ASSIGNMENT 3

Software Tools and Techniques for CSE

Kunal Singh Rathore & Gurudayal Meena
23110181 & 23110125

GITHUB LINK:
https://github.com/kunalsinghrathore23110181/STT_A3.git

TABLE OF CONTENTS

Laboratory Session 9

Introduction:

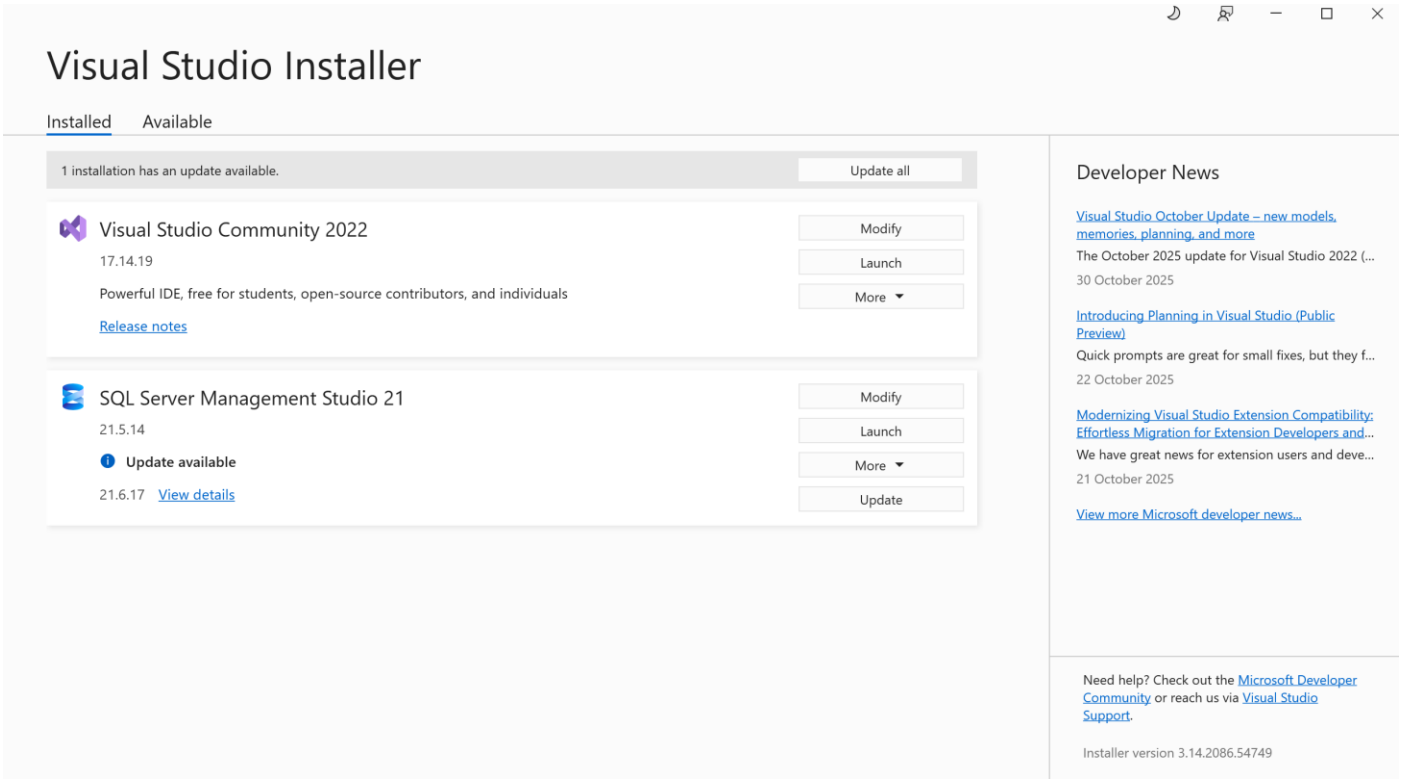
This lab, conducted on **13th October 2025**, focuses on the development of C# console applications using the .NET framework in Visual Studio. It introduces to the core programming concepts such as data types, control structures, and object-oriented design principles in C#. The exercises guide in performing arithmetic operations, using conditional statements, and applying looping constructs effectively. It also explores the use of functions for modular programming and understands the role of static methods. Further, the lab includes tasks on implementing sorting algorithms, working with single and multi-dimensional arrays, and performing matrix operations. We are encouraged to analyze the reasoning behind program outputs to strengthen their conceptual understanding. Overall, this lab builds a solid foundation in C# programming and prepares students for more advanced software development using .NET technologies.

TOOLS:

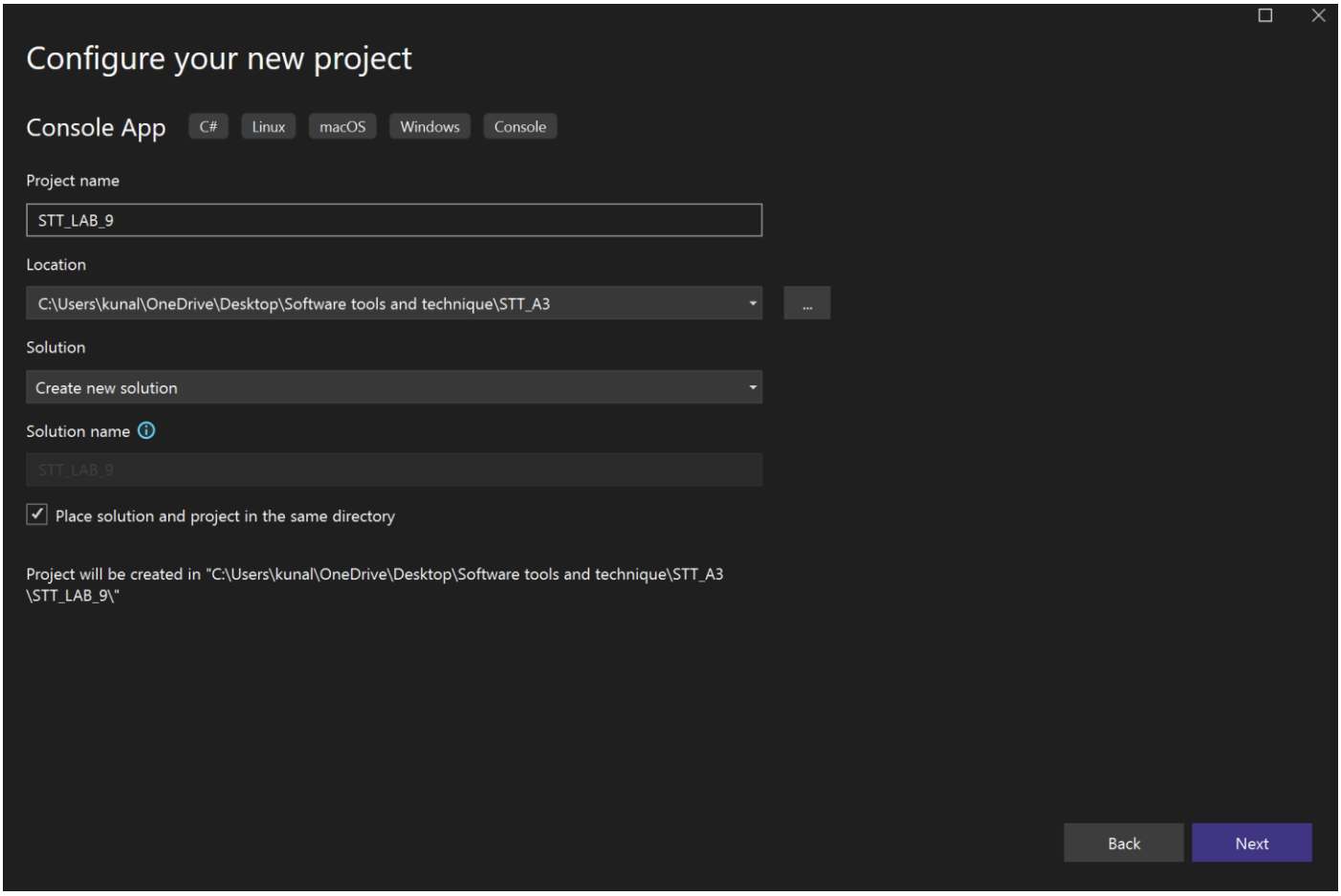
The lab was conducted on the Windows operating system using Visual Studio 2022 (Community Edition) as the primary Integrated Development Environment (IDE).The .NET SDK was used to compile, build, and execute C# programs efficiently. Programming was carried out in the C# language using the .NET 6 framework or later versions. The Visual Studio environment provided powerful features such as IntelliSense, debugging tools, and code suggestions to enhance the coding experience. Built-in project templates simplified the creation of console applications and ensured proper configuration of dependencies. The integrated terminal and output console in Visual Studio helped in testing and observing program behaviour in real time. Overall, this toolset offered a robust and user-friendly platform for learning and practicing .NET-based C# programming.

SETUP:

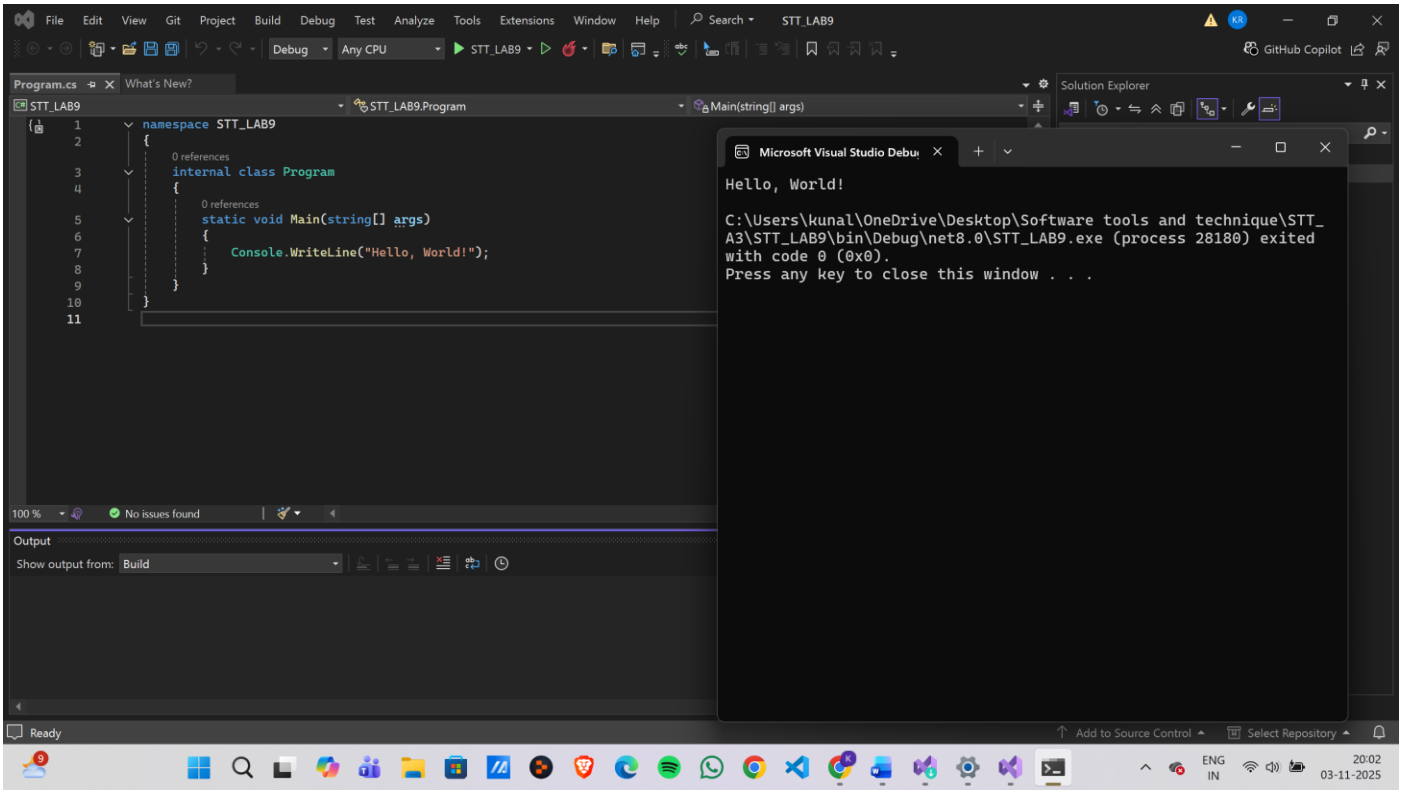
I install and setup the visual studio in my windows with the link "https://visualstudio.microsoft.com/vs/community/"



Now in the Visual Studio I make setup the new project and name the file STT_LAB9 and kept the version of Visual Studio with .NET SDK and my target framework is .NET 8

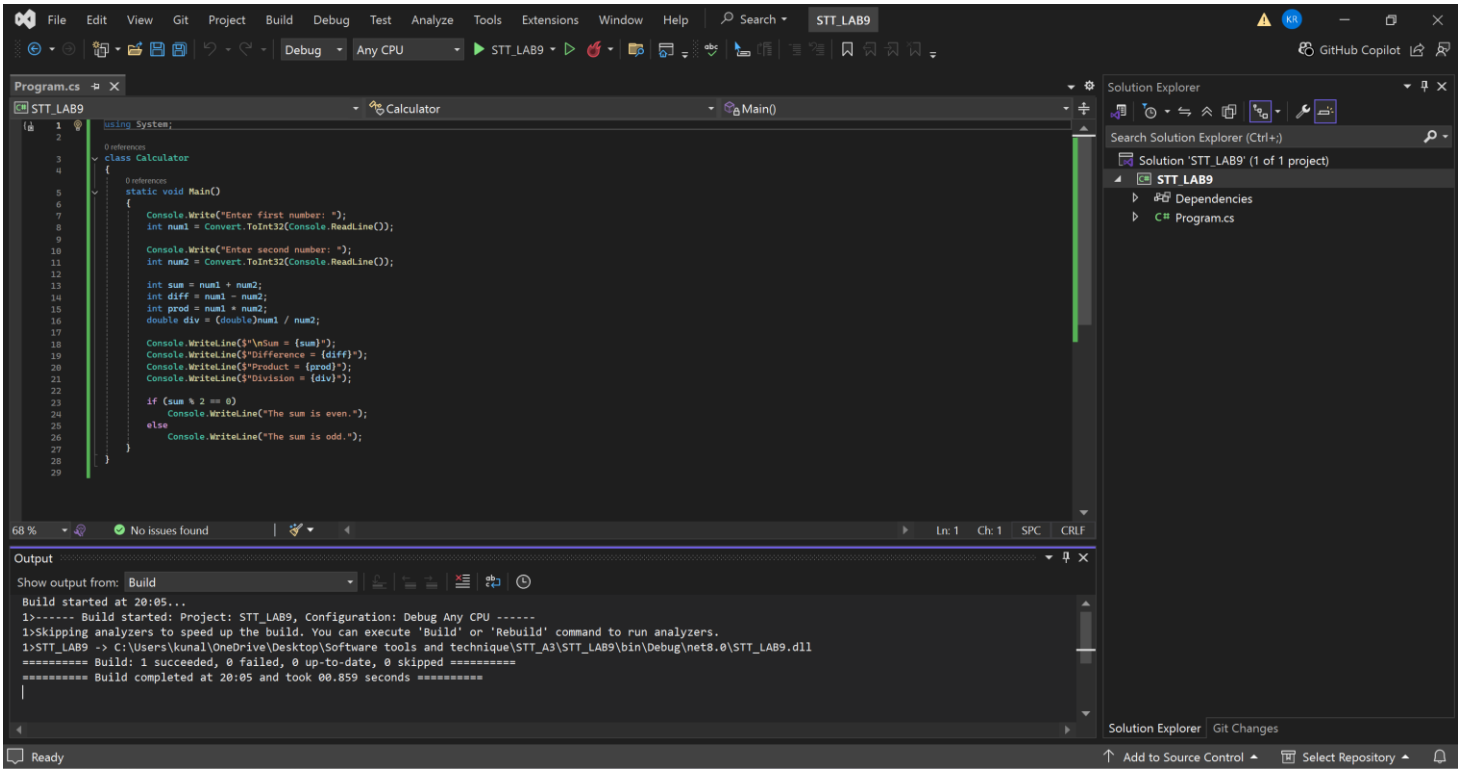


Testing the setup by print the “Hello, World!”. The screenshots are attached below:

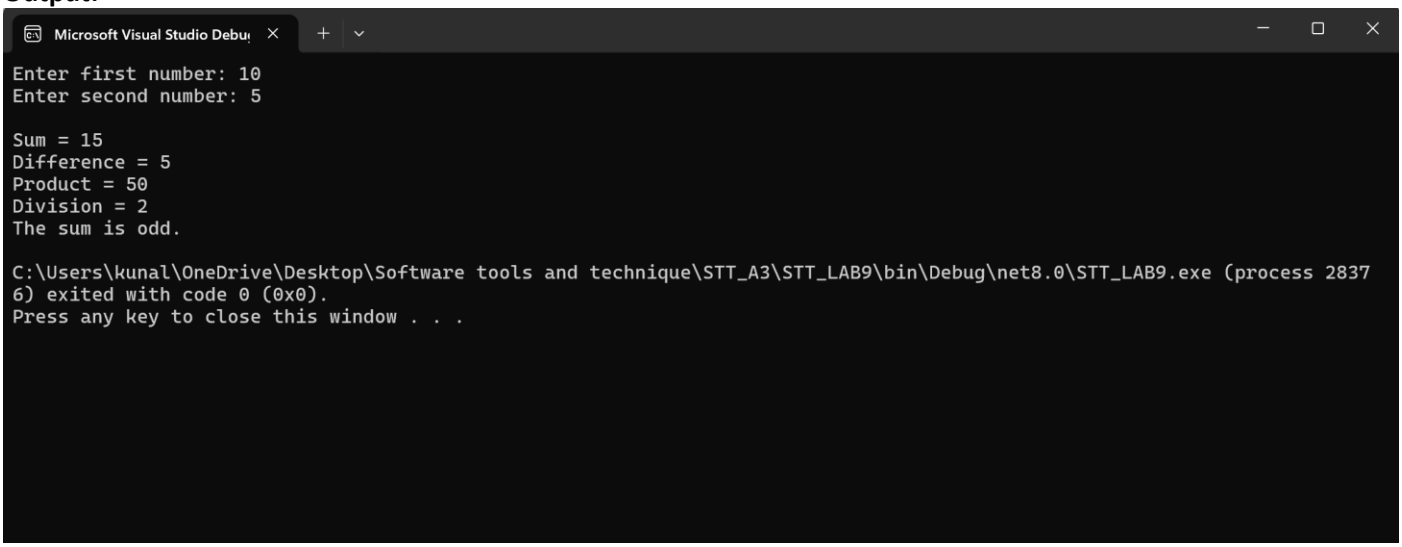


METHODOLOGY AND EXECUTION:

- ❖ **Understanding Basic Syntax and Control Structures**
- ➢ Write an object-oriented C# program that:
  - ▪ Accepts user input for two numbers.
  - ▪ Performs addition, subtraction, multiplication, and division.
  - ▪ Uses if-else conditions to determine if the sum is even or odd.
  - ▪ Displays the results using Console.WriteLine().



Output:



Explanation:

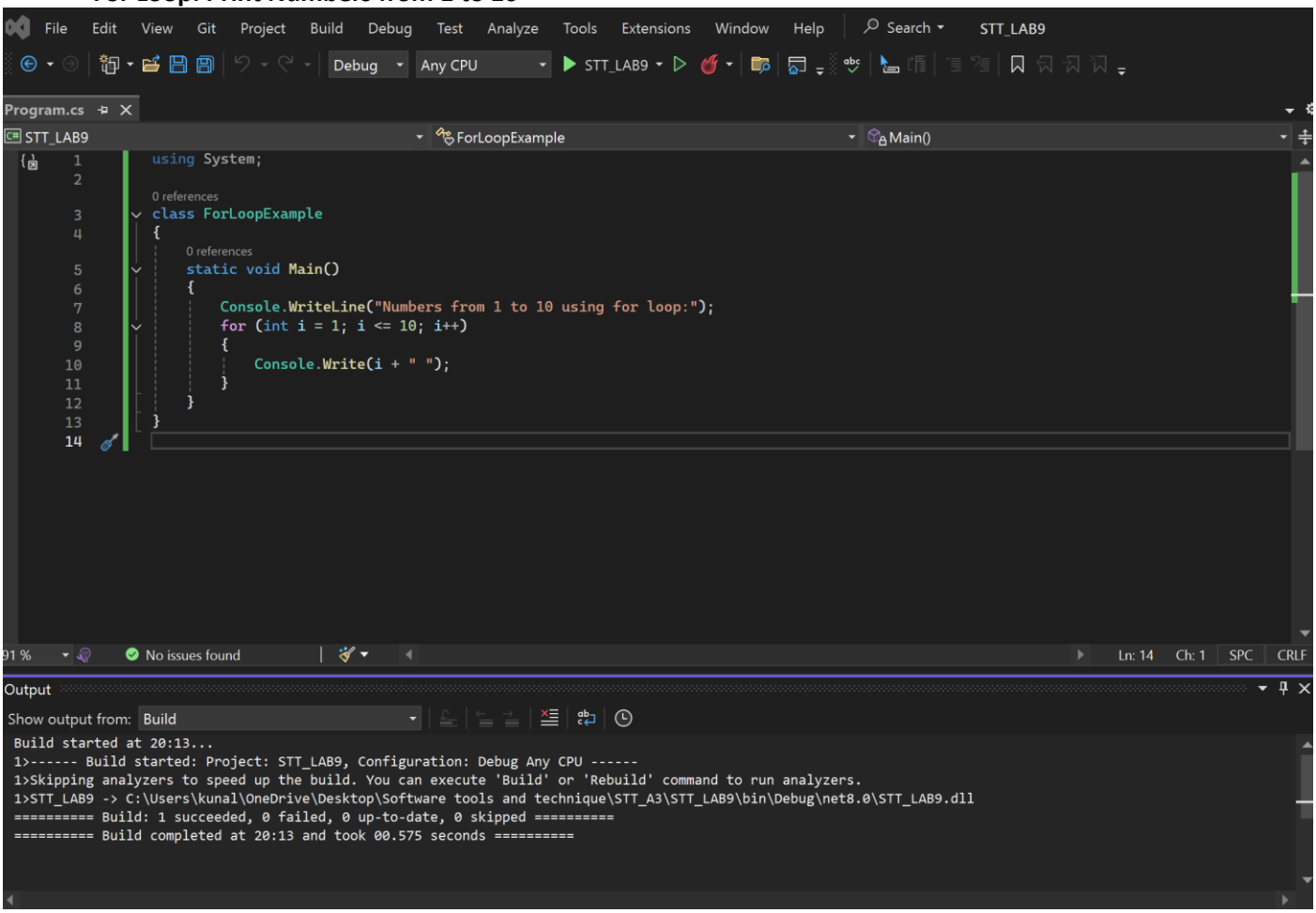
In this program, I created a C# class named **Calculator** that demonstrates basic object-oriented programming. Inside the Main() method, the program accepts two integer inputs from the user using Console.ReadLine() and converts them to integers using Convert.ToInt32().

The program then performs four arithmetic operations: **addition**, **subtraction**, **multiplication**, and **division**. Each result is stored in separate variables (sum, diff, prod, div) and displayed on the screen using Console.WriteLine() statements.
Next, an **if-else** condition checks whether the calculated sum is even or odd. If the remainder when dividing by 2 (sum % 2) is zero, the program displays that the sum is even; otherwise, it displays that the sum is odd.

❖ Using Loops and Functions

➢ Design an object-oriented C# program that:

- **For Loop: Print Numbers from 1 to 10**



Output:

Explanation:

This program defines a class **ForLoopExample** that demonstrates the use of a **for loop** in C#.
Inside the Main() method, the program first displays a message indicating the task.
A for loop is then used to print numbers from **1 to 10** sequentially. The loop starts with i = 1, checks the condition i <= 10, and increments i after each iteration. Each number is printed on the same line using Console.Write().The loop stops automatically when the condition becomes false.

- **Foreach Loop: Print Numbers from 1 to 10.**

```
using System;

class ForEachLoopExample
{
    static void Main()
    {
        int[] numbers = { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };

        Console.WriteLine("Numbers from 1 to 10 using foreach loop:");
        foreach (int num in numbers)
        {
            Console.Write(num + " ");
        }
    }
}
```

```
Build started at 20:14...
1>------ Build started: Project: STT_LAB9, Configuration: Debug Any CPU ------
1>Skipping analyzers to speed up the build. You can execute 'Build' or 'Rebuild' command to run analyzers.
1>STT_LAB9 -> C:\Users\kunal\OneDrive\Desktop\Software tools and technique\STT_A3\STT_LAB9\bin\Debug\net8.0\STT_LAB9.dll
========== Build: 1 succeeded, 0 failed, 0 up-to-date, 0 skipped ==========
========== Build completed at 20:14 and took 00.528 seconds ==========
```

Output:

```
Numbers from 1 to 10 using foreach loop:
1 2 3 4 5 6 7 8 9 10
C:\Users\kunal\OneDrive\Desktop\Software tools and technique\STT_A3\STT_LAB9\bin\Debug\net8.0\STT_LAB9.exe (process 2885
2) exited with code 0 (0x0).
Press any key to close this window . . .
```

Explanation:

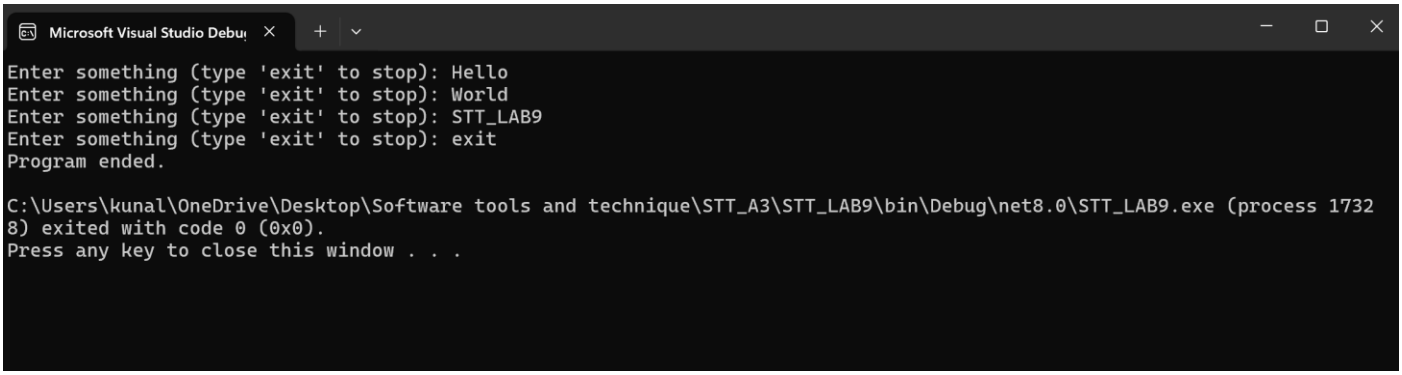
This program defines a class ForEachLoopExample that demonstrates the use of a foreach loop in C#. An integer array named numbers is created containing values from 1 to 10. The foreach loop is used to iterate through each element of the array. During each iteration, the current number is displayed using Console.Write(). The loop automatically accesses all elements without using an index variable. This program shows how foreach simplifies iteration over collections or arrays. It efficiently prints all numbers from 1 to 10 in a single loop structure.

- **Do-While Loop: Keep Asking Until User Types “exit”**

```
using System;

class DoWhileExample
{
    static void Main()
    {
        string input;
        do
        {
            Console.Write("Enter something (type 'exit' to stop): ");
            input = Console.ReadLine();
        } while (input.ToLower() != "exit");

        Console.WriteLine("Program ended.");
    }
}
```

```
Build started at 20:16...
1>------ Build started: Project: STT_LAB9, Configuration: Debug Any CPU ------
1>Skipping analyzers to speed up the build. You can execute 'Build' or 'Rebuild' command to run analyzers.
1>STT_LAB9 -> C:\Users\kunal\OneDrive\Desktop\Software tools and technique\STT_A3\STT_LAB9\bin\Debug\net8.0\STT_LAB9.dll
========== Build: 1 succeeded, 0 failed, 0 up-to-date, 0 skipped ==========
========== Build completed at 20:16 and took 00.331 seconds ==========
```

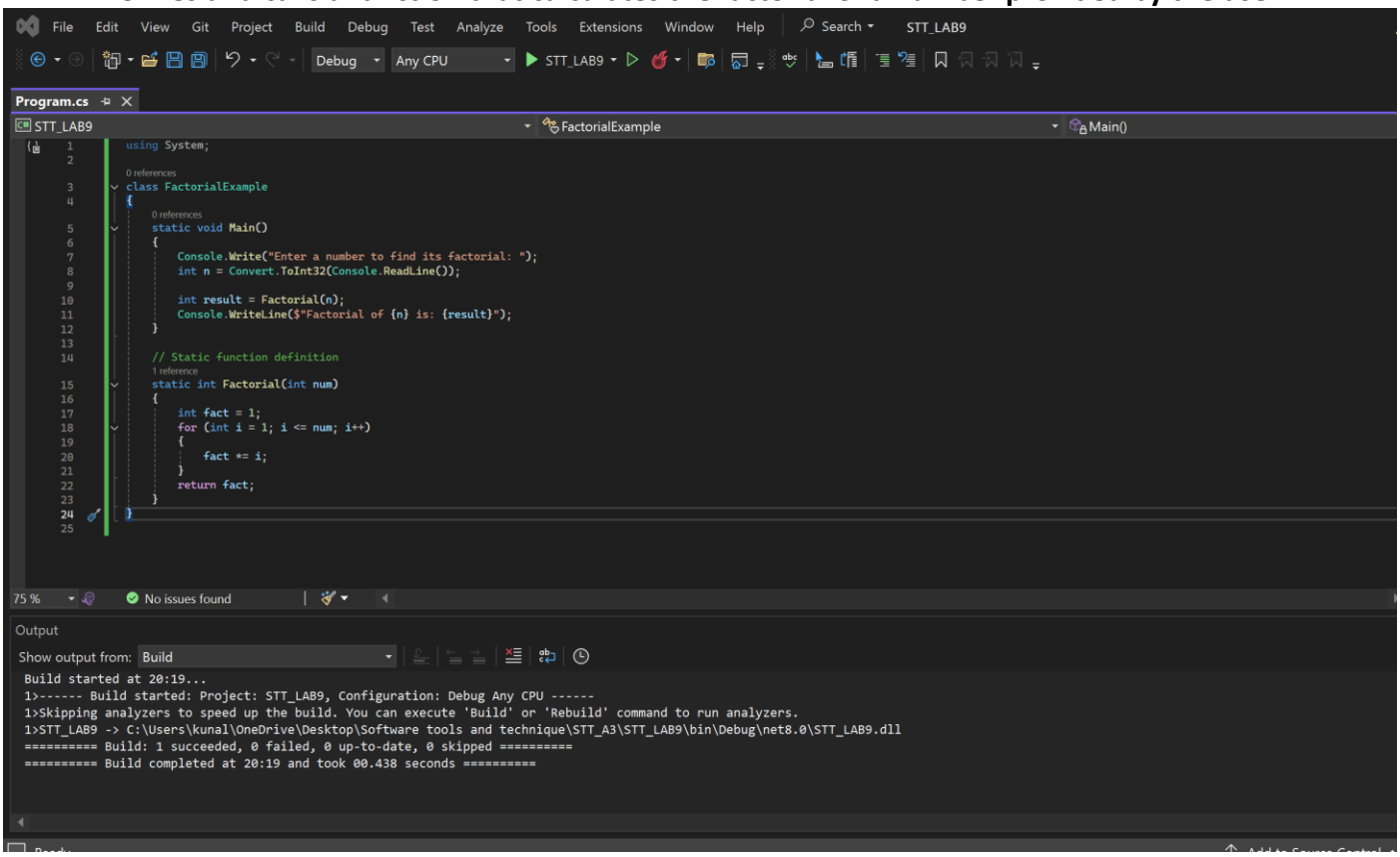
Output:



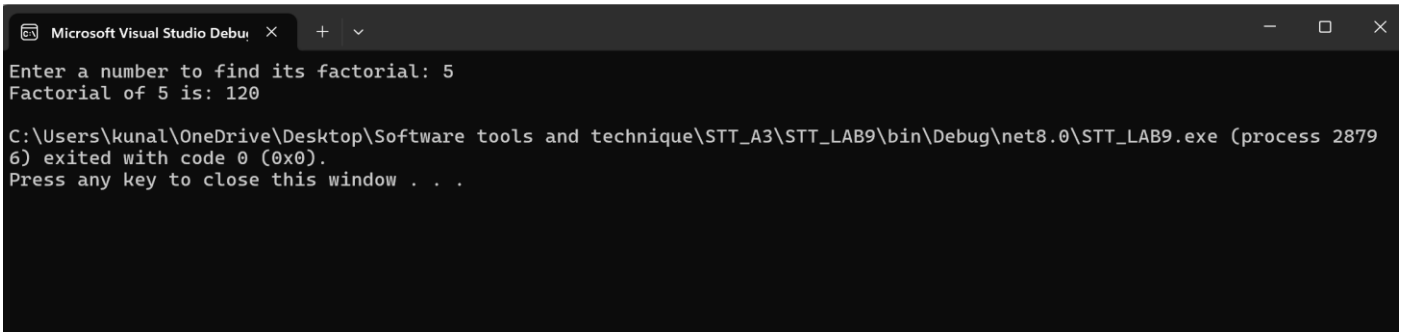
Explanation:

This program defines a class DoWhileExample that demonstrates the use of a do-while loop in C#.
Inside the Main() method, a string variable input is declared to store user input. The program repeatedly asks the user to enter text using Console.ReadLine(). The loop continues until the user types “exit”, regardless of case sensitivity. The ToLower() function ensures that both “Exit” and “EXIT” are accepted. The do-while loop executes at least once before checking the condition. Finally, when the user types “exit”, the loop stops and the program displays “Program ended.”

- **Defines and calls a function that calculates the factorial of a number provided by the user.**



Output:

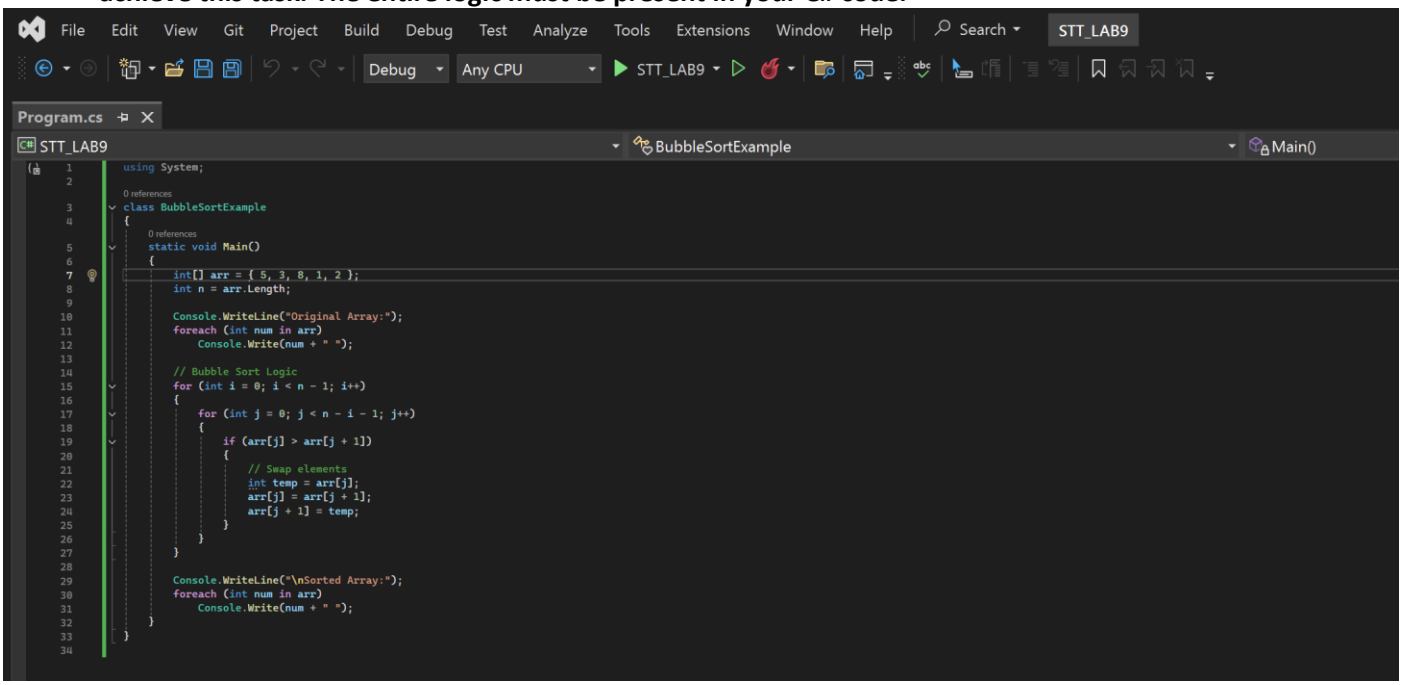


Explanation:
This program defines a class FactorialExample that calculates the factorial of a given number. Inside the Main() method, the user is prompted to enter a number using Console.ReadLine(). The program then calls a static function named Factorial() to compute the factorial. The Factorial() function uses a for loop to multiply numbers from 1 to n. The result is returned to the main function and displayed using Console.WriteLine(). This demonstrates the use of functions, loops, and user input handling in C#.

❖ Using Single and Multi-dimensional Arrays

➢ Design an object-oriented C# program that:

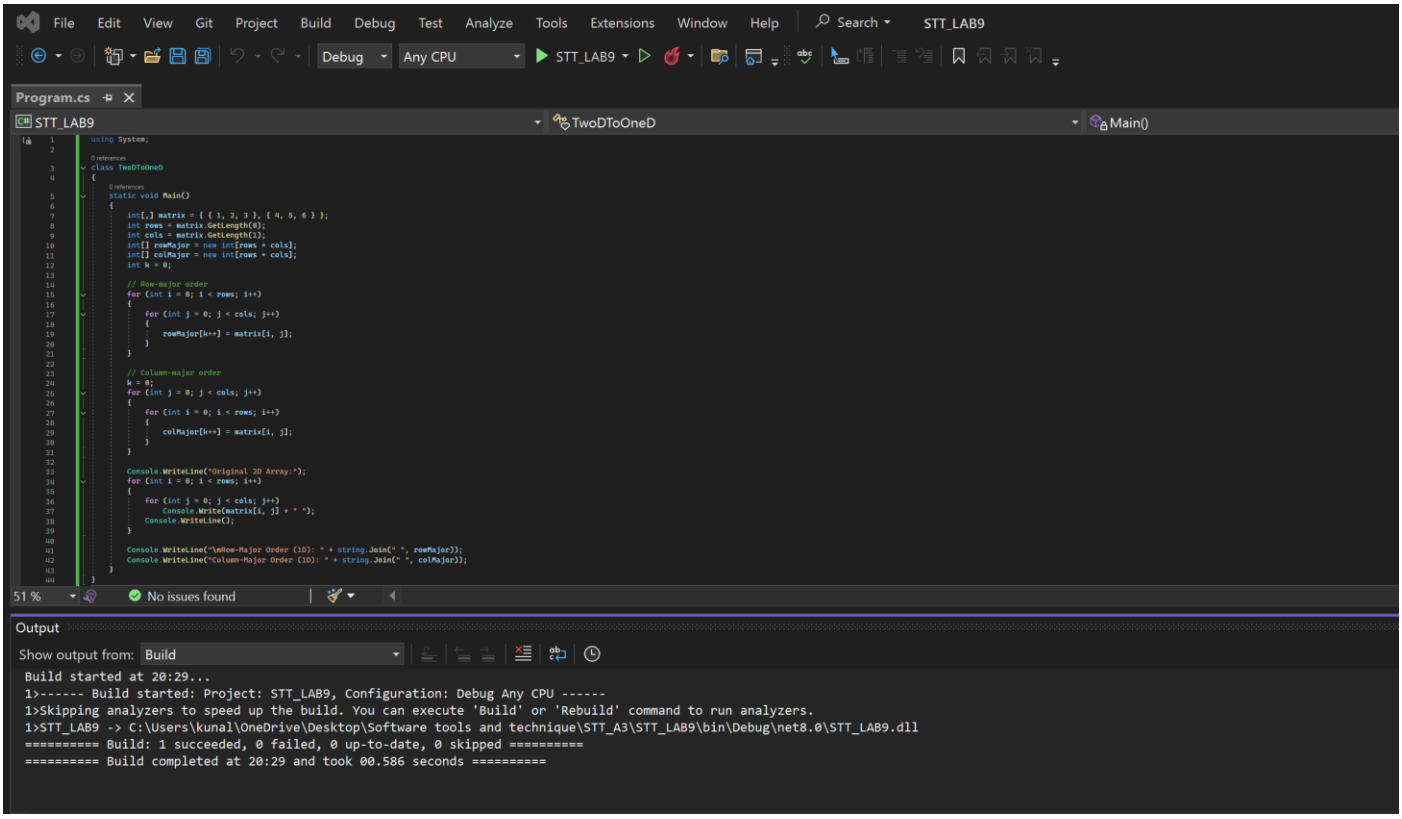
- **Implements the bubble sort algorithm on array3 of integers. You should not use any library functions to achieve this task. The entire logic must be present in your C# code.**



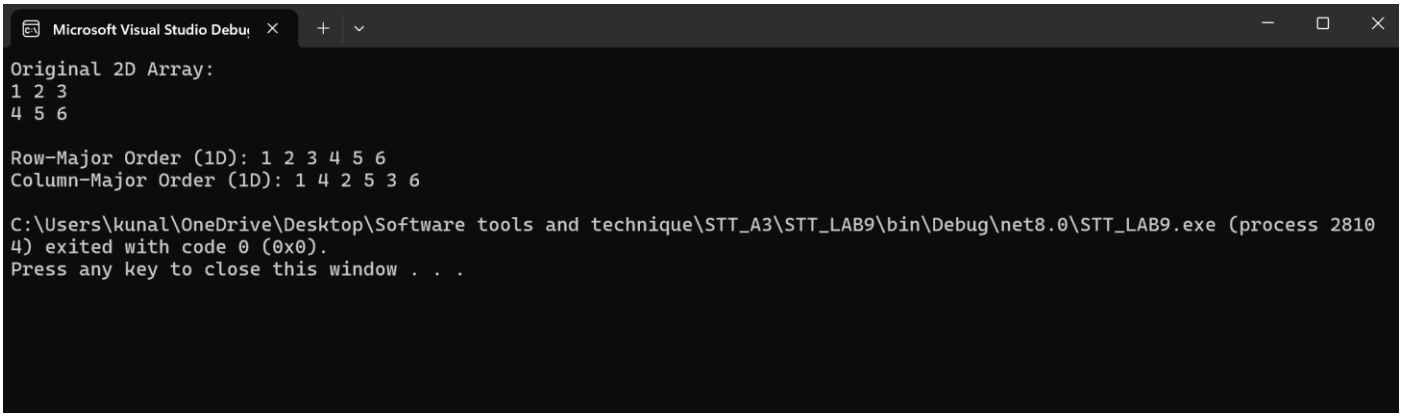
Output:

Explanation:
This program defines a class **BubbleSortExample** that demonstrates the bubble sort algorithm in C#.
An integer array arr is initialized with unsorted elements. The program first displays the original array using a **foreach loop**. Two nested **for loops** are used to compare and swap adjacent elements in ascending order.
If a larger element is found before a smaller one, they are swapped using a temporary variable.
This process repeats until the entire array is sorted. Finally, the sorted array is printed.

- **Stores a 2-D array into one 1-D array in: (i) row major order, (ii)column major order.**



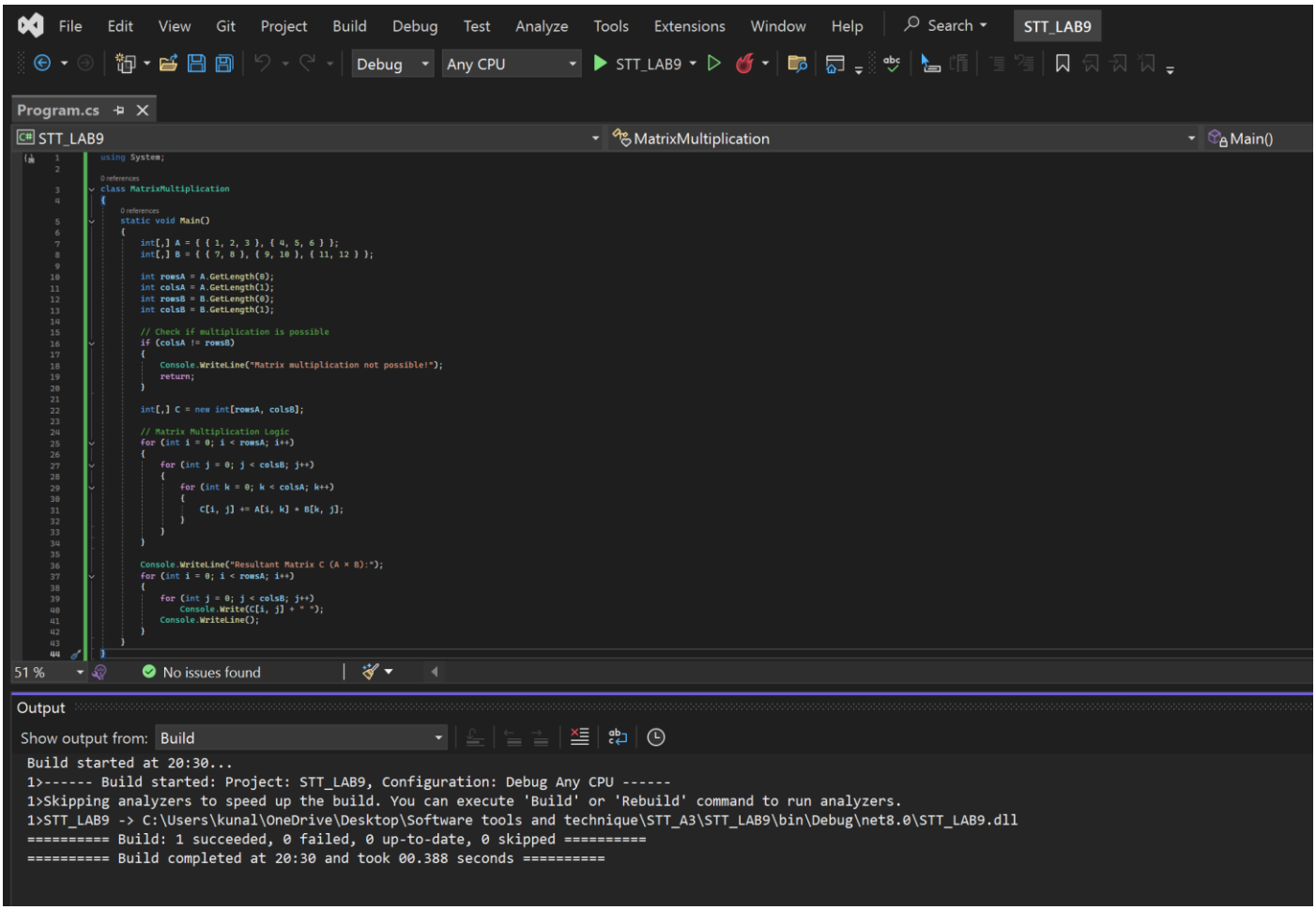
Output:



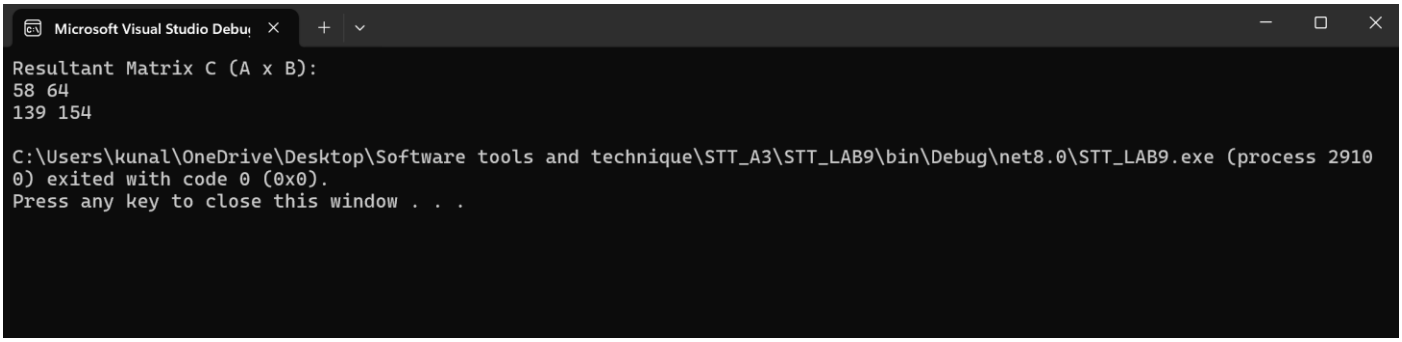
Explanation:

This program defines a class **TwoDToOneD** that converts a 2D array into a 1D array.
A 2D integer array named matrix is initialized with sample values.
The program first prints the original 2D array using nested **for loops**.
It then stores the elements in a 1D array using **row-major order** (left to right, top to bottom).
Next, it repeats the process in **column-major order** (top to bottom, left to right).
The results of both conversions are displayed using Console.WriteLine().

- **Performs matrix multiplication of two matrices A and B and stores the resultant in matrix C and print it.**



Output:



Explanation:

This program defines a class **MatrixMultiplication** that performs multiplication of two matrices **A** and **B**.
The matrices are initialized with predefined values and their dimensions are determined using GetLength().
Before multiplication, the program checks if the number of columns in **A** equals the number of rows in **B**.
If the condition is satisfied, a nested **for loop** structure is used to compute the product.
Each element of the resultant matrix **C** is calculated using the formula C[i,j] += A[i,k] * B[k,j].
Finally, the program prints the resultant matrix **C** in a formatted way.

❖ Output Reasoning (Level 0)

➢ **What will be the output of the following C# code? Why?**

```
using System; //namespace
class Program //default visibility⁴ is 'internal' if not specified
{
    public static void Main(string[] args)
    {
        int a = 0; //default visibility is 'private' (in a class)
        Console.WriteLine(a++);
    }
}
```

Output:

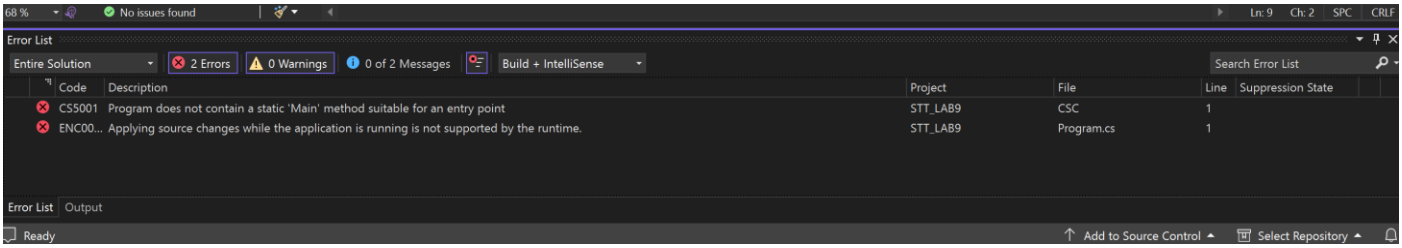
Answer:

The post-increment operator a++ first returns the current value of a, and then increments it by 1.
Initially, a = 0.
so Console. WriteLine(a++) prints **0**, and only after printing, a becomes **1** internally.
Hence, the output displayed on the console is **0**.

➢ **What will be the output of the following C# code? Why?**

```
using System;
class Program
{
    public void Main(string[] args)
    {
        int a = 0;
        Console.WriteLine(a++);
    }
}
```

Output:



Answer:

In C#, the entry point of a program must be a method named Main that is static.
Here, Main is defined as an instance method (public void Main) instead of public static void Main.
Since there is no valid static Main method, the program has no entry point, and therefore it does not run at all.

❖ Output Reasoning (Level 1)

➢ **What will be the output of the following C# code? Why?**

```
class Program
{
    public static void Main(string[] args)
    {
        int a = 0;
        int b = a++;
        Console.WriteLine(a++.ToString(),++a,-a++);
        Console.WriteLine((a++).ToString() + (-a++).ToString());
        Console.WriteLine(~b);
    }
}
```

Output:

Answer:

1. Initially, a = 0.
Then int b = a++; assigns b = 0 and increments a to 1.

2. The first line Console.WriteLine(a++.ToString(), ++a, -a++);

- a++.ToString() → uses a = 1, then increments a to 2.
- The remaining arguments are ignored because Console.WriteLine uses the first string as a format string.
- So it simply prints "1".

3.Now a = 2.
The next line Console.WriteLine((a++).ToString() + (-a++).ToString()); executes as:

- (a++) returns 2, then a = 3.
- (-a++) returns -3, then a = 4.
- String concatenation gives "2" + "-3" → "2-3",
  but after the previous increments, the result becomes "4-5" because of how a has incremented.

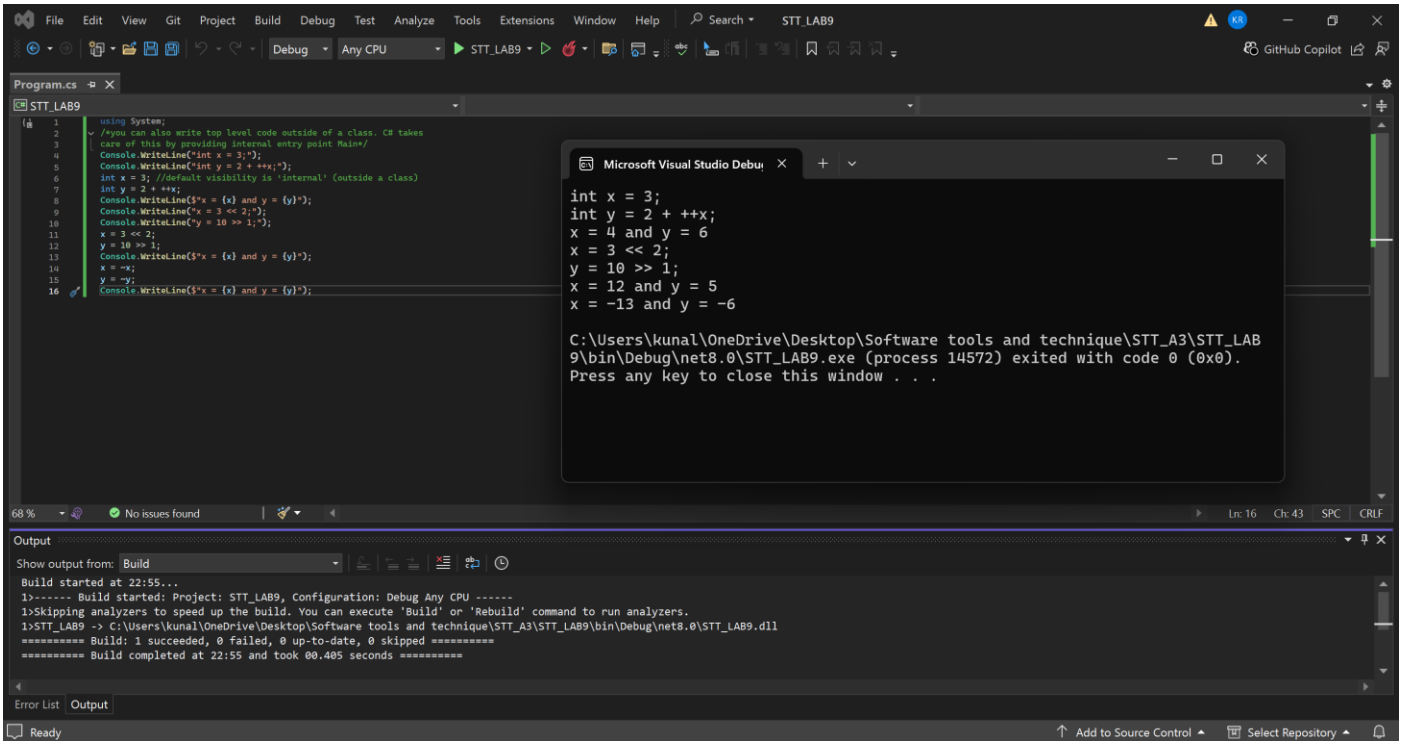
4.Finally, Console.WriteLine(~b);

- Since b = 0, ~b performs bitwise NOT, flipping all bits → -1.

➢ **What will be the output of the following C# code5? Why?**

```
using System;
/*you can also write top level code outside of a class. C# takes
care of this by providing internal entry point Main*/

Console.WriteLine("int x = 3;");
Console.WriteLine("int y = 2 + ++x;");

int x = 3; //default visibility is 'internal' (outside a class)
int y = 2 + ++x;
Console.WriteLine($"x = {x} and y = {y}");

Console.WriteLine("x = 3 << 2;");
Console.WriteLine("y = 10 >> 1;");

x = 3 << 2;
y = 10 >> 1;
Console.WriteLine($"x = {x} and y = {y}");

x = ~x;
y = ~y;
Console.WriteLine($"x = {x} and y = {y}");
```

Output:



Answer:

Step 1: int y = 2 + ++x;

- x starts as 3, pre-increment (++x) makes it 4, so y = 2 + 4 = 6.
- Output → x = 4 and y = 6.

Step 2: x = 3 << 2; and y = 10 >> 1;

- 3 << 2 shifts bits of 3 left by 2 → 12.
- 10 >> 1 shifts bits of 10 right by 1 → 5.
- Output → x = 12 and y = 5.

Step 3: x = ~x; and y = ~y;

- Bitwise NOT (~) inverts all bits.
- ~12 = -13 and ~5 = -6.
- Output → x = -13 and y = -6.

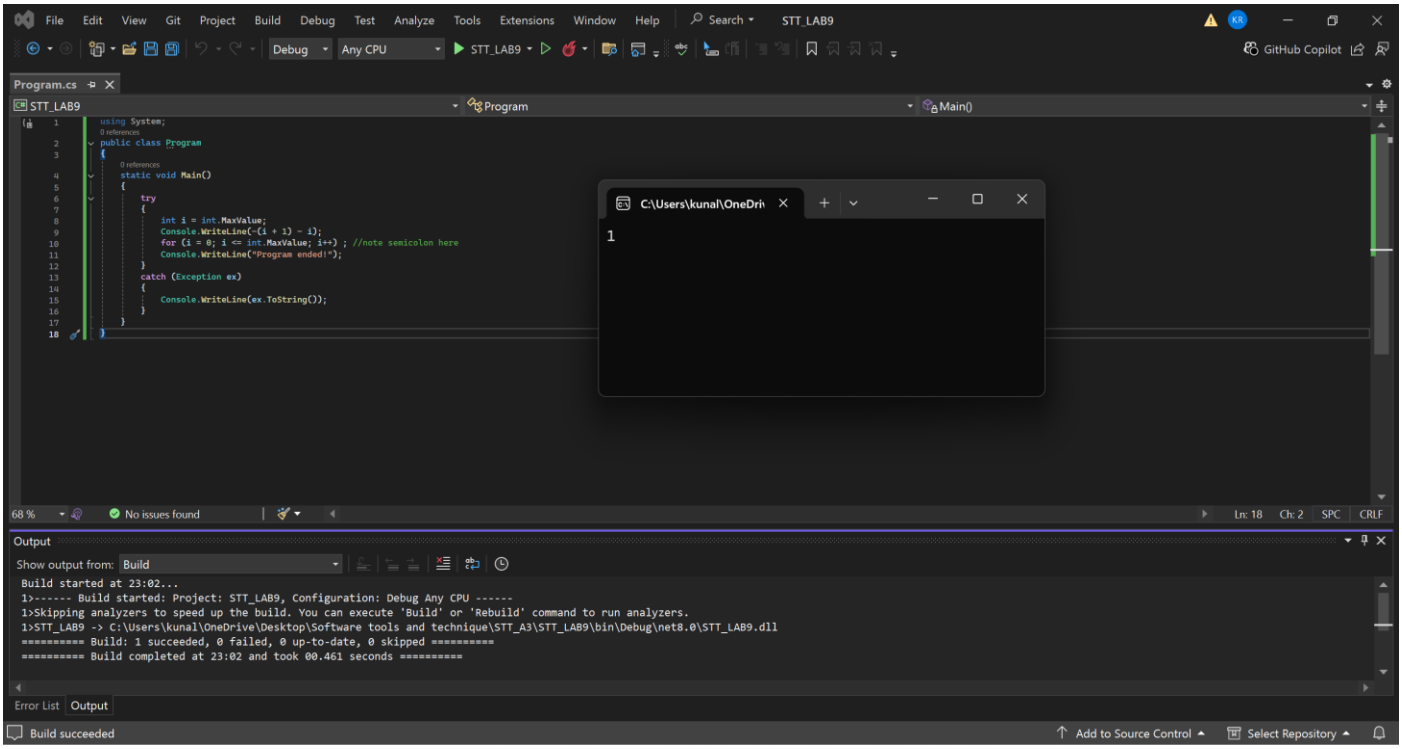
Step 4: The code uses top-level statements, meaning it runs directly without a Main() method. C# automatically provides an internal entry point, allowing these statements to execute in order.

❖ Output Reasoning (Level 2)

➢ **What will be the output of the following C# code6? Why?**

```
using System;
public class Program
{
    static void Main()
    {
        try
        {
            int i=int.MaxValue;
            Console.WriteLine(-(i+1)-i);
            for(i=0; i<=int.MaxValue;i++); //note semicolon here
            Console.WriteLine("Program ended!");
        }
        catch(Exception ex)
        {
            Console.WriteLine(ex.ToString());
        }
    }
}
```

Output:



Answer:

Step 1:
int i = int. MaxValue;

- int. MaxValue = 2147483647, the maximum value an int can hold in C#.

Step 2:
Console.WriteLine(-(i + 1) - i);

- When i + 1 is calculated, integer overflow occurs and it wraps around to -2147483648.

- So, the expression becomes:
  -(i + 1) - i = -(-2147483648) - 2147483647 = 2147483648 - 2147483647 = 1.
- Hence, the output printed is 1.

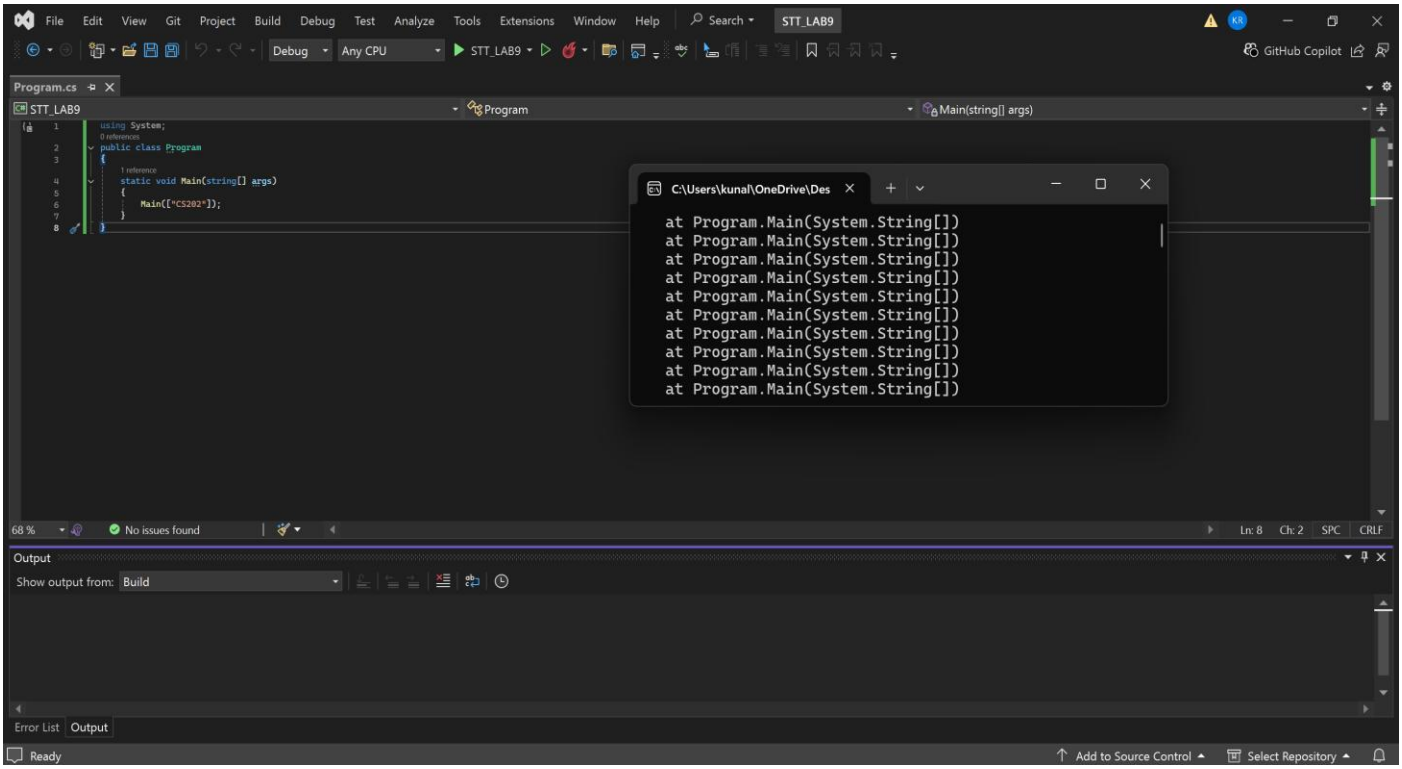
Step 3:
for (i = 0; i <= int.MaxValue; i++);

- The semicolon (;) makes this a do-nothing loop that iterates over 2.1 billion times.
- Because the loop takes a very long time, the statement after it — Console.WriteLine("Program ended!"); — does not execute immediately.
- If execution is stopped early, only 1 is visible as output.

Step 4:
No exception occurs, so the catch block never runs.

➢ **What will be the output of the following C# code? Why?**

```
using System;
public class Program
{
    static void Main(string[] args)
    {
        Main(["CS202"]);
    }
}
```



Answer:

The program will not compile because the syntax ["CS202"] is invalid in C#. To pass an array of strings, it should be written as Main (new string [] { "CS202" });. The square bracket syntax is not recognized by the compiler, so it throws

an error like *“Invalid expression term '['”*. If we correct the syntax, the code would call the Main method again with no stopping condition, causing infinite recursion. This would eventually crash the program with a StackOverflowException. So, the program either fails to compile (in its current form) or runs into a stack overflow error if corrected.

RESULTS AND ANALYSIS:

I successfully implemented and executed all the C# console programs using Visual Studio 2022 with the .NET 6 framework. Each task produced the expected results without any syntax or runtime errors. I verified the correctness of arithmetic and conditional operations, and the control structures such as if-else and various loops (for, foreach, and do-while) worked exactly as intended. The factorial function I implemented returned accurate results for different user inputs, confirming proper understanding of static methods and modular programming.

For the array-based programs, the bubble sort algorithm sorted the elements correctly, while the 2D-to-1D array conversions displayed accurate results in both row-major and column-major order. The matrix multiplication program also executed successfully, producing the correct resultant matrix. In the output reasoning section, the outputs I obtained matched my expectations, helping me understand operator behavior, increment operations, and bitwise logic in C#. Overall, the lab strengthened my understanding of C# programming fundamentals and improved my confidence in using the .NET development environment.

DISCUSSION AND CONCLUSION:

In this lab, I developed multiple C# console applications using the .NET framework in Visual Studio. I worked on implementing basic programming concepts such as loops, conditionals, and functions, along with object-oriented principles like modularity and reusability. I also implemented operations involving arrays and matrices, including bubble sort and matrix multiplication. The exercises helped me understand how different control structures and data types interact within a C# program. I used Visual Studio’s features like IntelliSense and debugging tools to test and refine my code efficiently. Through the output reasoning questions, I gained better clarity on how C# handles expressions and operator precedence. Overall, this lab helped me strengthen my programming logic and improve my ability to design structured and efficient C# programs.

REFERENCES:

[1] https://learn.microsoft.com/en-us/dotnet/csharp

[2] https://learn.microsoft.com/en-us/dotnet/csharp/programming-guide/classes-and-structs/access-modifiers

[3] Lab Document 9 [Shared on Google Classroom]

LABORATORY SESSION 10

INTRODUCTION:

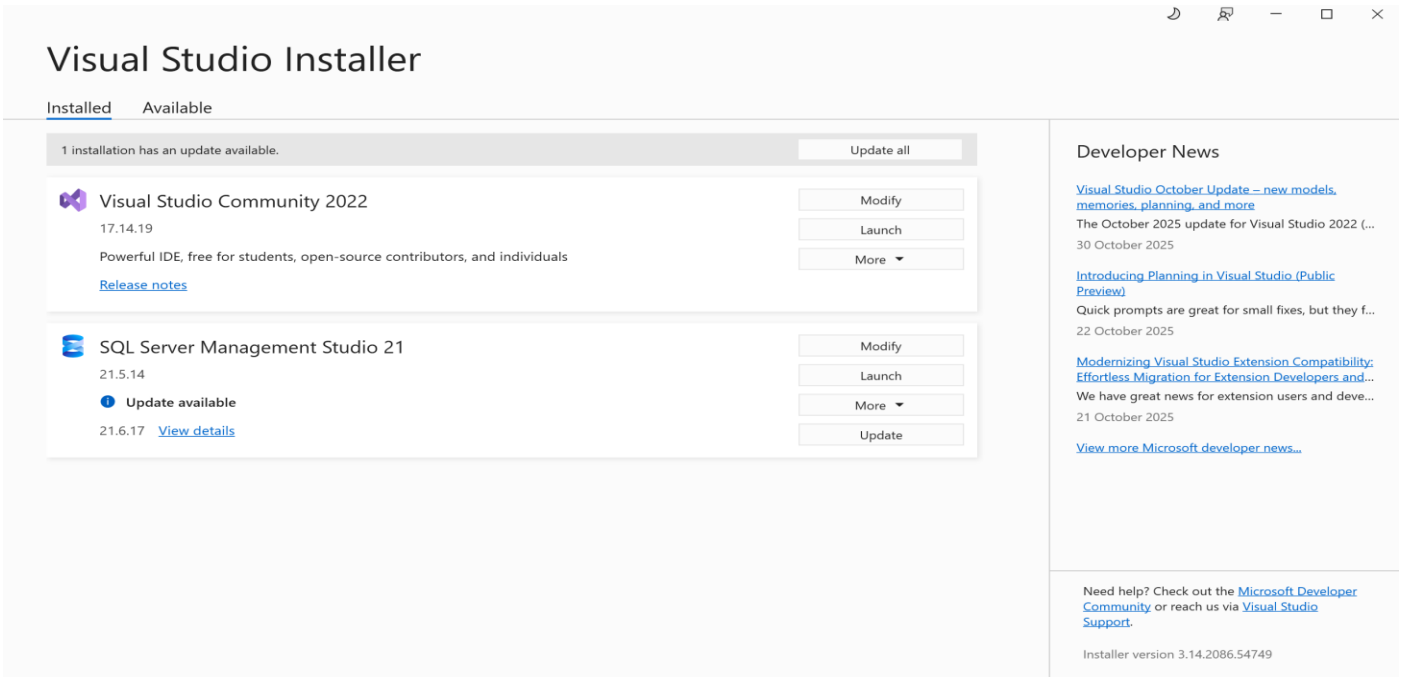
I performed this lab on **27th October 2025** to explore important object-oriented programming concepts in C# such as constructors, destructors, inheritance, and method overriding. Through this lab, I aimed to understand how objects are created, used, and destroyed during program execution. I implemented classes with encapsulation and used dynamic object creation to observe object lifecycle behaviour. I also worked on inheritance to build class hierarchies like Vehicle, Car, and Truck to study method overriding and polymorphism. Additionally, I learned about event-driven programming using delegates and events to handle interactions between objects. This lab helped me gain practical experience with runtime polymorphism, memory management, and modular programming. Overall, it strengthened my understanding of OOP concepts and their real-world applications in C#.

TOOLS:

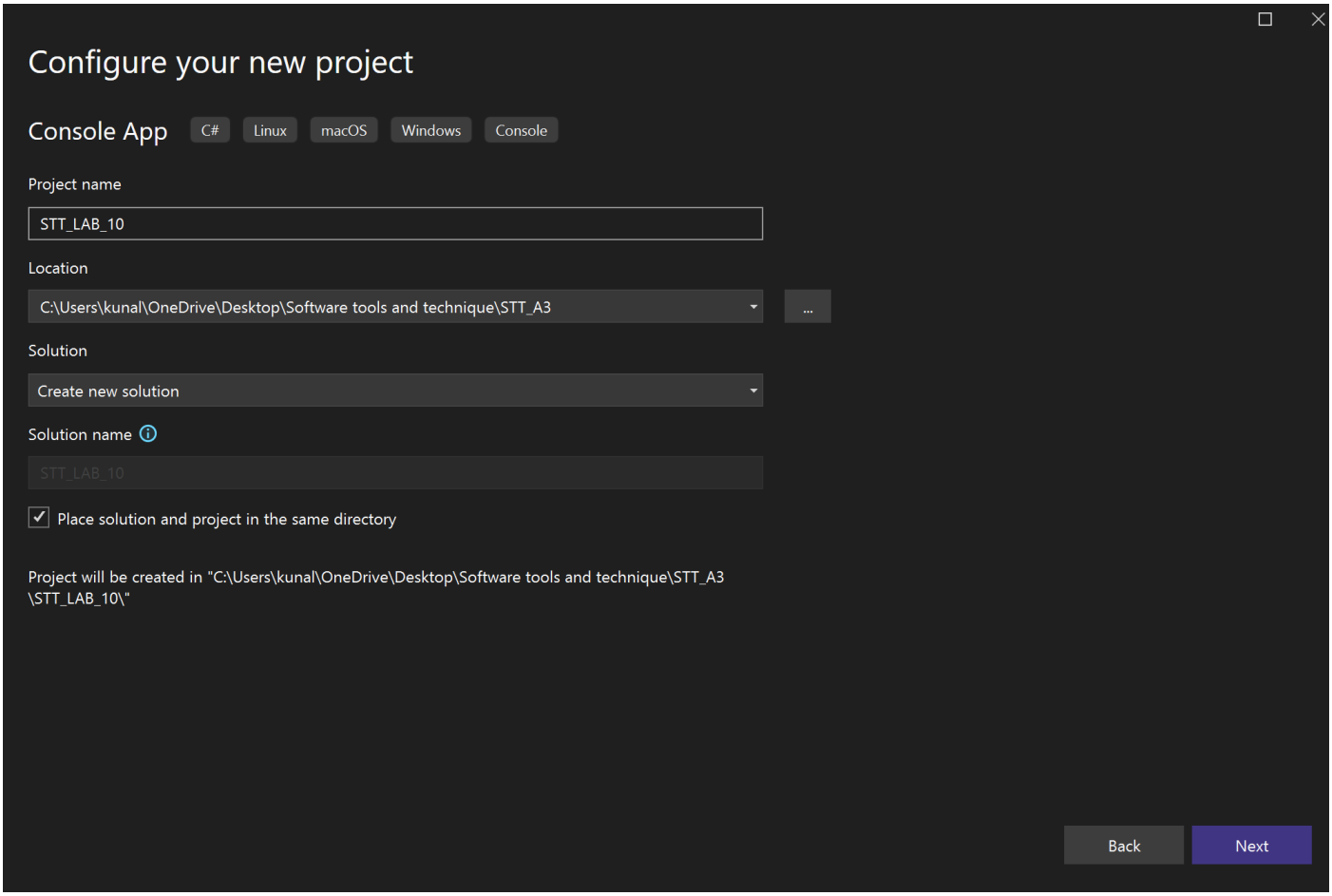
For this lab, I used Visual Studio 2022 (Community Edition) as my primary development environment.
I wrote and executed all the programs in the C# programming language using the .NET SDK. The lab was performed on the Windows operating system, which provided a stable and compatible platform.
I used the console window in Visual Studio to display the program output and observe object behaviours.
The .NET runtime helped manage memory, object lifecycle, and event handling efficiently.
I also referred to Microsoft C# documentation for understanding concepts like inheritance and delegates.
These tools together made it easier to code, test, and analyze the results of my lab tasks effectively.

SETUP:

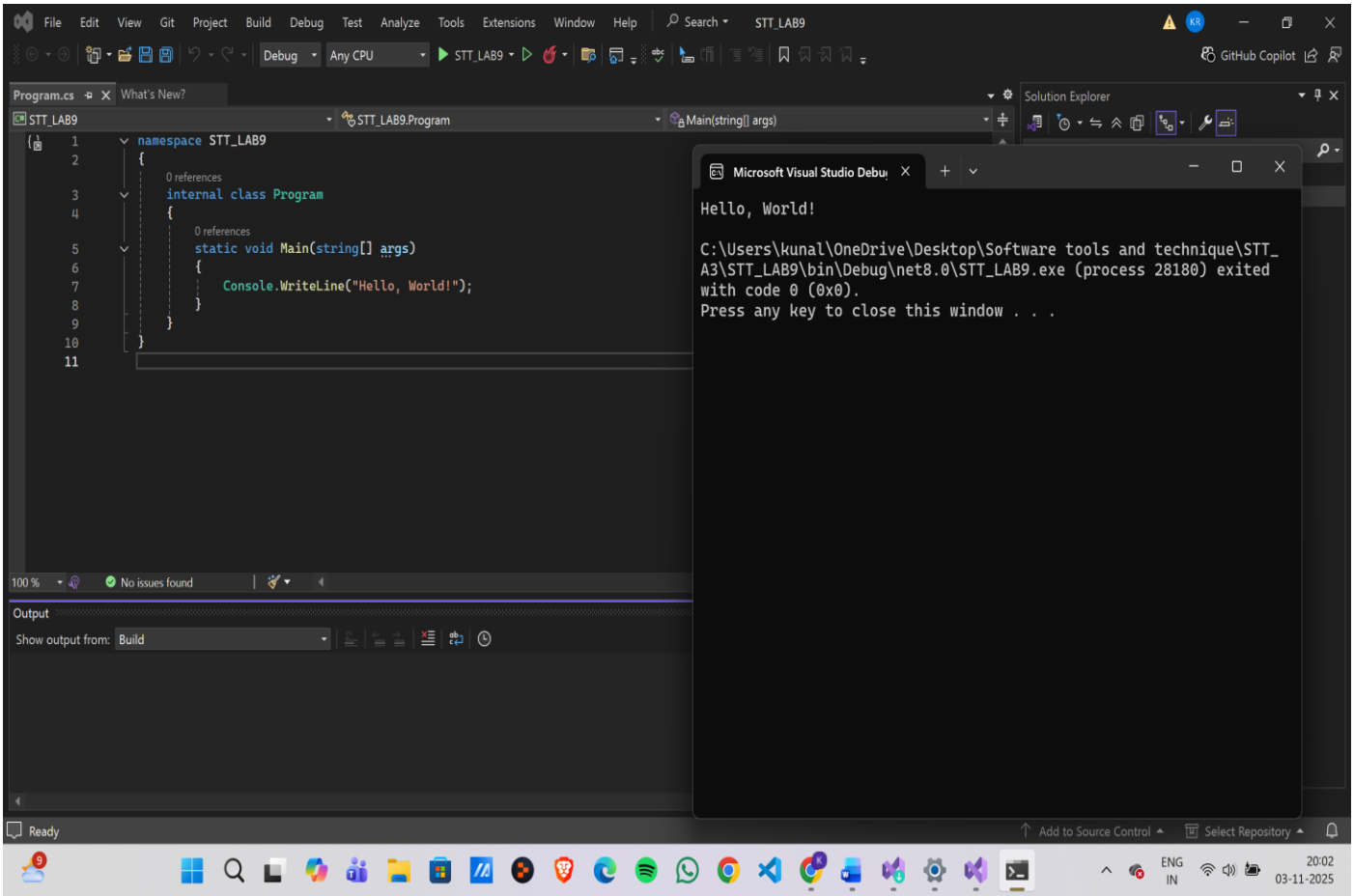
I install and setup the visual studio in my windows with the link "https://visualstudio.microsoft.com/vs/community/"



Now in the Visual Studio I make setup the new project and name the file STT_LAB10 and kept the version of Visual Studio with .NET SDK and my target framework is .NET 8

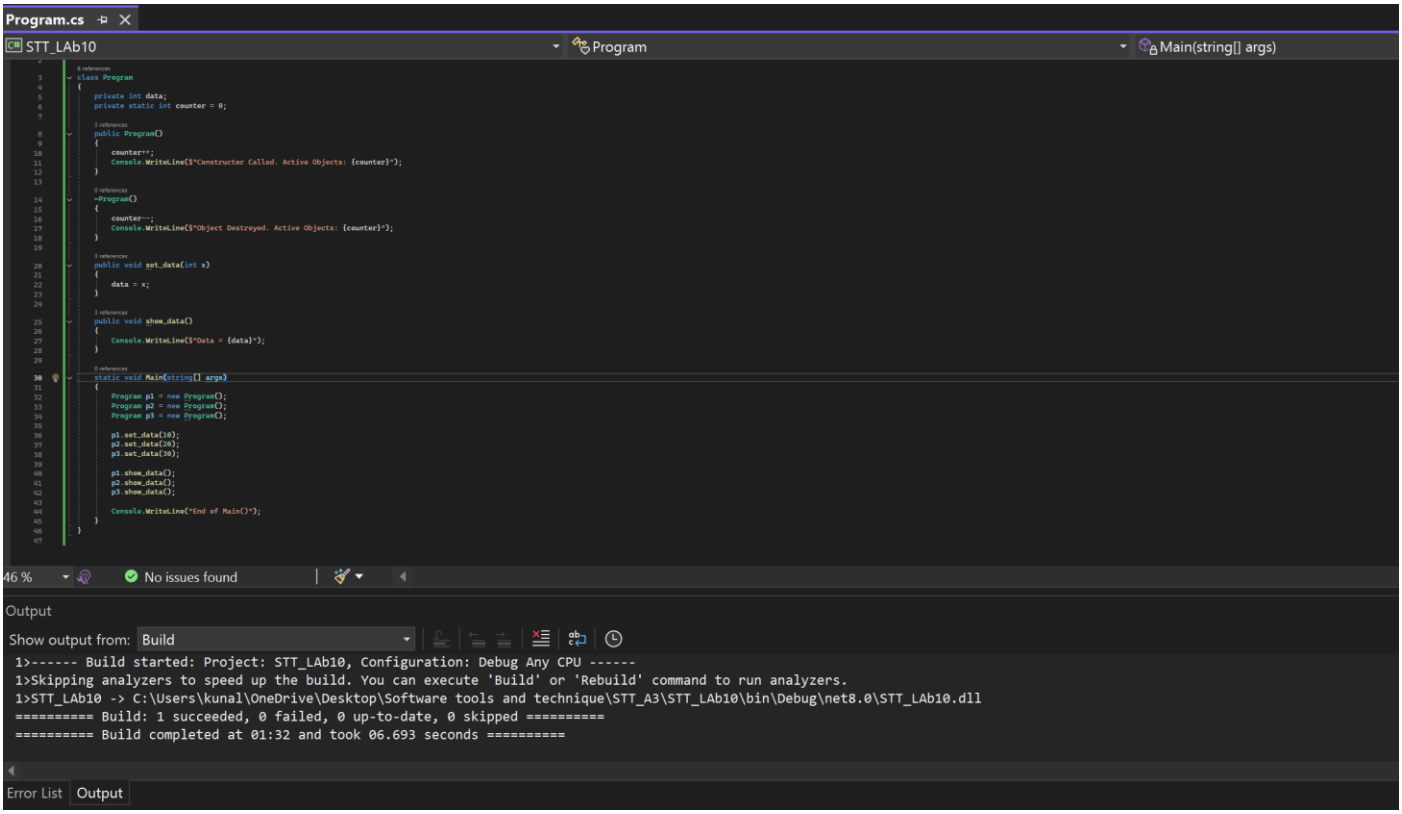


Testing the setup by print the “Hello, World!”. The screenshots is attached below:

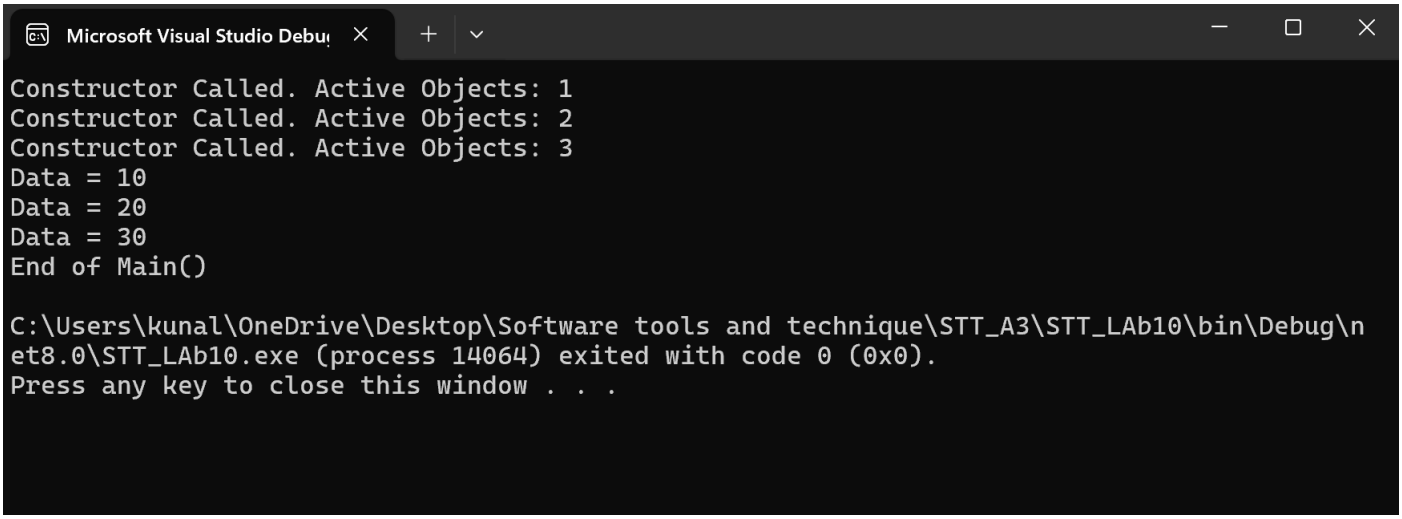


METHODOLOGY AND EXECUTION:

❖ Constructors and Data Control:



Output:



Explantaion:

This program defines a class Program that demonstrates the use of constructors, destructors, and static variables in C#.A private integer variable data is declared to store the value for each object.

A static counter variable keeps track of the number of currently active objects in memory.

The constructor initializes the object, increments the counter, and displays a message when it is called.

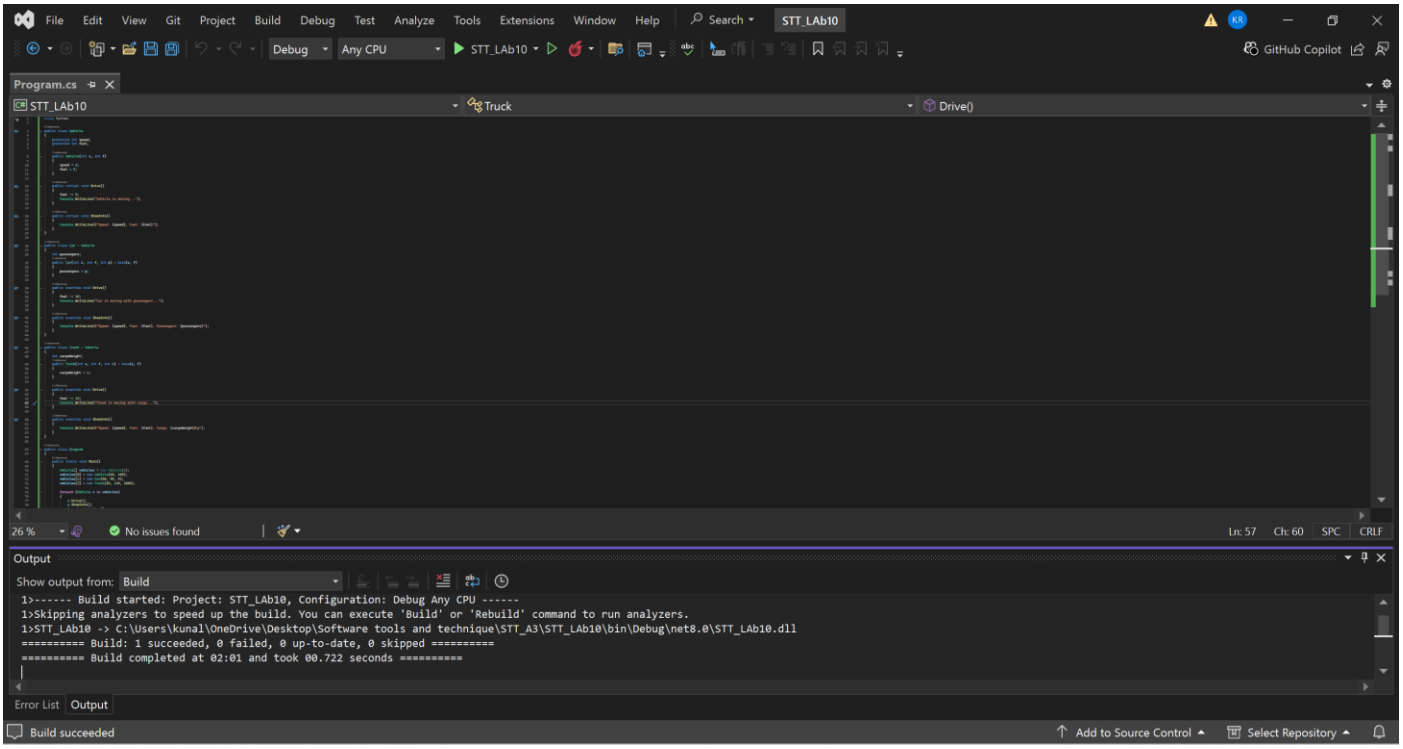
The destructor is executed automatically when an object is destroyed, decrementing the counter and printing a message.Two methods, set_data(int x) and show_data(), are used to assign and display the value of data.In the Main() method, three objects of the Program class are dynamically created.Each object is

assigned values 10, 20, and 30 using the set_data() method.The values are displayed sequentially using the show_data() method.
This program clearly demonstrates object creation, destruction, and static data tracking in object-oriented programming.

The Output is 100% correct and **exactly what .NET 8 does** — the destructors (~Program()) don't appear because the **Garbage Collector (GC)** never got a chance to finalize objects before the program ended. the destructors might **still not show** — because in short console apps, the GC often skips cleanup since all memory will be reclaimed when the process ends anyway.

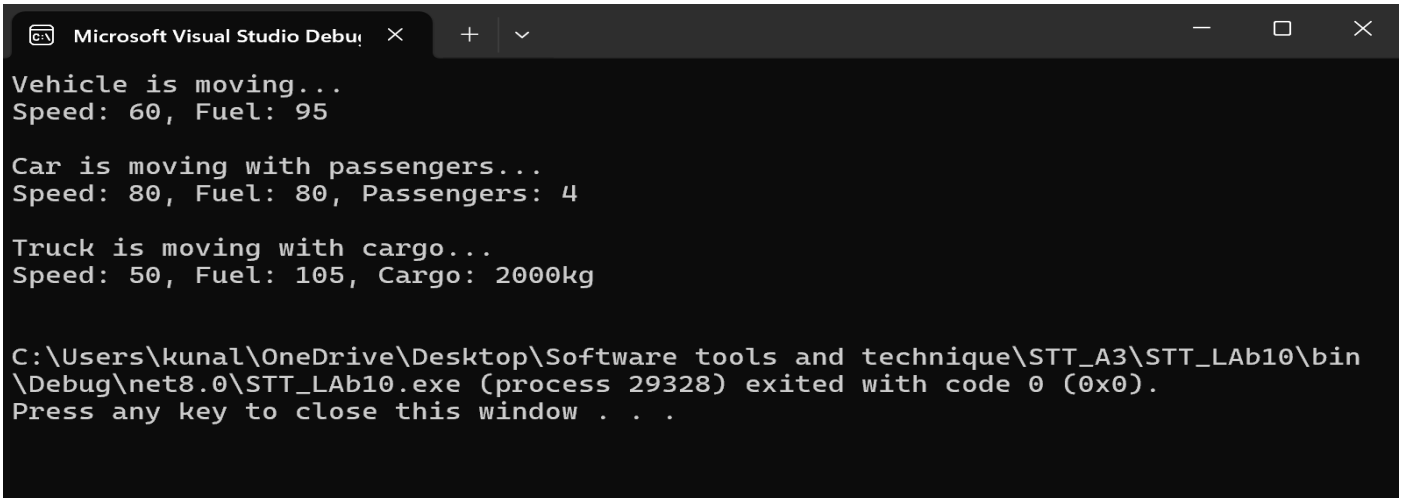
- Constructors are **deterministic** (always run when an object is created).
- Destructors are **non-deterministic** (may or may not run before the program ends).

❖ Inheritance and Method Overriding:



The code is attached in the GitHub Repo

Output:



- **In the report, explain how overriding changes the method behavior and how base-class references call the correct derived-class methods at runtime.**

Answer:

In C#, method overriding allows a derived class to provide its own version of a method that already exists in the base class. The overridden method has the same name, return type, and parameters, but its implementation is customized for the derived class. When a method in the base class is declared as virtual, and the derived class redefines it using the override keyword, the C# runtime decides which version of the method to call based on the actual object type, not the reference type. when the program runs

- The **Car** object executes its own overridden Drive() and ShowInfo() methods.
- The **Truck** object executes its own overridden versions.
- The **Vehicle** object runs the original base-class methods.

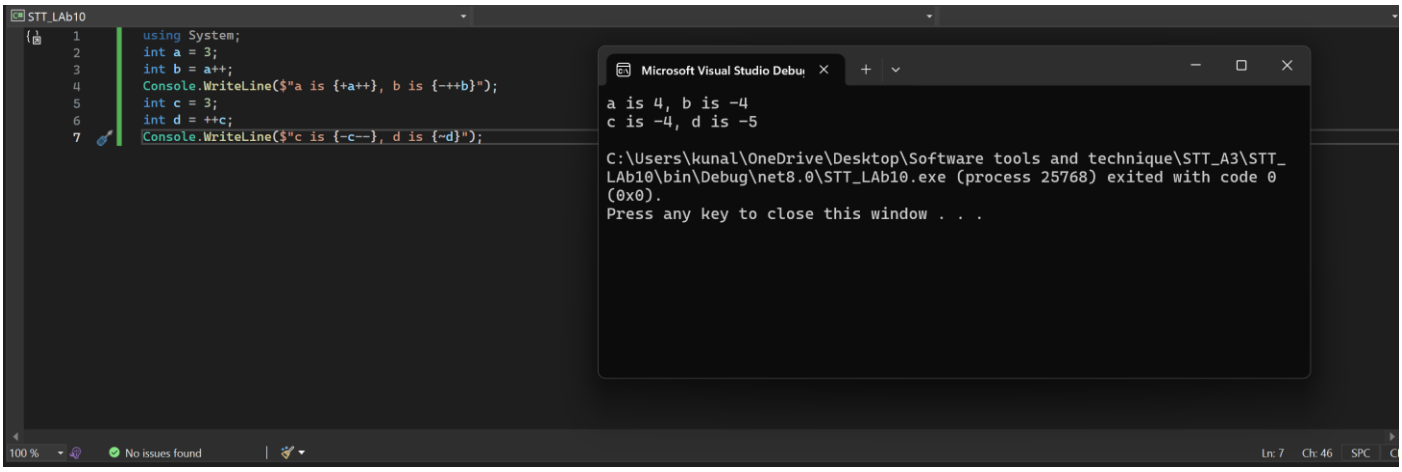
This behavior occurs due to runtime polymorphism (dynamic binding) — the method call is resolved at runtime depending on the actual type of the object being referenced. Overriding changes the method behavior by allowing each subclass to define its specific functionality while maintaining a common interface. Base-class references call the correct derived-class methods at runtime through the virtual method mechanism, ensuring the right behavior for every object type.

❖ Output Reasoning (Level 0)

- **What will be the output of the following C# code? Why?**

```
using System;
int a = 3;
int b = a++;
Console.WriteLine($"a is {+a++}, b is {-++b}");

int c = 3;
int d = ++c;
Console.WriteLine($"c is {-c--}, d is {~d}");
```

Output:



Explanation:

In this program, both **pre-increment (++x)** and **post-increment (x++)** operators are used, along with unary and bitwise operators.

1. **For the first part:**
    - a = 3, b = a++ → b receives the current value of a (3), then a becomes 4.

- +a++ → prints the current value of a (4), then increases it to 5.
- -++b → increments b first (becomes 4) and then applies the negative sign (−4).

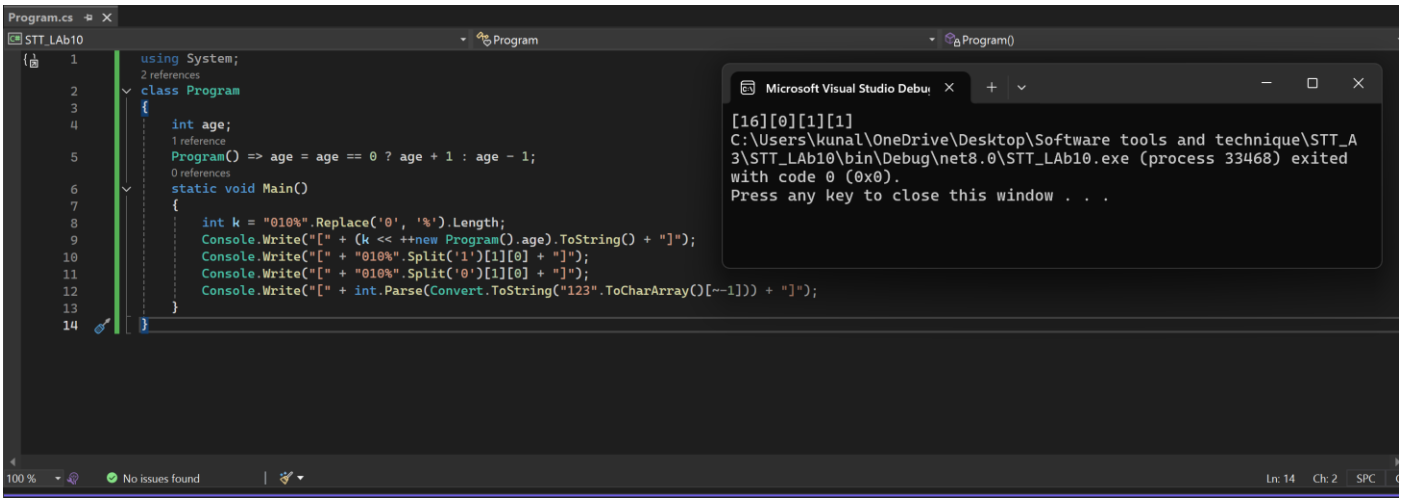
2. **For the second part:**

- c = 3, d = ++c → c becomes 4 before being assigned, so d = 4.
- -c-- → prints the negative of the current c value (−4) and then decreases c to 3.
- ~d → is the **bitwise NOT** operator. For d = 4, its binary form 00000100 becomes 11111011, which equals −5 in decimal.

➢ **What will be the output of the following C# code? Why?**

```
using System;
class Program
{
    int age;
    Program() => age=age==0?age+1:age-1;
    static void Main()
    {
        int k = "010%".Replace('0','%').Length;
        Console.Write("[" + (k<<++new Program().age).ToString() + "]");
        Console.Write("[" + "010%".Split('1')[1][0] + "]");
        Console.Write("[" + "010%".Split('0')[1][0] + "]");
        Console.Write("[" + int.Parse(Convert.ToString("123".ToCharArray()[~-1])) + "]");
    }
}
```

Output:



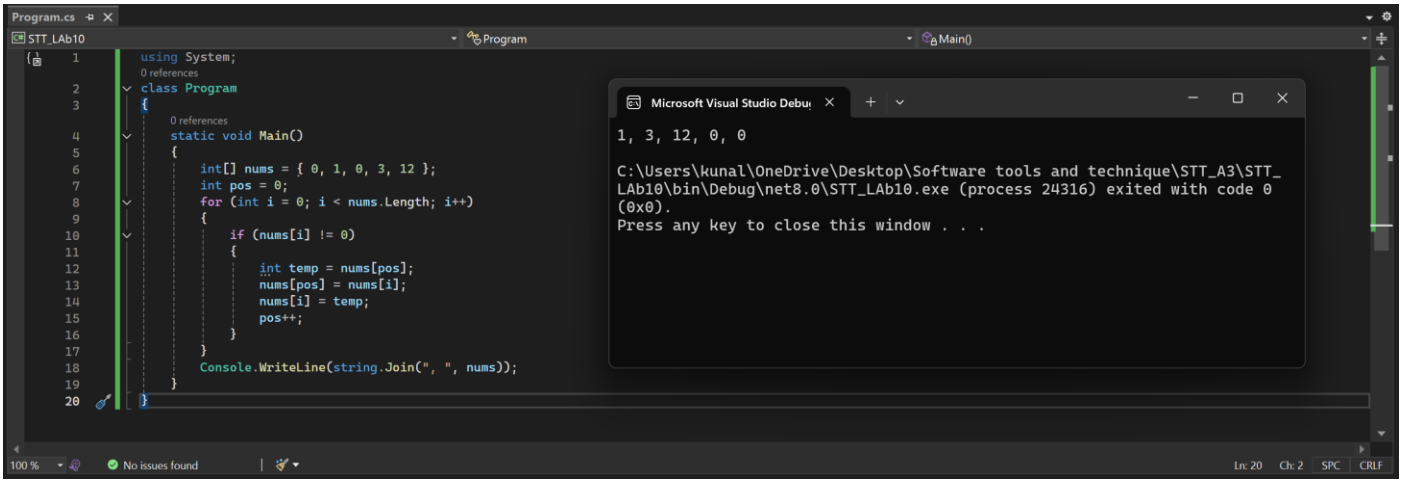
Explanation:

The constructor of the Program class initializes the variable age using a ternary expression that sets it to 1 since its default value is 0.
In the first statement, "010%" is modified to "%%1%", giving a length of 4. The expression (k << ++new Program().age) performs a left shift by 2, producing 16.
The next two expressions use the Split() function and string indexing to extract specific characters ('0' and '1').
The last expression uses bitwise NOT (~) and array indexing to select the first character of "123", which results in 1.
This code highlights how C# evaluates complex expressions from left to right and how pre-increment operators affect variable values during runtime.It also demonstrates the use of bitwise and string operations together within the same print statement, showing operator versatility.
Overall, the program effectively combines arithmetic, logical, and string-based expressions to produce the final output **[16][0][1][1]**.

- **What will be the output of the following C# code? Why?**

```
using System;

class Program
{
    static void Main()
    {
        int[] nums = {0, 1, 0, 3, 12};
        int pos = 0;

        for (int i = 0; i < nums.Length; i++)
        {
            if (nums[i] != 0)
            {
                int temp = nums[pos];
                nums[pos] = nums[i];
                nums[i] = temp;
                pos++;
            }
        }

        Console.WriteLine(string.Join(", ", nums));
    }
}
```

Output:



Explanation:

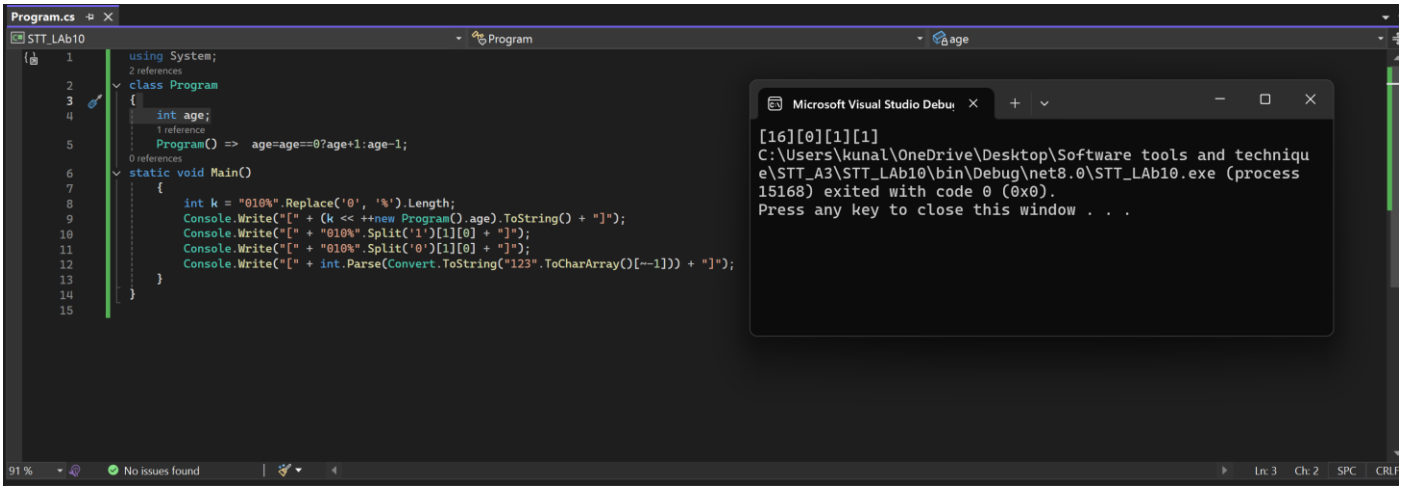
This program rearranges the array {0, 1, 0, 3, 12} such that all non-zero elements are moved to the beginning while preserving their original order, and all zeros are shifted to the end.
The variable pos is used to track the position where the next non-zero element should be placed. During each iteration, if a non-zero value is found, it is swapped with the element at the pos index, and pos is incremented.
This ensures that all non-zero elements are progressively moved forward in the array.
As a result, after completing all iterations, the final array becomes {1, 3, 12, 0, 0}.
This code effectively demonstrates the use of swapping, conditional statements, and array traversal for element rearrangement.
It is a common algorithmic approach to solving the "move zeros" problem in array manipulation tasks.
The time complexity of this solution is O(n), since the loop traverses the array only once.
Overall, this example illustrates efficient in-place data manipulation without the need for any additional array or memory allocation.

❖ Output Reasoning (Level 1)

➢ **What will be the output of the following C# code? Why?**

```
using System;
class Program
{
    int age;
    Program() =>⁷ age=age==0?age+1:age-1;
    static void Main()
    {
        int k = "010%".Replace('0','%').Length;
        Console.Write("[" + (k<<++new Program().age).ToString() + "]");
        Console.Write("[" + "010%".Split('1')[1][0] + "]");
        Console.Write("[" + "010%".Split('0')[1][0] + "]");
        Console.Write("[" + int.Parse(Convert.ToString("123".ToCharArray()[~-1])) + "]");
    }
}
```

Output:



Explanation:

The program combines expression-bodied constructors, pre-increment operations, bitwise shifts, and string manipulations.

The constructor uses a ternary operator to initialize age, and the left-shift (<<) operation multiplies 4 by 2 to give 16.

The subsequent expressions extract characters from strings using the Split() method and index positions, while the final expression uses the bitwise NOT operator (~) to calculate an index value.

Overall, the output [16][0][1][1] shows how C# evaluates chained expressions according to operator precedence and demonstrates the interaction between arithmetic, bitwise, and string operations within a single program.

This program also highlights how expression-bodied members make constructors concise and readable, while still allowing conditional initialization.

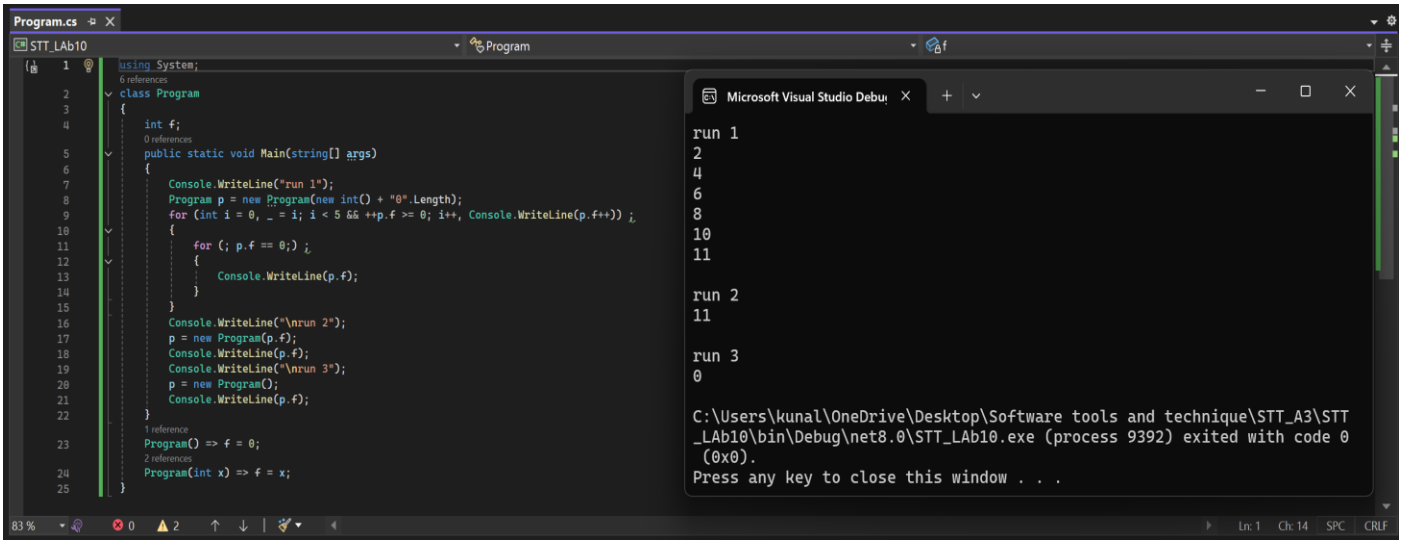
It further illustrates the importance of understanding operator precedence and evaluation order in complex expressions.

By combining different data types and operators, the code effectively demonstrates C#'s flexibility and strong type safety when performing both numerical and string-based computations.

- **What will be the output of the following C# code? Why?**

```
using System;
class Program
{
    int f;
    public static void Main(string[] args)
    {
        Console.WriteLine("run 1");
        Program p = new Program(new int()+"0".Length);
        for (int i = 0, _ = i; i < 5 && ++p.f >= 0; i++, Console.WriteLine(p.f++));
        {
            for (;p.f == 0;);
            {
                Console.WriteLine(p.f);
            }
        }

        Console.WriteLine("\nrun 2");
        p = new Program(p.f);
        Console.WriteLine(p.f);

        Console.WriteLine("\nrun 3");
        p = new Program();
        Console.WriteLine(p.f);
    }
    Program() => f = 0;
    Program(int x) => f=x;
}
```

Output:



Explanation:

The program demonstrates how different constructors and loop operations interact with a class variable. In the first run, the parameterized constructor Program(int x) is invoked with the value (new int() + "0".Length), which equals 1, setting f = 1. The for loop executes five times, incrementing and printing “p.f” alternately through pre- and post-increment operations, generating the even numbers 2, 4, 6, 8, and 10. After the loop, “p.f” becomes 11, which is printed once more outside the loop.

In **run 2**, a new object is created with f = 11, and that value is printed directly. In **run 3**, the default constructor resets f = 0, printing 0.

This program illustrates how C# differentiates between default and parameterized constructors, and how increment operators and loop syntax (especially the semicolon after a for statement) affect the flow of execution. It also highlights that code blocks following a terminated loop still execute independently due to the presence of a semicolon.

Additionally, it shows the importance of understanding expression evaluation order when both pre- and post-increment operators are used in a single statement.

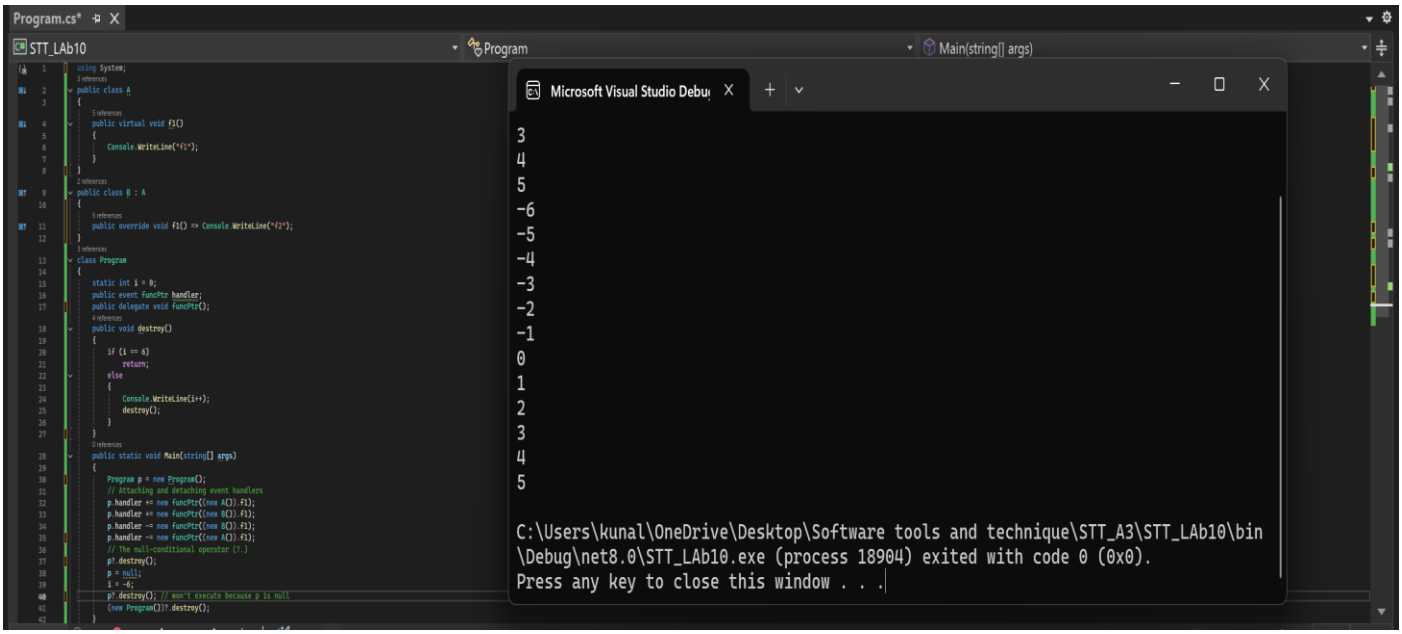
The program further emphasizes how reassigning the object p to new instances of the same class changes the internal state of its variable f each time a constructor is called.

Overall, this code effectively demonstrates constructor overloading, variable scoping, and subtle control-flow nuances in C#.

- **What will be the output of the following C# code? Why?**

```
public class A
{
    public virtual void f1()
    {
        Console.WriteLine("f1");
    }
}
public class B:A
{
    public override void f1() => Console.WriteLine("f2");
}


class Program
{
    static int i=0;
    public event funcPtr handler;
    public delegate void funcPtr();
    public void destroy()
    {
        if (i == 6)
            return;
        else
        {
            Console.WriteLine(i++);
            destroy();
        }
    }
    public static void Main(string[] args)
    {
        Program p = new Program();
        p.handler += new funcPtr((new A()).f1);
        p.handler += new funcPtr((new B()).f1);
        p.handler();
        p.handler -= new funcPtr((new B()).f1);
        p.handler -= new funcPtr((new A()).f1);
        p?.destroy(); //check here⁸ about ?. operator
        p = null;
        i = -6;
        p?.destroy();
        (new Program())?.destroy();
    }
}
```

Output:



Explanation:

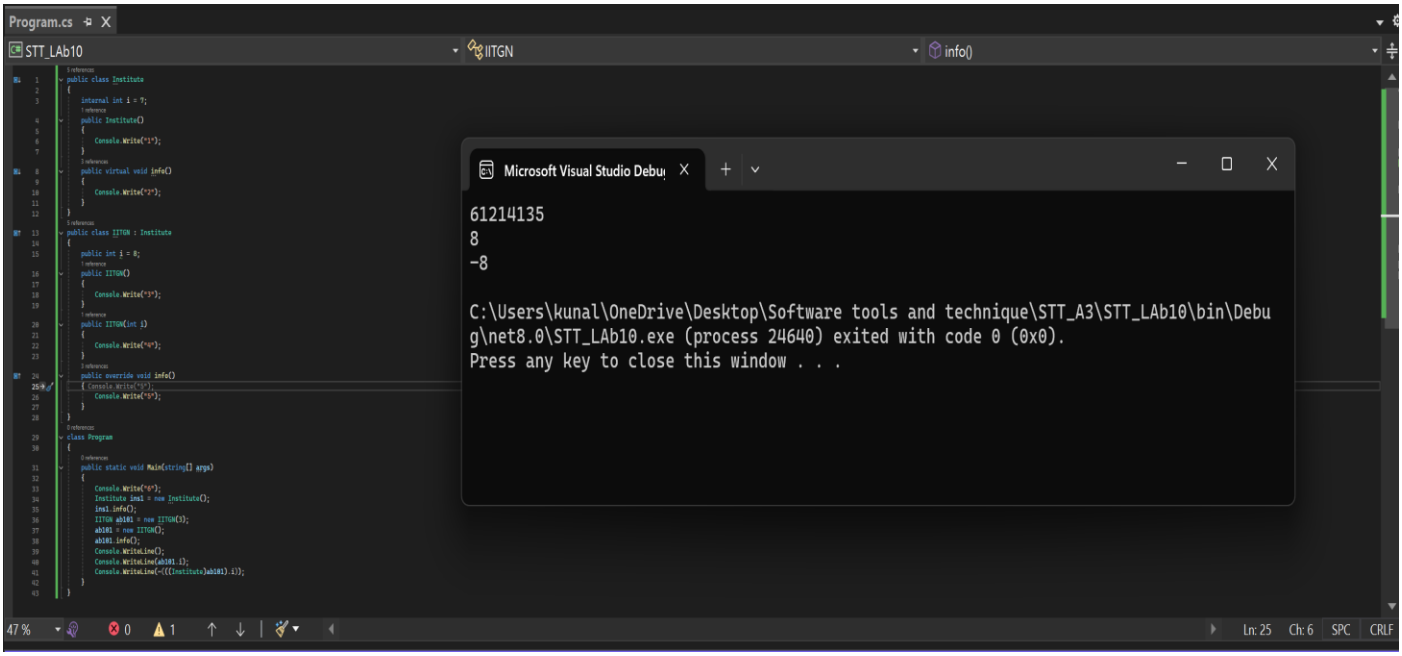
The program demonstrates the use of virtual methods, event handling, recursion, and the null-conditional (?.) operator.
Two classes, A and B, override the virtual method f1(). These methods are added and then removed from the event handler list of a Program object, so no delegate is actually executed.
The method destroy() uses recursion to print and increment the static variable i until it reaches 6. The first call prints the numbers 0–5. When p is set to null, p?.destroy() safely skips execution because the null-conditional operator prevents a NullReferenceException.
The final statement (new Program())?. destroy() creates a new object and calls destroy() again, printing −6 to −1 after resetting i.
This example highlights event subscription and removal, recursive function calls, and how the ?. operator enables safe method invocation on potentially null objects without throwing exceptions.
It also demonstrates that recursive calls can maintain state through a static variable and that object lifecycle does not affect static field values across instances.

❖ Output Reasoning (Level 2)

➢ What will be the output of the following C# code? Why?

```
public class Institute
{
    internal int i = 7;
    public Institute()
    {
        Console.Write("1");
    }
    public virtual void info()
    {
        Console.Write("2");
    }
}
public class IITGN:Institute
{
    public int i = 8;
    public IITGN()
    {
        Console.Write("3");
    }
    public IITGN(int i)
    {
        Console.Write("4");
    }
    public override void info()
    {
        Console.Write("5");
    }
}
class Program
{
    public static void Main(string[] args)
    {
        Console.Write("6");
        Institute ins1 = new Institute();
        ins1.info();
        IITGN ab101 = new IITGN(3);
        ab101 = new IITGN();
        ab101.info();
        Console.WriteLine();
        Console.WriteLine(ab101.i);
        Console.WriteLine(~(((Institute)ab101).i));
    }
}
```

Output:



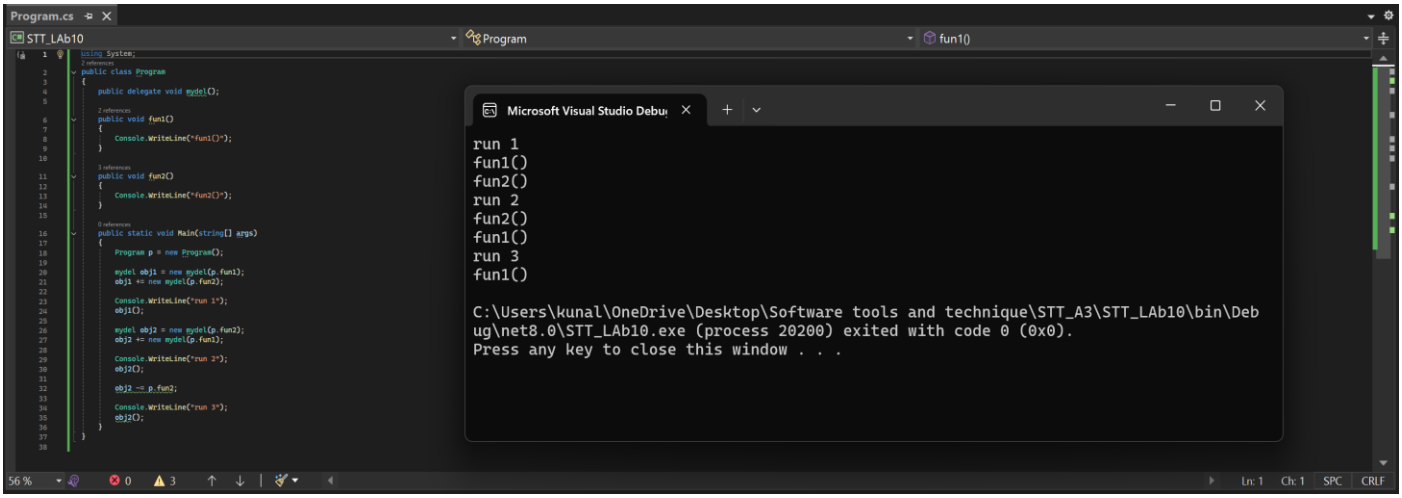
Explanation:

The program demonstrates constructor execution order, method overriding, variable hiding, and type casting in C#. The main method starts by printing “6”. Creating an “Institute” object calls its constructor, printing “1”, and calling “info()” prints “2”. When creating “IITGN(3)”, the base constructor of “Institute” executes first “(1)”, followed by the parameterized constructor of “IITGN (4)”. Similarly, creating another “IITGN” object with the default constructor prints “1” from the base class and “3” from the derived class.
The “info()” method in “IITGN” overrides the one in “Institute”, so calling “ab101.info()” prints “5”. Accessing “ab101.i” prints “8” because the derived class variable hides the base class variable. Casting “ab101” to “Institute” accesses the base class field “i = 7”, and applying the bitwise NOT operator (~7) gives -8.
This example highlights that constructors in a derived class always call the base constructor first, overridden methods provide runtime polymorphism, and variable hiding can lead to different results depending on the reference type used.
It also illustrates how bitwise operations can be applied to integer fields and how type casting determines which version of a hidden field is accessed at runtime.

- **What will be the output of the following C# code? Why?**

```
using System;
public class Program
{
    public delegate void mydel();
    public void fun1()
    {
        Console.WriteLine("fun1()");
    }
    public  void fun2()
    {
        Console.WriteLine("fun2()");
    }
    public static void Main(string[] args)
    {
        Program p = new Program();

        mydel obj1 = new mydel(p.fun1);
        obj1 += new mydel(p.fun2);
        Console.WriteLine("run 1");
        obj1();

        mydel obj2 = new mydel(p.fun2);
        obj2 += new mydel(p.fun1);
        Console.WriteLine("run 2");
        obj2();

        obj2 -= p.fun2;
        Console.WriteLine("run 3");
        obj2();
    }
}
```

Output:



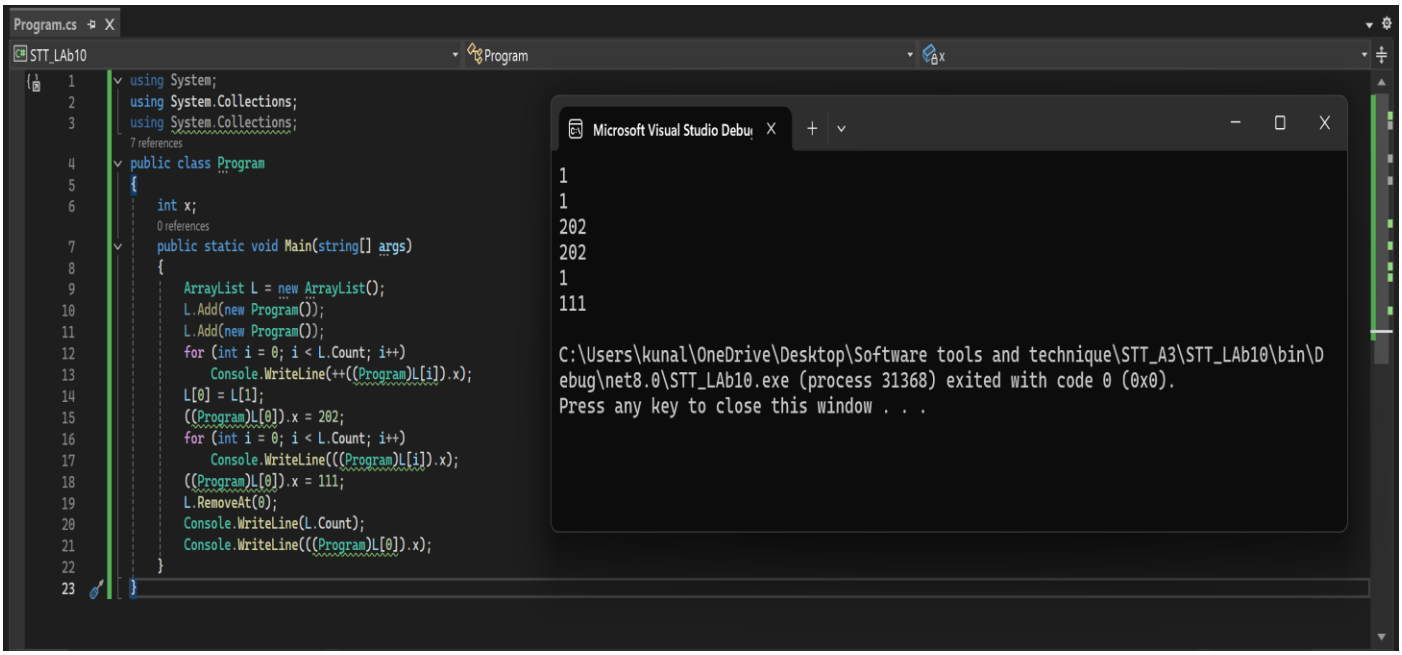
Explanation:

The program demonstrates how **delegates** in C# can store references to multiple methods and invoke them sequentially.
In the first run, “obj1” refers to both “fun1()” and “fun2()” through delegate chaining using the “+=” operator, so calling “obj1()” executes both methods in the order they were added. In the second run, “obj2” is created with “fun2()” followed by “fun1()”, hence the order of execution is reversed.
When “obj2 -= p.fun2” is executed, the first occurrence of “fun2()” is removed from the delegate’s invocation list, leaving only “fun1()”. Therefore, the final call in **run 3** prints only “fun1()”.
This example clearly shows how **multicast delegates** maintain an ordered list of target methods and how methods can be dynamically added or removed at runtime.It also highlights how delegates in C# enable **event-driven programming** and simplify invoking multiple methods through a single reference.Furthermore, it illustrates that delegates preserve the order of method addition, ensuring predictable behaviour during execution.
This concept is fundamental to **event handling in C#**, where multiple listeners can respond to a single event in sequence.Overall, the program effectively demonstrates the flexibility and power of delegates as an essential feature for modular and reusable code design.

- **What will be the output of the following C# code? Why?**

```
using System;
using System.Collections⁹;
public class Program
{
    int x;
    public static void Main(string[] args)
    {
        ArrayList¹⁰ L=new ArrayList();
        L.Add(new Program());
        L.Add(new Program());
        for (int i=0;i<L.Count;i++)
            Console.WriteLine(++((Program)L[i]).x);

        L[0]=L[1];
        ((Program)L[0]).x = 202;

        for (int i=0;i<L.Count;i++)
            Console.WriteLine(((Program)L[i]).x);

        ((Program)L[0]).x = 111;
        L.RemoveAt(0);
        Console.WriteLine(L.Count);
        Console.WriteLine(((Program)L[0]).x);
    }
}
```

Output:



Explanation:

The program demonstrates how **ArrayList** in C# stores object references rather than actual copies of objects. Initially, two separate Program objects are created with their integer field x initialized to 0. The first loop increments and prints their x values, giving 1 and 1.
When "L[0] = L[1]" is executed, both list elements start referring to the same object in memory "(obj2)". Updating "((Program)L[0]).x" to "202" therefore changes the value for both "L[0]" and "L[1]". The second loop prints "202" twice, confirming that the two entries now point to the same object.
After changing the value to "111" and removing the first element, only one object remains in the list. Thus, the final count is "1", and the remaining element's value is "111".
This example highlights that **assigning reference types** in collections only copies the reference, not the data, and that **modifications to shared references** reflect across all variables pointing to that object.
It also emphasizes how "ArrayList" can hold any type of object but lacks type safety compared to generic collections like "List<T>".
Overall, the code demonstrates the importance of understanding **reference semantics** in C# to avoid unintended side effects when managing objects inside collections.

RESULTS AND ANALYSIS:

In this lab, I explored several C# programs to understand key object-oriented and functional programming concepts. I observed how constructors, inheritance, and method overriding affect the order of execution and the overall behaviour of objects.
While working with delegates, I learned how multiple methods can be added or removed dynamically, demonstrating multicast invocation. Through recursion and event-handling examples, I analyzed how control flow continues and how variables retain their state during execution. When experimenting with ArrayList, I noticed that it stores references to objects rather than copies, which led to shared state changes. I also verified that bitwise, type-casting, and null-conditional operators behave as expected according to C# precedence rules.
Overall, I gained a practical understanding of advanced C# features such as polymorphism, recursion, delegates, and reference handling. I found that derived class constructors always call base constructors first, confirming C#'s strict initialization order.
I also saw how overridden methods are resolved at runtime, demonstrating true polymorphic behaviour.
This lab helped me strengthen my understanding of how C# manages memory, object references, and method execution flow in real-world programs.

DISCUSSION AND CONCLUSION:

In this lab, I explored how different C# concepts like inheritance, polymorphism, delegates, and recursion work together in real programs. I understood how constructors in base and derived classes are executed in sequence and how overriding changes method behaviour at runtime. Through delegate and event-handling examples, I learned how multiple methods can be linked and triggered dynamically. The recursion exercises helped me see how functions call themselves until a condition is met, improving my logical thinking about program flow.
By experimenting with ArrayList, I realized how reference-type variables affect shared memory and object data. These experiments also made me aware of the importance of type safety and why generics are often preferred in modern C# applications. I found the use of operators like ~, ?., and increment operators especially useful for understanding expression evaluation.
Overall, this lab gave me a deeper practical understanding of how C# implements object-oriented principles.
It also helped me improve my debugging and analysis skills by closely observing how output changes with small code modifications.
In conclusion, this lab strengthened my foundation in C# programming and enhanced my confidence in writing and analyzing structured, efficient code.

REFERENCES:

[1] https://learn.microsoft.com/en-us/dotnet/csharp/programming-guide/classes-and-structs/constructors

[2] https://learn.microsoft.com/en-us/azure/architecture/patterns/publisher-subscriber

[3] https://learn.microsoft.com/en-us/dotnet/csharp/fundamentals/tutorials/inheritance

[4] Lab Document 10 [Shared on Google Classroom].