## Task 1

This task is to check the d-separation of X, Y and Z. The total runtime is less than 0.4 seconds. It has a time complexity and memory complexity of O(V+E) where V is the total number of vertices and E is the total number of edges. While the time cost is mainly contributed by turning the graph from directed to undirected through a BFS, plus the DFS search to check the connectivity.

## Task 2

This task consists of 2 parts. For the part of learning outcome space funciton, the time complexity and memory complexity is O(row \* column) since the function must iterate through all possible values of each column of the data. The function for probability table learning has a time complexity and memory complexity of O(V \* (OutcomeSpaceMax ^ E)), which is mainly contributed by the efforts of constructing the probability table of all the nodes.

## Tasks 3-5

As for tasks 3 to 5, the overall experimental results can be shown from the figure above.

### Task 3

The Bayesian Network Classifier has the best overall accuracy and the lowest standard deviation. This is because Bayesian Network Classifier uses the complete graph information and the CPT of all vertices. Because of this property, the time and memory complexity of this task is constructed of 2 parts:

1. The maximum size of the CPT table constructed by the markov blanket of the target variable. In the worst case, such size of CPT table is the size of CPT table for all vertices. And this is just the memory complexity of Task 2, which is O(V \* (OutcomeSpaceMax ^ E)).

2. The size of the testing data, which can be represented by O(row \* column), and row and column are the total rows and columns of test data.

And total time complexity for the cross validation of Bayesian Network Classifier is O(K(V \* (OutcomeSpaceMax ^ E) + row)), where K is the number of the folds. And the memory complexity is O(K(V \* (OutcomeSpaceMax ^ E) + row \* column)) since the function must use all of the test data.

### Task 4

The Naive Bayes Classifier has the worst performance with lowest accuracy and highest standard deviation value, since it ignores the relationship between different vertices. The time complexity of this task is O(K(row \* OutcomeSpaceMax \* V)) which is to construct and search through the probability result for target variable. And the memory complexity is O(K(row \* OutcomeSpaceMax \* V + row \* column)).

### Task 5

The Tree-augmented Naïve Bayes Classifier (TAN) tends to find the strong connections between vertices but may ignore some of the vertices relationships in most cases. This could explain why it performs slightly worse than the Bayesian Network Classifier. The time complexity is O(K(V^2 \* OutcomeSpaceMax^3 + row)) so that it can find the strong inner relationships first then use it to construct the spanning tree, then do the classification. And the space complexity is O(K(V^2 \* OutcomeSpaceMax^3 + row \* column))