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

from sklearn.model_selection import train_test_split, GridSearchCV, cross_val_score
from sklearn.preprocessing import StandardScaler
from sklearn.pipeline import Pipeline
from sklearn.ensemble import RandomForestClassifier
from sklearn.linear_model import SGDClassifier
from sklearn.svm import SVC
from sklearn.metrics import classification_report, confusion_matrix, accuracy_score, ConfusionMatrixDisplay
import joblib
```

```
C:\Users\patil\anaconda3\lib\site-packages\pandas\core\computation\expressions.py:21: UserWarning: Pandas requires vers
ion '2.8.4' or newer of 'numexpr' (version '2.8.3' currently installed).
  from pandas.core.computation.check import NUMEXPR_INSTALLED
C:\Users\patil\anaconda3\lib\site-packages\pandas\core\arrays\masked.py:61: UserWarning: Pandas requires version '1.3.
6' or newer of 'bottleneck' (version '1.3.5' currently installed).
  from pandas.core import (
```

In [2]:
```
df = pd.read_csv(r'D:\Oasis\TASK 6\WineQT.csv')
df.head()
```

Out[2]:

	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	density	pH	sulphates	alcohol	quality	Id
0	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4	5	0
1	7.8	0.88	0.00	2.6	0.098	25.0	67.0	0.9968	3.20	0.68	9.8	5	1
2	7.8	0.76	0.04	2.3	0.092	15.0	54.0	0.9970	3.26	0.65	9.8	5	2
3	11.2	0.28	0.56	1.9	0.075	17.0	60.0	0.9980	3.16	0.58	9.8	6	3
4	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4	5	4

In [3]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1143 entries, 0 to 1142
Data columns (total 13 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   fixed acidity         1143 non-null   float64
 1   volatile acidity      1143 non-null   float64
 2   citric acid           1143 non-null   float64
 3   residual sugar        1143 non-null   float64
 4   chlorides             1143 non-null   float64
 5   free sulfur dioxide   1143 non-null   float64
 6   total sulfur dioxide  1143 non-null   float64
 7   density               1143 non-null   float64
 8   pH                    1143 non-null   float64
 9   sulphates             1143 non-null   float64
 10  alcohol               1143 non-null   float64
 11  quality               1143 non-null   int64
 12  Id                    1143 non-null   int64
dtypes: float64(11), int64(2)
memory usage: 116.2 KB
```

In [4]:
```
df.describe()
```

Out[4]:

	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	density	pH	sulphates	
count	1143.000000	1143.000000	1143.000000	1143.000000	1143.000000	1143.000000	1143.000000	1143.000000	1143.000000	1143.000000	114
mean	8.311111	0.531339	0.268364	2.532152	0.086933	15.615486	45.914698	0.996730	3.311015	0.657708	
std	1.747595	0.179633	0.196686	1.355917	0.047267	10.250486	32.782130	0.001925	0.156664	0.170399	
min	4.600000	0.120000	0.000000	0.900000	0.012000	1.000000	6.000000	0.990070	2.740000	0.330000	
25%	7.100000	0.392500	0.090000	1.900000	0.070000	7.000000	21.000000	0.995570	3.205000	0.550000	
50%	7.900000	0.520000	0.250000	2.200000	0.079000	13.000000	37.000000	0.996680	3.310000	0.620000	
75%	9.100000	0.640000	0.420000	2.600000	0.090000	21.000000	61.000000	0.997845	3.400000	0.730000	
max	15.900000	1.580000	1.000000	15.500000	0.611000	68.000000	289.000000	1.003690	4.010000	2.000000	

In [5]:
```
print("Missing value per column")
df.isna().sum()
```

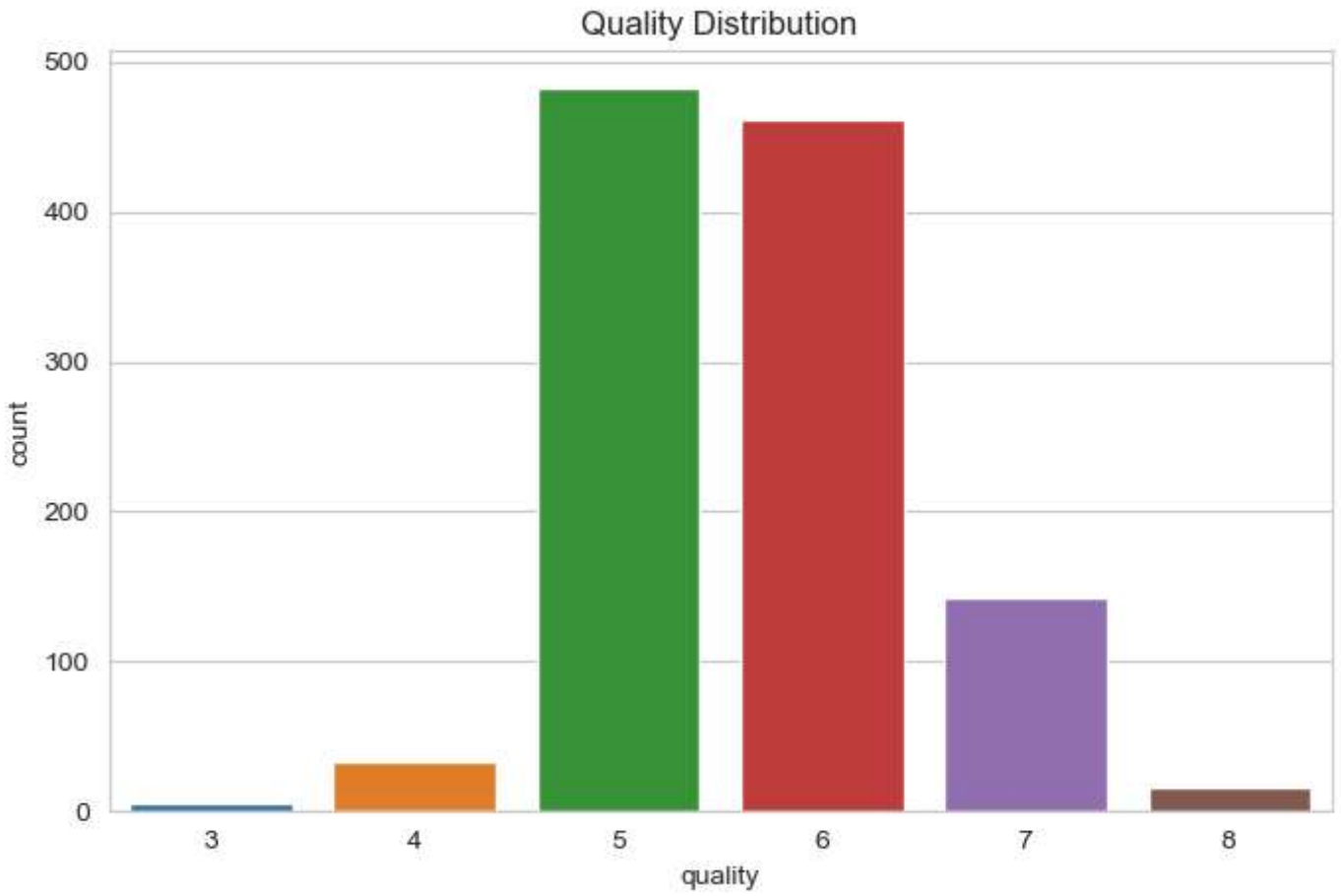
Out[5]:
```
Missing value per column
fixed acidity           0
volatile acidity        0
citric acid             0
residual sugar          0
chlorides               0
free sulfur dioxide     0
total sulfur dioxide    0
density                 0
pH                      0
sulphates               0
alcohol                 0
quality                 0
Id                      0
dtype: int64
```

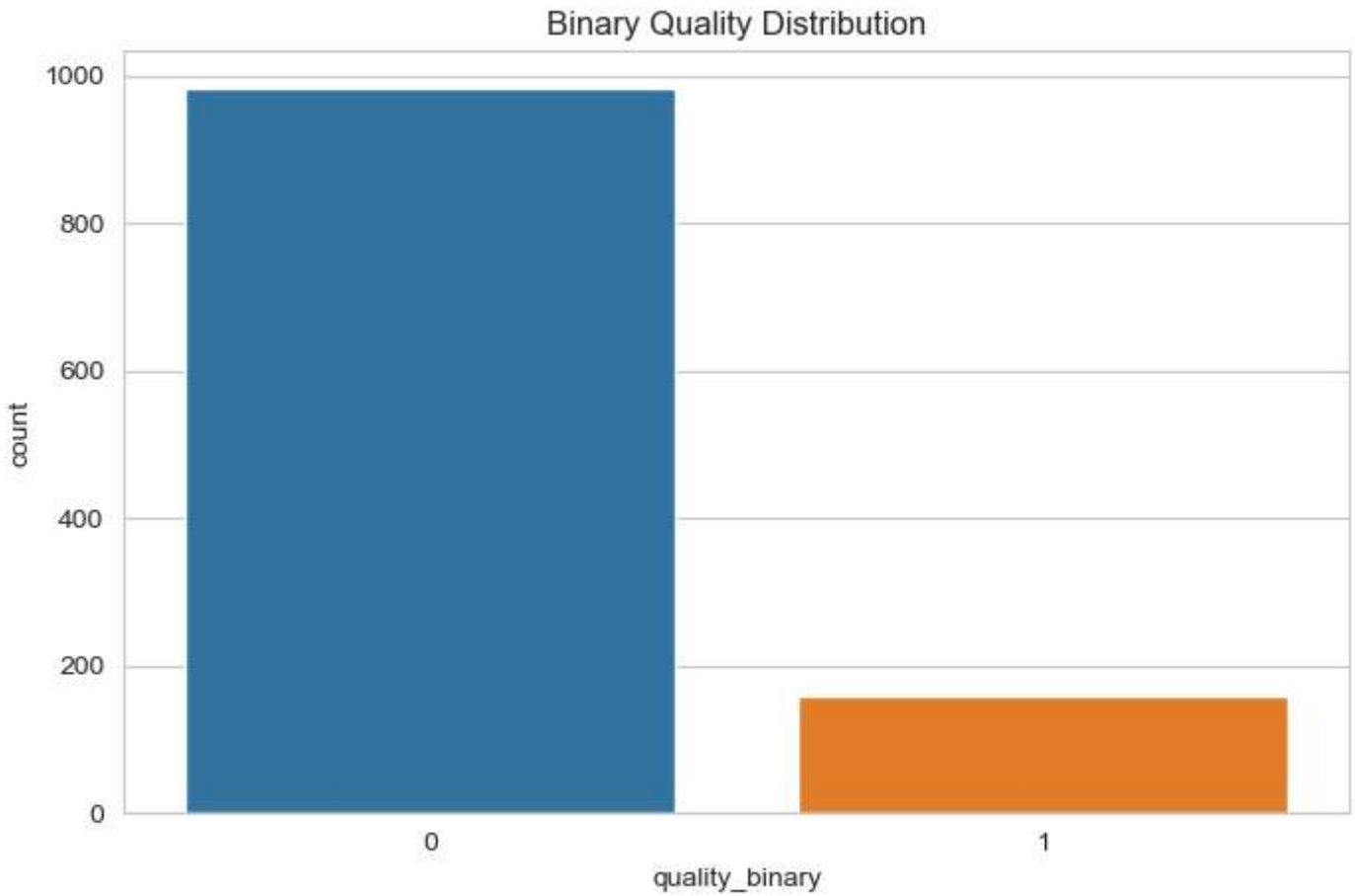
In [6]:
```
if 'quality' not in df.columns:
    raise ValueError("Expected a column named 'quality'")
print("Quality distribution:")
print(df['quality'].value_counts().sort_index())

df['quality_binary'] = (df['quality'] >= 7).astype(int)

print("\nBinary label distribution:")
print(df['quality_binary'].value_counts())
```

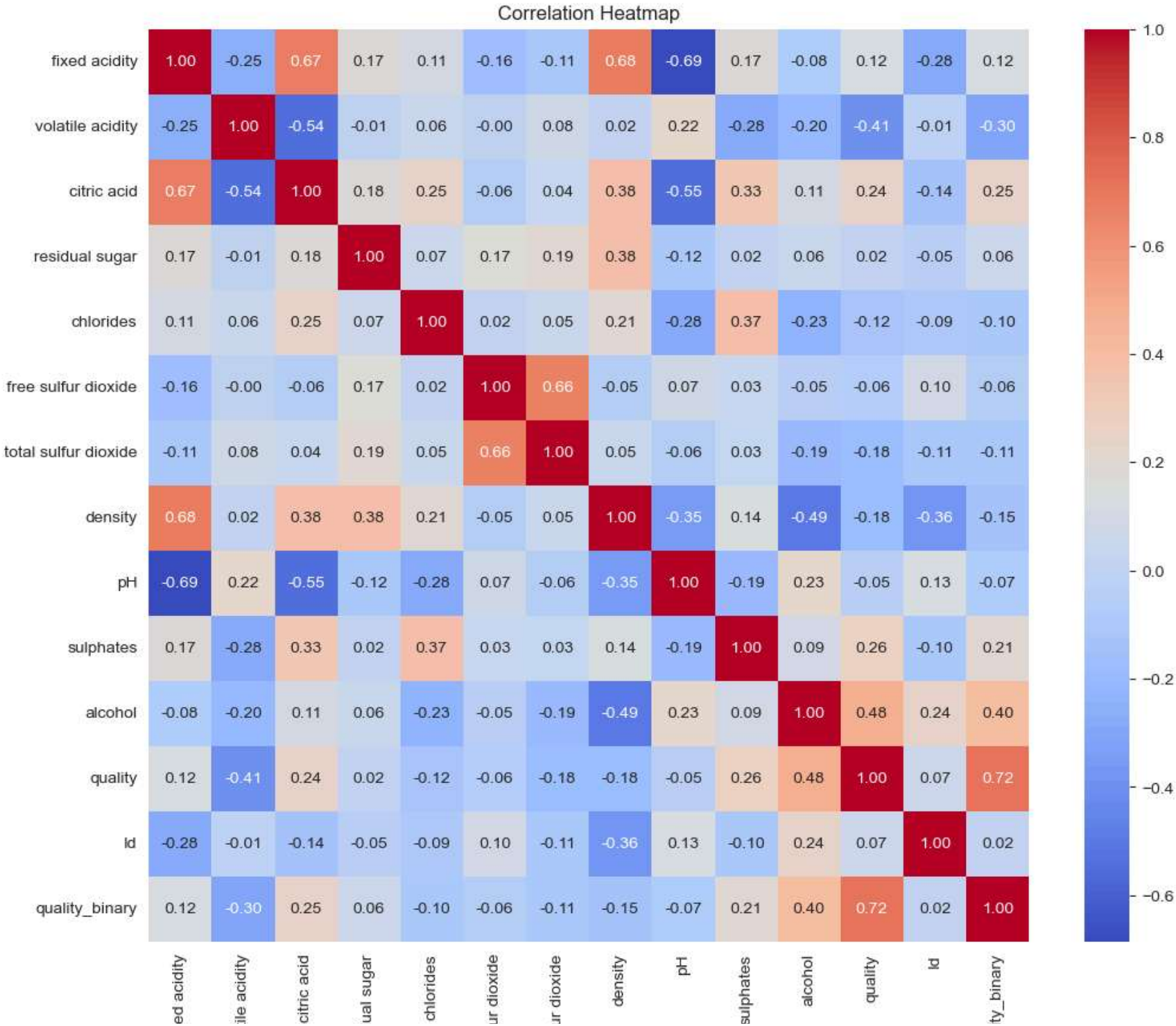
```
Quality distribution:
quality
3      6
4     33
5    483
6    462
7    143
8     16
Name: count, dtype: int64

Binary label distribution:
quality_binary
0    984
1    159
Name: count, dtype: int64
```

In [7]:
```
# Visualizations
sns.set_style("whitegrid")
```

```
plt.figure(figsize=(8,5))
sns.countplot(x='quality', data=df)
plt.title("Quality Distribution")
plt.show()

plt.figure(figsize=(8,5))
sns.countplot(x='quality_binary', data=df)
plt.title("Binary Quality Distribution")
plt.show()

# Correlation Heatmap
plt.figure(figsize=(12,10))
sns.heatmap(df.corr(), annot=True, cmap="coolwarm", fmt=".2f")
plt.title("Correlation Heatmap")
plt.show()
```




Binary Quality Distribution
1000
800
600
400
200
0
count
0
1
quality_binary


Correlation Heatmap
fixed acidity 1.00 -0.25 0.67 0.17 0.11 -0.16 -0.11 0.68 -0.69 0.17 -0.08 0.12 -0.28 0.12
volatile acidity -0.25 1.00 -0.54 -0.01 0.06 -0.00 0.08 0.02 0.22 -0.28 -0.20 -0.41 -0.01 -0.30
citric acid 0.67 -0.54 1.00 0.18 0.25 -0.06 0.04 0.38 -0.55 0.33 0.11 0.24 -0.14 0.25
residual sugar 0.17 -0.01 0.18 1.00 0.07 0.17 0.19 0.38 -0.12 0.02 0.06 0.02 -0.05 0.06
chlorides 0.11 0.06 0.25 0.07 1.00 0.02 0.05 0.21 -0.28 0.37 -0.23 -0.12 -0.09 -0.10
free sulfur dioxide -0.16 -0.00 -0.06 0.17 0.02 1.00 0.66 -0.05 0.07 0.03 -0.05 -0.06 0.10 -0.06
total sulfur dioxide -0.11 0.08 0.04 0.19 0.05 0.66 1.00 0.05 -0.06 0.03 -0.19 -0.18 -0.11 -0.11
density 0.68 0.02 0.38 0.38 0.21 -0.05 0.05 1.00 -0.35 0.14 -0.49 -0.18 -0.36 -0.15
pH -0.69 0.22 -0.55 -0.12 -0.28 0.07 -0.06 -0.35 1.00 -0.19 0.23 -0.05 0.13 -0.07
sulphates 0.17 -0.28 0.33 0.02 0.37 0.03 0.03 0.14 -0.19 1.00 0.09 0.26 -0.10 0.21
alcohol -0.08 -0.20 0.11 0.06 -0.23 -0.05 -0.19 -0.49 0.23 0.09 1.00 0.48 0.24 0.40
quality 0.12 -0.41 0.24 0.02 -0.12 -0.06 -0.18 -0.18 -0.05 0.26 0.48 1.00 0.07 0.72
Id -0.28 -0.01 -0.14 -0.05 -0.09 0.10 -0.11 -0.36 0.13 -0.10 0.24 0.07 1.00 0.02
quality_binary 0.12 -0.30 0.25 0.06 -0.10 -0.06 -0.11 -0.15 -0.07 0.21 0.40 0.72 0.02 1.00
ed acidity
ile acidity
citric acid
ual sugar
chlorides
ur dioxide
ur dioxide
density
pH
sulphates
alcohol
quality
Id
ty_binary
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6

fix volat resid free sulfi total sulfi quali

In [8]:
```
# Prepare data
FEATURE_COLS = [col for col in df.columns if col not in ['quality', 'quality_binary']]

X = df[FEATURE_COLS].values
y = df['quality'].values  # multiclass target

X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, random_state=42, stratify=y
)

print("Training set:", X_train.shape)
print("Testing set:", X_test.shape)
print("\nFeatures used:", FEATURE_COLS)
```

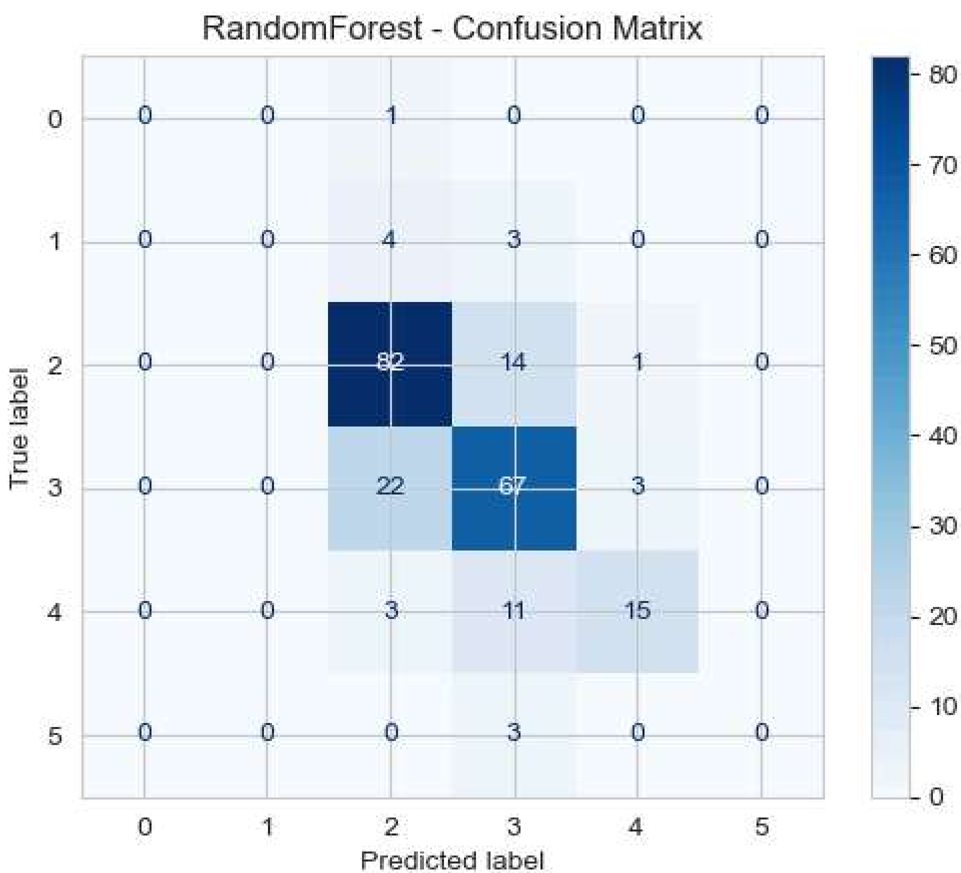
```
Training set: (914, 12)
Testing set: (229, 12)

Features used: ['fixed acidity', 'volatile acidity', 'citric acid', 'residual sugar', 'chlorides', 'free sulfur dioxid
e', 'total sulfur dioxide', 'density', 'pH', 'sulphates', 'alcohol', 'Id']
```

In [9]:
```
#  Classifier pipelines

# Random Forest
pipe_rf = Pipeline([
    ('scaler', StandardScaler()),
    ('rf', RandomForestClassifier(random_state=42))])
# SGDClassifier
pipe_sgd = Pipeline([
    ('scaler', StandardScaler()),
    ('sgd', SGDClassifier(max_iter=5000, tol=1e-3, random_state=42))])

# SVC
pipe_svc = Pipeline([
    ('scaler', StandardScaler()),
    ('svc', SVC(probability=True, random_state=42))])

models = {
    "RandomForest": pipe_rf,
    "SGDClassifier": pipe_sgd,
    "SVC": pipe_svc
}
```

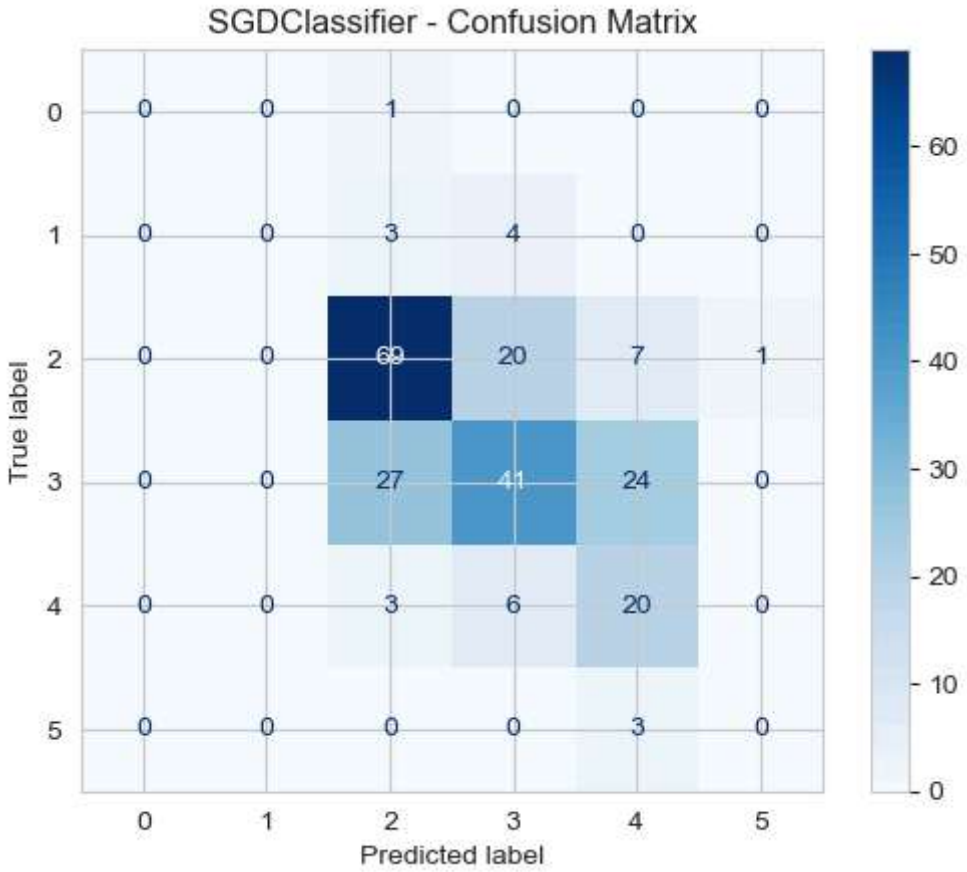
In [10]:
```python
# 8. Train & evaluate
results = {}

for name, model in models.items():
    print(f"\n--- Training {name} ---")
    model.fit(X_train, y_train)

    preds = model.predict(X_test)
    acc = accuracy_score(y_test, preds)
    results[name] = acc

    print(f"{name} Accuracy: {acc:.4f}")
    print(classification_report(y_test, preds))

    # Confusion Matrix
    plt.figure(figsize=(6,4))
    ConfusionMatrixDisplay(confusion_matrix(y_test, preds)).plot(cmap="Blues")
    plt.title(f"{name} - Confusion Matrix")
    plt.show()
```

```
--- Training RandomForest ---
RandomForest Accuracy: 0.7162
              precision    recall  f1-score   support

           3       0.00      0.00      0.00         1
           4       0.00      0.00      0.00         7
           5       0.73      0.85      0.78        97
           6       0.68      0.73      0.71        92
           7       0.79      0.52      0.62        29
           8       0.00      0.00      0.00         3

    accuracy                           0.72       229
   macro avg       0.37      0.35      0.35       229
weighted avg       0.68      0.72      0.69       229
```

```
C:\Users\patil\anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1318: UndefinedMetricWarning: Precision a
nd F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
C:\Users\patil\anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1318: UndefinedMetricWarning: Precision a
nd F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
C:\Users\patil\anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1318: UndefinedMetricWarning: Precision a
nd F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
<Figure size 600x400 with 0 Axes>
```

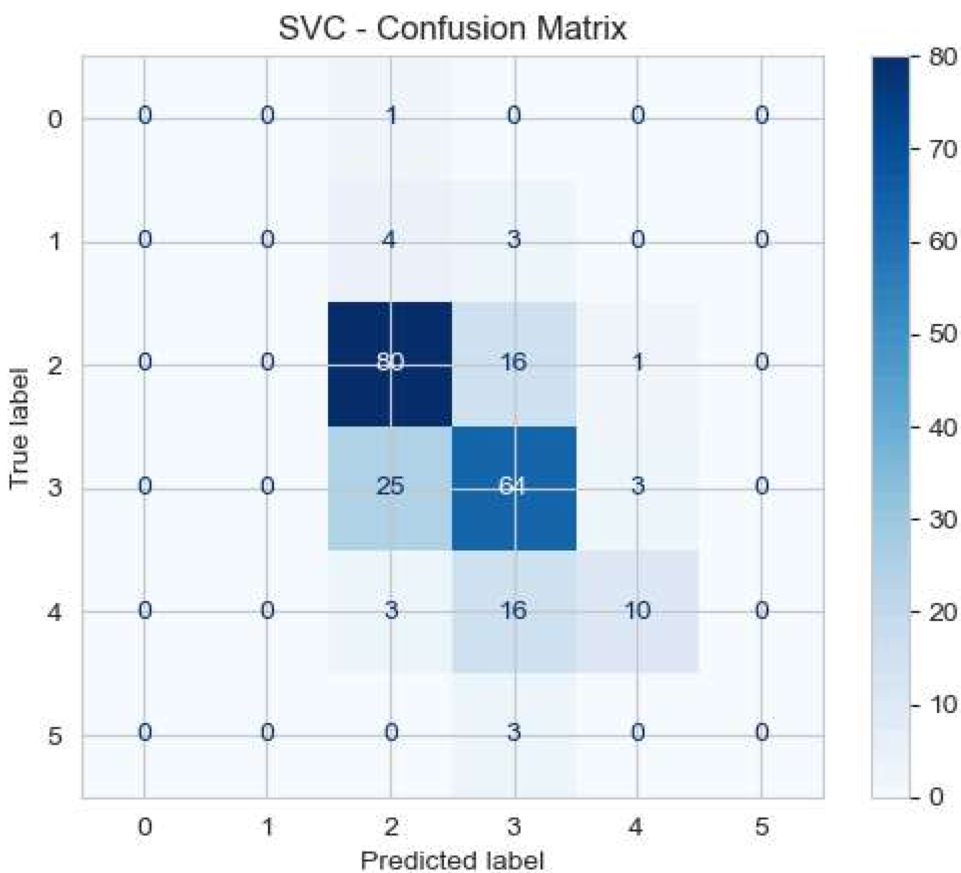


```
--- Training SGDClassifier ---
SGDClassifier Accuracy: 0.5677
              precision    recall  f1-score   support

           3       0.00      0.00      0.00         1
           4       0.00      0.00      0.00         7
           5       0.67      0.71      0.69        97
           6       0.58      0.45      0.50        92
           7       0.37      0.69      0.48        29
           8       0.00      0.00      0.00         3

    accuracy                           0.57       229
   macro avg       0.27      0.31      0.28       229
weighted avg       0.56      0.57      0.56       229

C:\Users\patil\anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1318: UndefinedMetricWarning: Precision a
nd F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
C:\Users\patil\anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1318: UndefinedMetricWarning: Precision a
nd F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
C:\Users\patil\anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1318: UndefinedMetricWarning: Precision a
nd F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
<Figure size 600x400 with 0 Axes>
```




```
--- Training SVC ---
SVC Accuracy: 0.6725
              precision    recall  f1-score   support

           3       0.00      0.00      0.00         1
           4       0.00      0.00      0.00         7
           5       0.71      0.82      0.76        97
           6       0.63      0.70      0.66        92
           7       0.71      0.34      0.47        29
           8       0.00      0.00      0.00         3

    accuracy                           0.67       229
   macro avg       0.34      0.31      0.31       229
weighted avg       0.64      0.67      0.65       229
```

```
C:\Users\patil\anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1318: UndefinedMetricWarning: Precision a
nd F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
C:\Users\patil\anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1318: UndefinedMetricWarning: Precision a
nd F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
C:\Users\patil\anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1318: UndefinedMetricWarning: Precision a
nd F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
<Figure size 600x400 with 0 Axes>
```



In [11]:
```
# 9. Cross-validation
for name, model in models.items():
    print(f"\nCross-validating {name}...")
```

```
    scores = cross_val_score(model, X, y, cv=5, scoring='accuracy')
    print(f"{name} CV Mean Accuracy: {scores.mean():.4f}")
```

```
Cross-validating RandomForest...
RandomForest CV Mean Accuracy: 0.5425

Cross-validating SGDClassifier...
SGDClassifier CV Mean Accuracy: 0.5372

Cross-validating SVC...
SVC CV Mean Accuracy: 0.5835
```

In [12]:
```
# 10. Hyperparameter tuning

# Random Forest Grid
rf_grid = {
    'rf__n_estimators': [100, 200],
    'rf__max_depth': [None, 10, 20]
}

rf_search = GridSearchCV(pipe_rf, rf_grid, cv=4, scoring='accuracy', n_jobs=-1)
rf_search.fit(X_train, y_train)

print("Best RF Params:", rf_search.best_params_)
print("Best RF Accuracy:", rf_search.best_score_)

# SVC Grid
svc_grid = {
    'svc__C': [0.1, 1, 10],
    'svc__kernel': ['rbf', 'linear']
}

svc_search = GridSearchCV(pipe_svc, svc_grid, cv=4, scoring='accuracy', n_jobs=-1)
svc_search.fit(X_train, y_train)

print("Best SVC Params:", svc_search.best_params_)
print("Best SVC Accuracy:", svc_search.best_score_)
```

```
Best RF Params: {'rf__max_depth': None, 'rf__n_estimators': 200}
Best RF Accuracy: 0.6444543399984678
Best SVC Params: {'svc__C': 1, 'svc__kernel': 'rbf'}
Best SVC Accuracy: 0.6094767486401593
```

In [13]:
```
# 11. Save models
joblib.dump(rf_search.best_estimator_, "best_random_forest.joblib")
joblib.dump(svc_search.best_estimator_, "best_svc.joblib")
```

```
joblib.dump(pipe_sgd, "baseline_sgd.joblib")

print("Models saved successfully.")
```

```
Models saved successfully.
```

In [14]:
```
# 12. Example prediction
sample = X_test[0].reshape(1, -1)

print("Sample Prediction:")
print("RF:", rf_search.best_estimator_.predict(sample)[0])
print("SVC:", svc_search.best_estimator_.predict(sample)[0])
print("SGD:", pipe_sgd.predict(sample)[0])
```

```
Sample Prediction:
RF: 6
SVC: 6
SGD: 6
```

In [ ]:
```

```