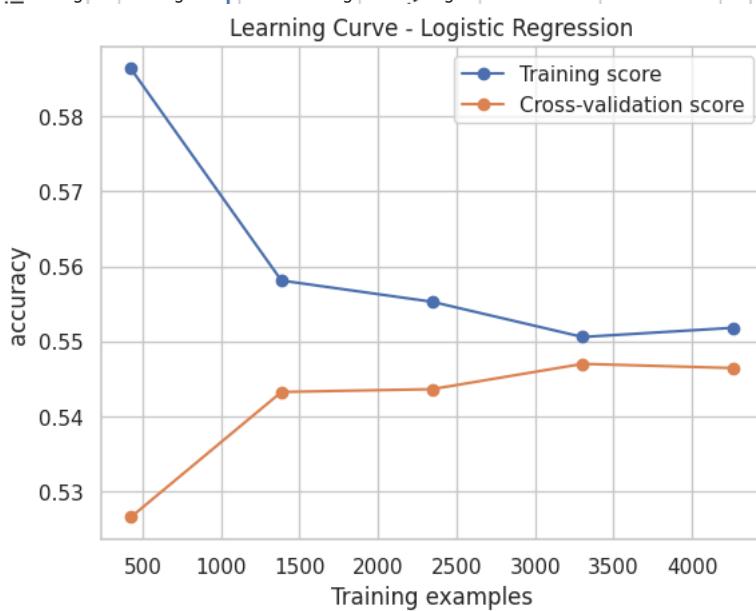
```

def plot_learning_curve(estimator, title, X_data, y_data, cv=5, scoring='accuracy'):
    train_sizes, train_scores, test_scores = learning_curve(estimator, X_data,
                                                            y_data, cv=cv, n_jobs=-1,
                                                            train_sizes=np.linspace(500, 4500, 10),
                                                            scoring=scoring, n_jobs=-1)
    train_mean = np.mean(train_scores, axis=1)
    test_mean = np.mean(test_scores, axis=1)
    plt.figure()
    plt.plot(train_sizes, train_mean, 'o-', label='Training score')
    plt.plot(train_sizes, test_mean, 'o-', label='Cross-validation score')
    plt.title(title)
    plt.xlabel('Training examples')
    plt.ylabel(scoring)
    plt.legend(loc='best')
    plt.grid(True)
    plt.show()

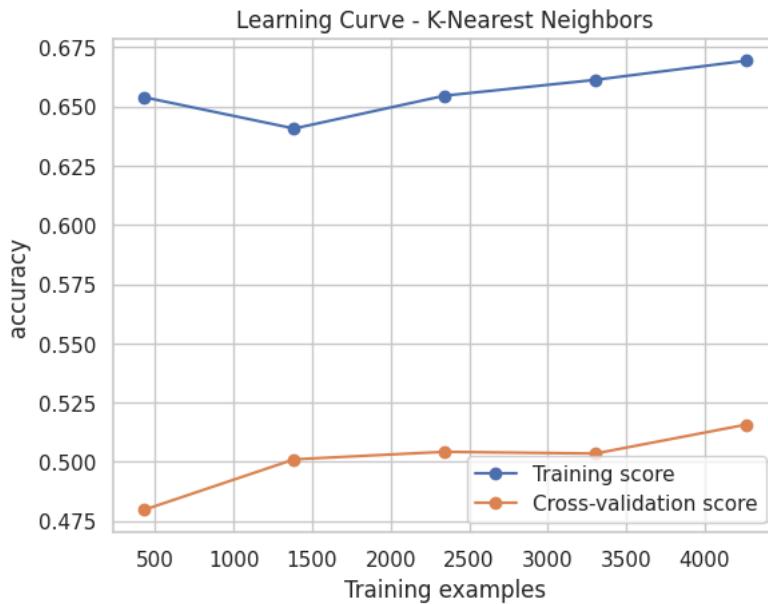
for name, clf in fitted_models.items():
    print("Plotting learning curve for:", name)
    plot_learning_curve(clf, f"Learning Curve - {name}", X, y, cv=5, scoring='accuracy')

```

Plotting learning curve for: Logistic Regression



Plotting learning curve for: K-Nearest Neighbors



Plotting learning curve for: Decision Tree

Learning Curve - Decision Tree

### 13. Visualizations: feature distributions, correlation heatmap, scatter.

```

n_features = min(12, X.shape[1])
plt.figure(figsize=(15, 10))
for i, col in enumerate(X.columns[:n_features], 1):
    plt.subplot((n_features+3)//4, 4, i)
    sns.histplot(X[col], bins=30, kde=False)
    plt.title(col)
plt.tight_layout()
plt.show()
topn = min(30, X.shape[1])
plt.figure(figsize=(12,10))
sns.heatmap(X.iloc[:, :topn].corr(), cmap='coolwarm', center=0)
plt.title("Correlation heatmap (first {} features)".format(topn))
plt.show()
variances = X.var().sort_values(ascending=False)
top_two = variances.index[:2].tolist()
if len(top_two) >= 2:
    plt.figure(figsize=(7,6))
    if len(np.unique(y)) <= 10:
        sns.scatterplot(x=X[top_two[0]], y=X[top_two[1]], hue=y, palette='deep')
        plt.legend(title='target', bbox_to_anchor=(1.05, 1), loc='upper left')
    else:
        plt.scatter(X[top_two[0]], X[top_two[1]], alpha=0.6)
    plt.xlabel(top_two[0]); plt.ylabel(top_two[1])
    plt.title(f"Scatter plot: {top_two[0]} vs {top_two[1]}")
    plt.show()

```

