Scope

Lecture 5

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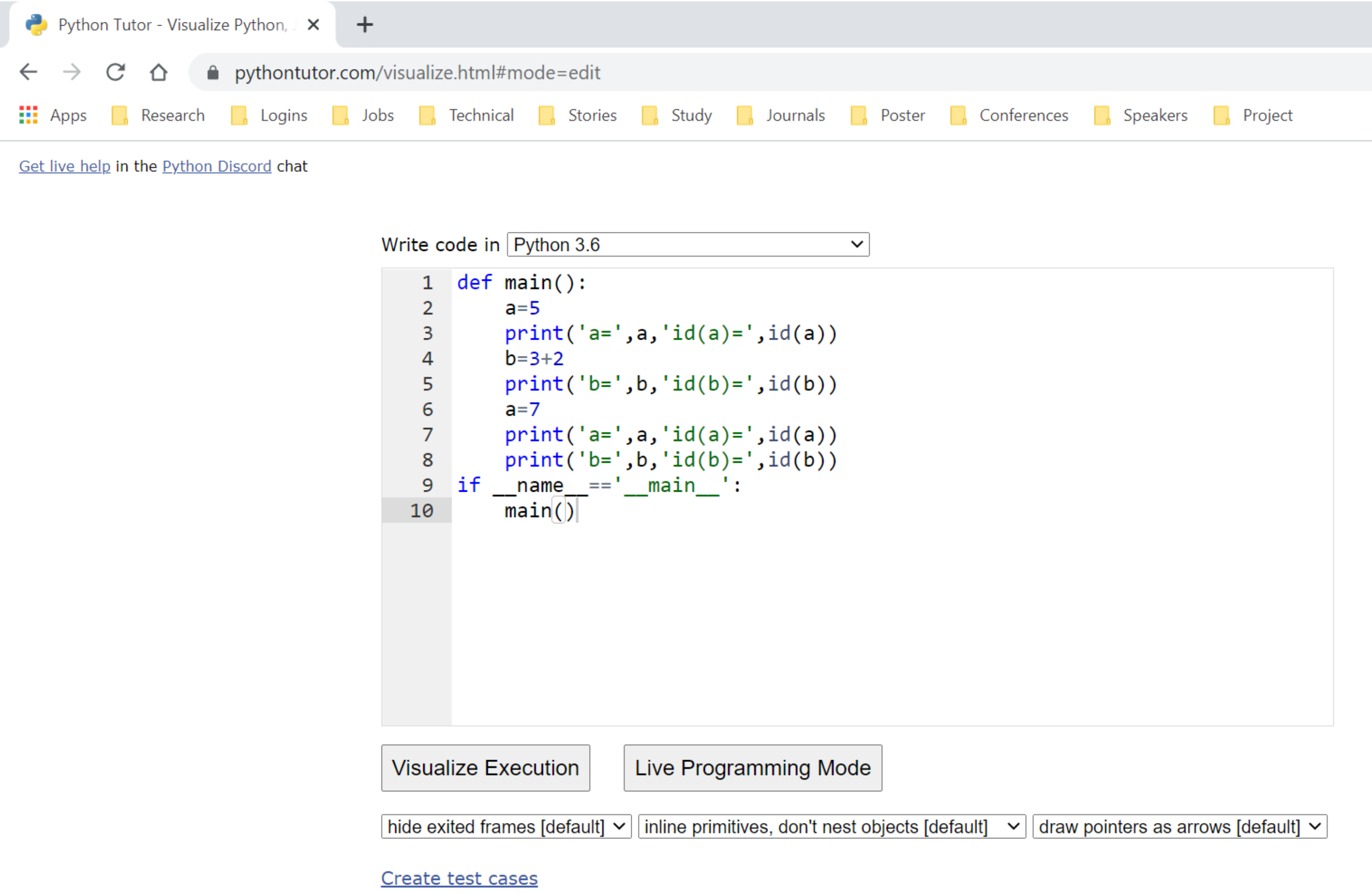
Contents

- Visualization in Python tutor
- Objects and Object IDs
- Namespaces
- Scope

*Python Programming: A Modular Approach by Sheetal Taneja and Kumar Naveen, Pearson Education India, Inc., 2017

Visualization of Example-I in Python tutor

- Each object in Python is assigned a unique identifier that can be accessed using the function id
- Visit the following website www.pythontutor.com
- Click on Edit this code
- Now write the code
- Click on Visualize Execution



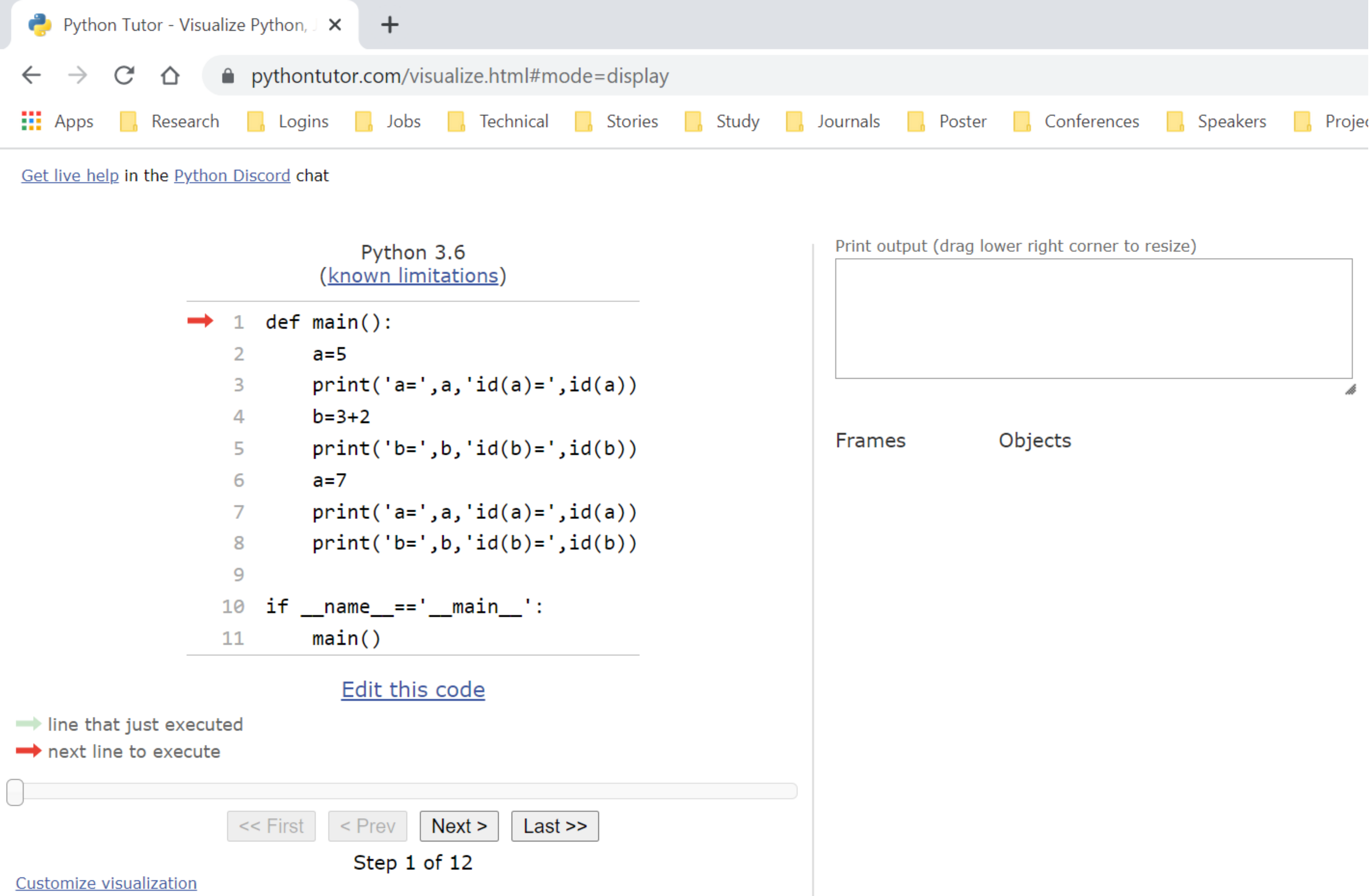
Write code in Python 3.6

```
def main():
    a=5
    print('a=',a,'id(a)=',id(a))
    b=3+2
    print('b=',b,'id(b)=',id(b))
    a=7
    print('a=',a,'id(a)=',id(a))
    print('b=',b,'id(b)=',id(b))
if __name__=='__main__':
    main()
```

hide exited frames [default] | inline primitives, don't nest objects [default] | draw pointers as arrows [default]

Example-I (continued)

- After clicking on Visualize Execution, a **<Print output>** box will appear at the right top



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Python 3.6
(known limitations)

```
def main():
    a=5
    print('a=',a,'id(a)=',id(a))
    b=3+2
    print('b=',b,'id(b)=',id(b))
    a=7
    print('a=',a,'id(a)=',id(a))
    print('b=',b,'id(b)=',id(b))

if __name__=='__main__':
    main()
```

Edit this code

line that just executed

next line to execute

Step 1 of 12

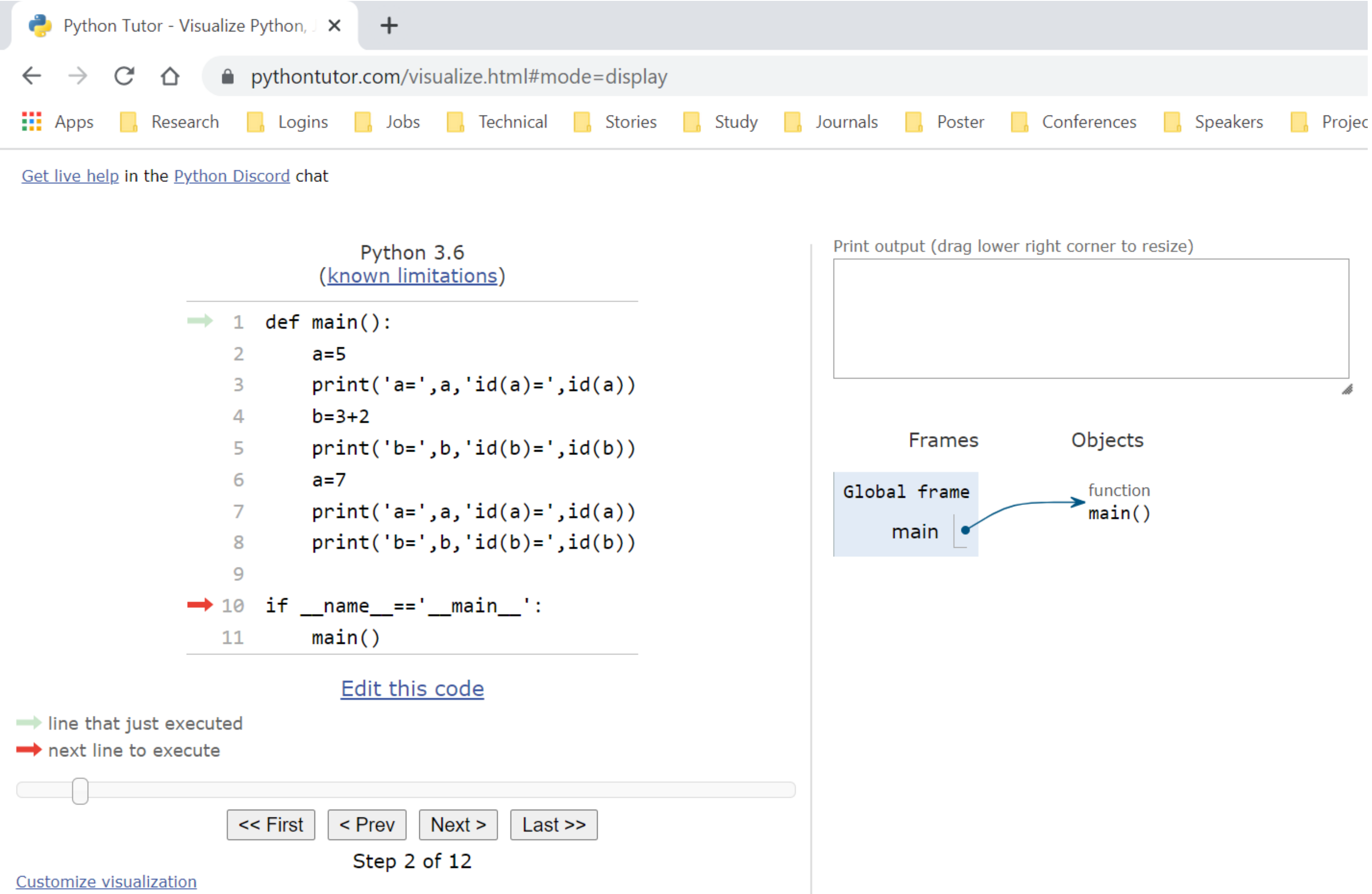
Customize visualization

Print output (drag lower right corner to resize)

Frames Objects

Example-I (continued)

- To start visualization, we click **<Next >**. On encountering the **main** function definition, the global frame lists the identifier **main** as shown in the Figure
- The red arrow marks the next line to be executed, and the green arrow marks the line just executed



Python 3.6
(known limitations)

```
def main():
    a=5
    print('a=',a,'id(a)=',id(a))
    b=3+2
    print('b=',b,'id(b)=',id(b))
    a=7
    print('a=',a,'id(a)=',id(a))
    print('b=',b,'id(b)=',id(b))

if __name__=='__main__':
    main()
```

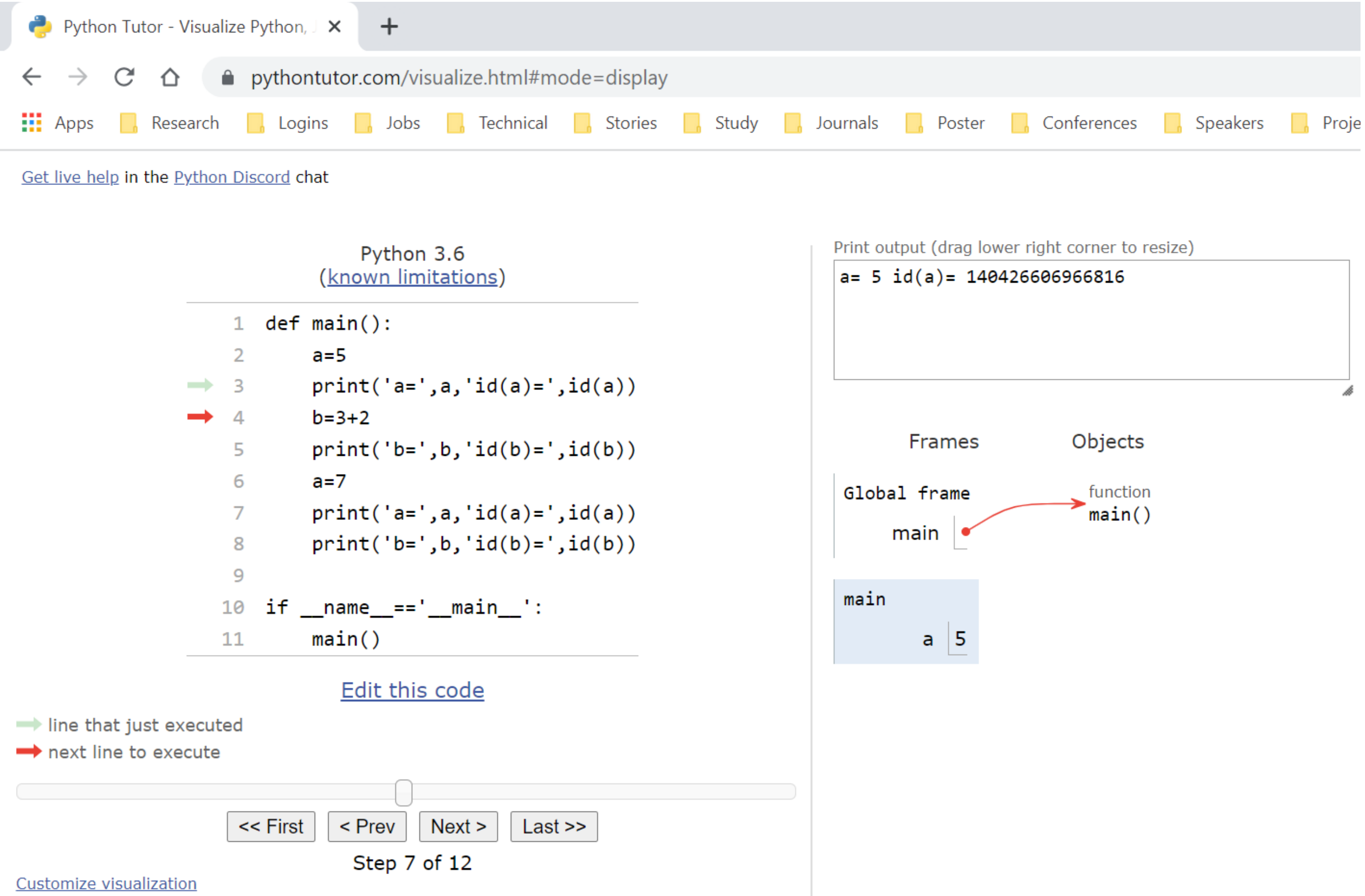
line that just executed

next line to execute

Step 2 of 12

Example-I (continued)

- Now clicking **<Next>**, it executes the **if** statement. Clicking **<Next>** again executes the call to the function **main** and the visualizer shows the frame for the **main** function
- Clicking **<Next>**, it moves the next line pointer to line 2, and its execution shows the creation of **int** object **5** having name **a**. Later, clicking **<Next>** shows the output of the execution of line 3 in **<Print output>** box



```
 1  def main():
 2      a=5
 3      print('a=',a,'id(a)=',id(a))
 4      b=3+2
 5      print('b=',b,'id(b)=',id(b))
 6      a=7
 7      print('a=',a,'id(a)=',id(a))
 8      print('b=',b,'id(b)=',id(b))
 9
10  if __name__=='__main__':
11      main()
```

Print output (drag lower right corner to resize)

```
a= 5 id(a)= 140426606966816
```

Global frame

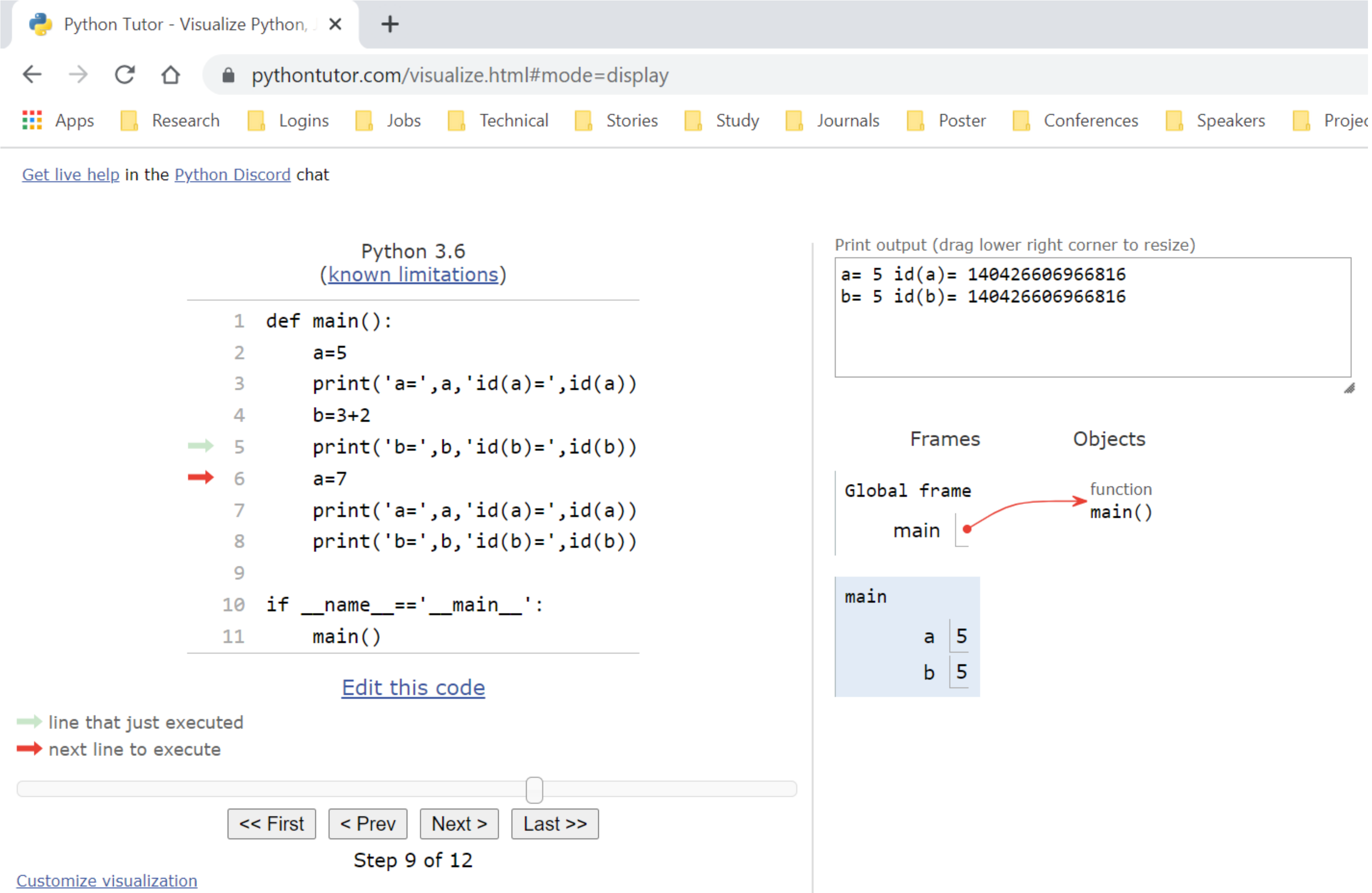
main → main()

main

a 5

Example-I (continued)

- Next click executes line 4 and the name **b** is mapped to the **int** object **5** created earlier
- Further click executes line 5 and the output appears in the **<Print output>** box



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Python 3.6
(known limitations)

```
 1  def main():
 2      a=5
 3      print('a=',a,'id(a)=',id(a))
 4      b=3+2
 5      print('b=',b,'id(b)=',id(b))
 6      a=7
 7      print('a=',a,'id(a)=',id(a))
 8      print('b=',b,'id(b)=',id(b))
 9
10  if __name__=='__main__':
11      main()
```

Edit this code

line that just executed
next line to execute

Step 9 of 12

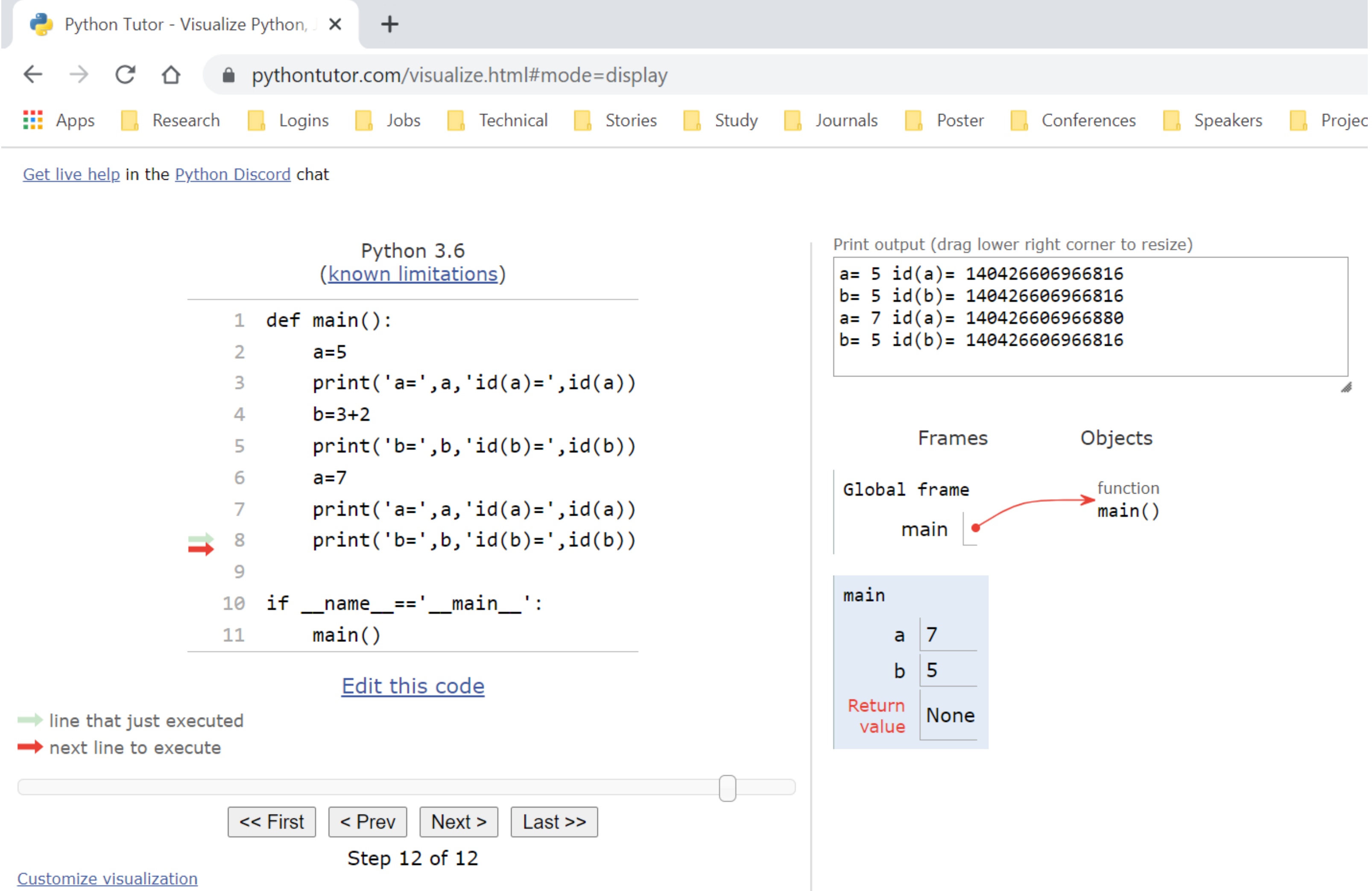
Customize visualization

Print output (drag lower right corner to resize)

```
a= 5 id(a)= 140426606966816
b= 5 id(b)= 140426606966816
```

Example-I (continued)

- Clicking **<Next>** executes line 6, resulting in creation of a new `int` object 7 and its mapping to `a`
- Further clicks execute lines 7 and 8 and the output appears in the <**Print output**> box
- Next click shows return value **None** associated with the function **main** as it does not return any value



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Python 3.6
(known limitations)

```
1  def main():
2      a=5
3      print('a=',a,'id(a)=',id(a))
4      b=3+2
5      print('b=',b,'id(b)=',id(b))
6      a=7
7      print('a=',a,'id(a)=',id(a))
8      print('b=',b,'id(b)=',id(b))
9
10 if __name__=='__main__':
11     main()
```

Edit this code

Step 12 of 12

Customize visualization

Print output (drag lower right corner to resize)

```
a= 5 id(a)= 140426606966816
b= 5 id(b)= 140426606966816
a= 7 id(a)= 140426606966880
b= 5 id(b)= 140426606966816
```

Explanation of execution for Example-I

- Recall that when this program script is executed, Python makes a note of the definition of the function main in the global frame

- Next, on encountering the `if` statement, Python checks whether the name of the current module is `__main__`

- This being true, the expression `__ name__ == '__main__'` evaluates as True, and the function main gets invoked
- Next, the statements in the main function are executed in a sequence
- Execution of line 2 creates an `int` object `5` and assigns it the name `a`. This object has `a` unique object id but can have multiple names as the execution of the script proceeds.
- For example, execution of the statement

```
b = 3 + 2
```

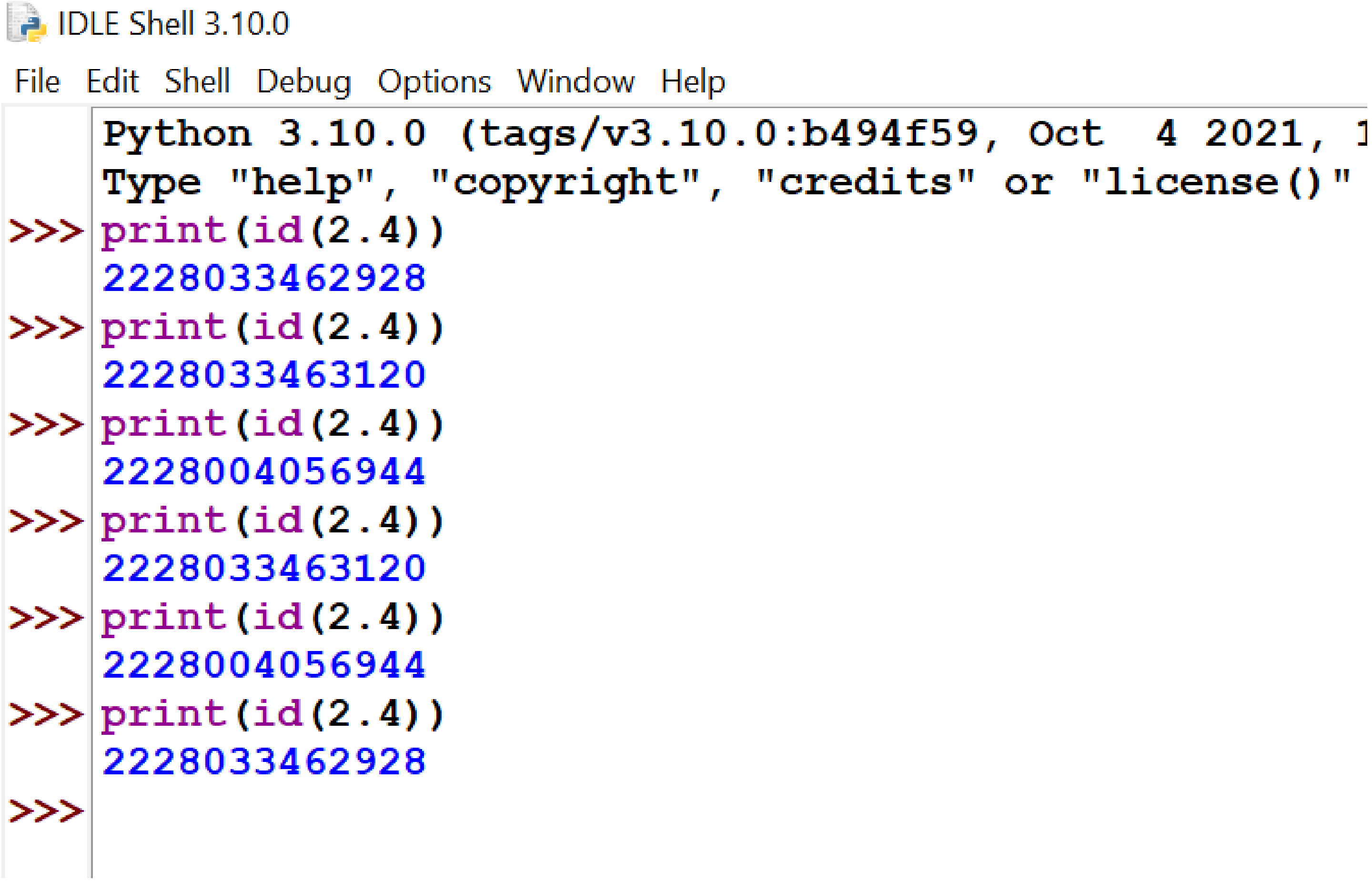
in line 4 does not generate a new object, but only associates the name `b` to the `int` object `5` created earlier

- Now, `a` and `b` have the same object id. However, execution of line 6 creates an `int` object `7` and associates it with the name `a`
- The name `b` continues to be associated with int object `5` created earlier.

*Python Programming: A Modular Approach by Sheetal Taneja and Kumar Naveen, Pearson Education India, Inc., 2017

Object ID for different data types

- The general principle is expressed by saying that Python caches or interns small integer objects (typically, up to 100) for future use. The same may not hold for other forms of data

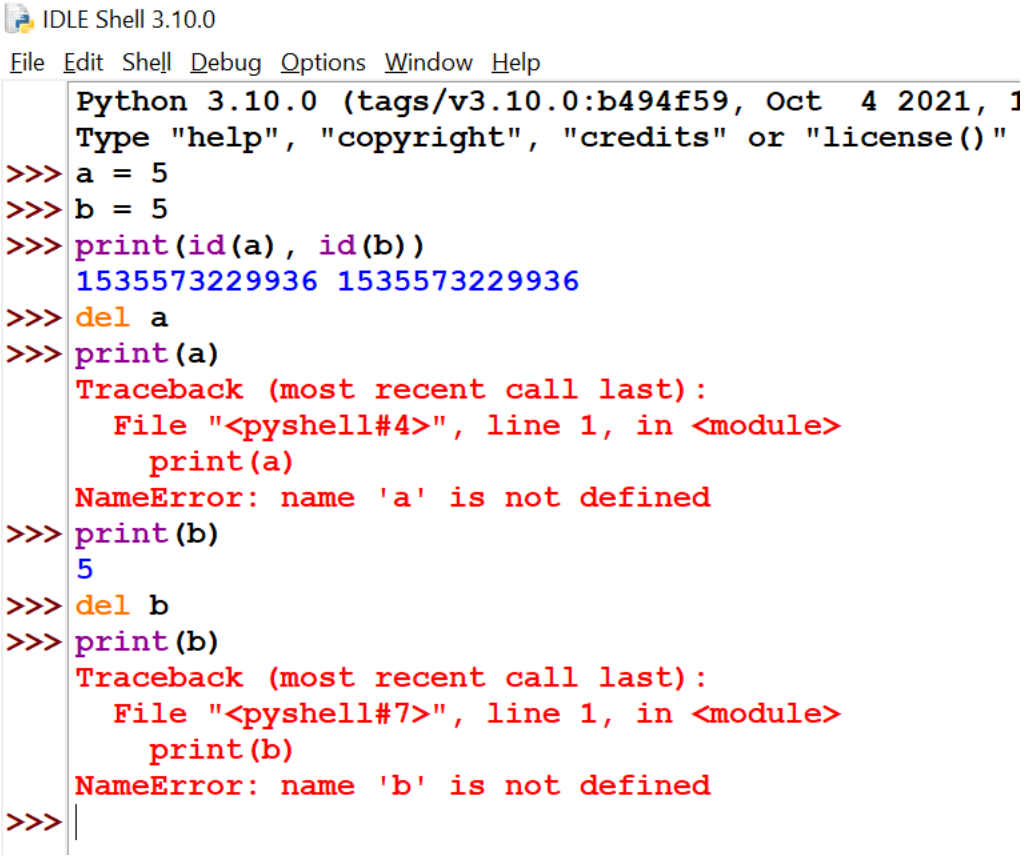


```
Python 3.10.0 (tags/v3.10.0:b494f59, Oct  4 2021, 1
Type "help", "copyright", "credits" or "license()"
>>> print(id(2.4))
    2228033462928
>>> print(id(2.4))
    2228033463120
>>> print(id(2.4))
    2228004056944
>>> print(id(2.4))
    2228033463120
>>> print(id(2.4))
    2228004056944
>>> print(id(2.4))
    2228033462928
>>>
```

- Note that the first three instructions create new objects
- However, subsequent instructions sometimes used the objects created earlier

del operator

- It makes a name (i.e. the association between the name and the object) undefined

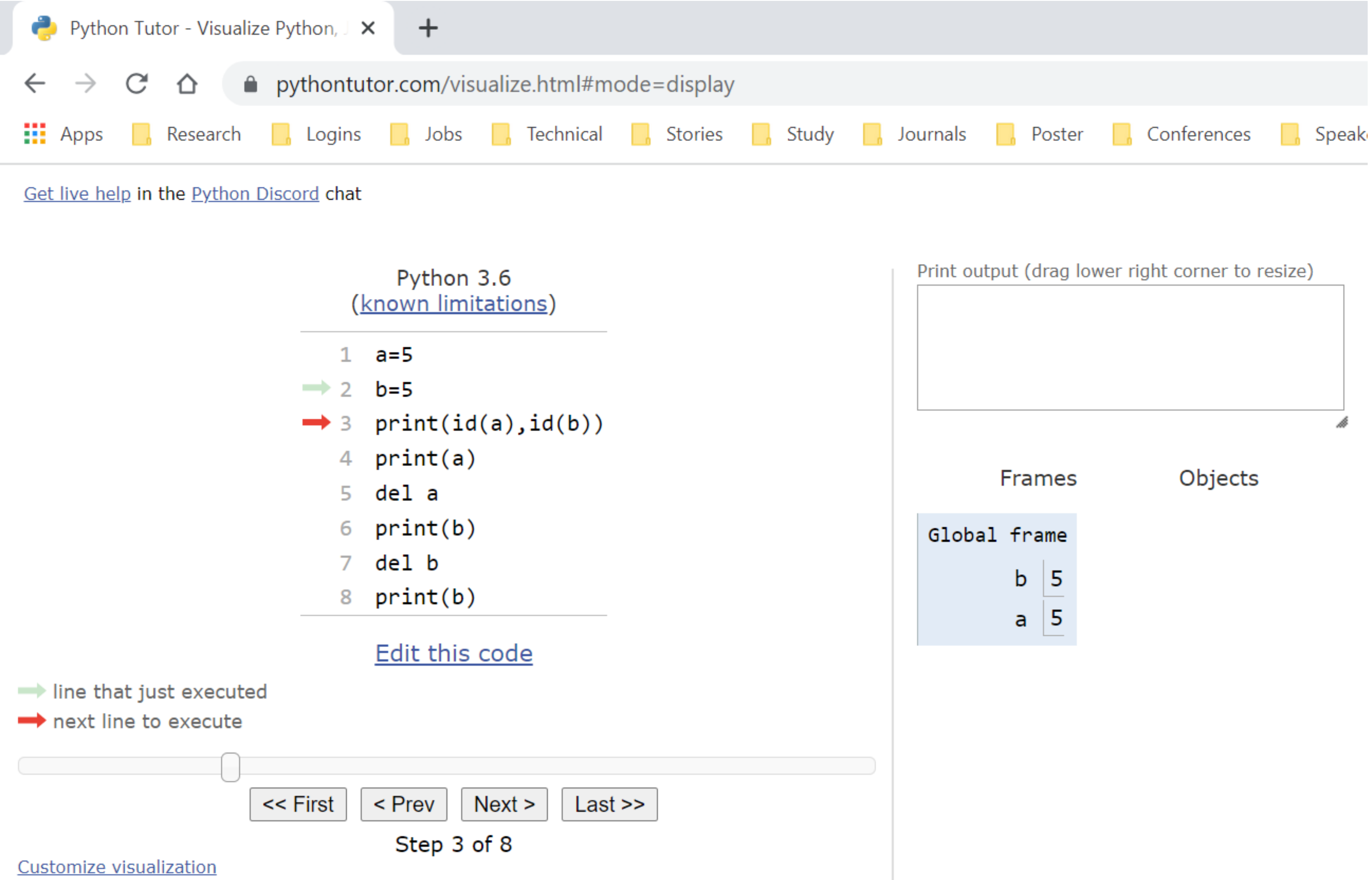


```
Python 3.10.0 (tags/v3.10.0:b494f59, Oct  4 2021, 1
Type "help", "copyright", "credits" or "license()"
>>> a = 5
>>> b = 5
>>> print(id(a), id(b))
    1535573229936 1535573229936
>>> del a
>>> print(a)
    Traceback (most recent call last):
      File "<pyshell#4>", line 1, in <module>
        print(a)
    NameError: name 'a' is not defined
>>> print(b)
    5
>>> del b
>>> print(b)
    Traceback (most recent call last):
      File "<pyshell#7>", line 1, in <module>
        print(b)
    NameError: name 'b' is not defined
>>> 
```

- The first statement creates an `int` object `5` and binds it to name `a`
- The second statement does not create a new object
- It binds the same object to name `b` and thus creates another reference to `int` object `a`

Visualization of `del` operator in Python tutor

- The first statement creates an `int` object `5` and binds it to name `a`
- The second statement does not create a new object
- It binds the same object to name `b` and thus creates another reference to `int` object `a`



```
a=5
b=5
print(id(a),id(b))
print(a)
del a
print(b)
del b
print(b)
```

line that just executed

next line to execute

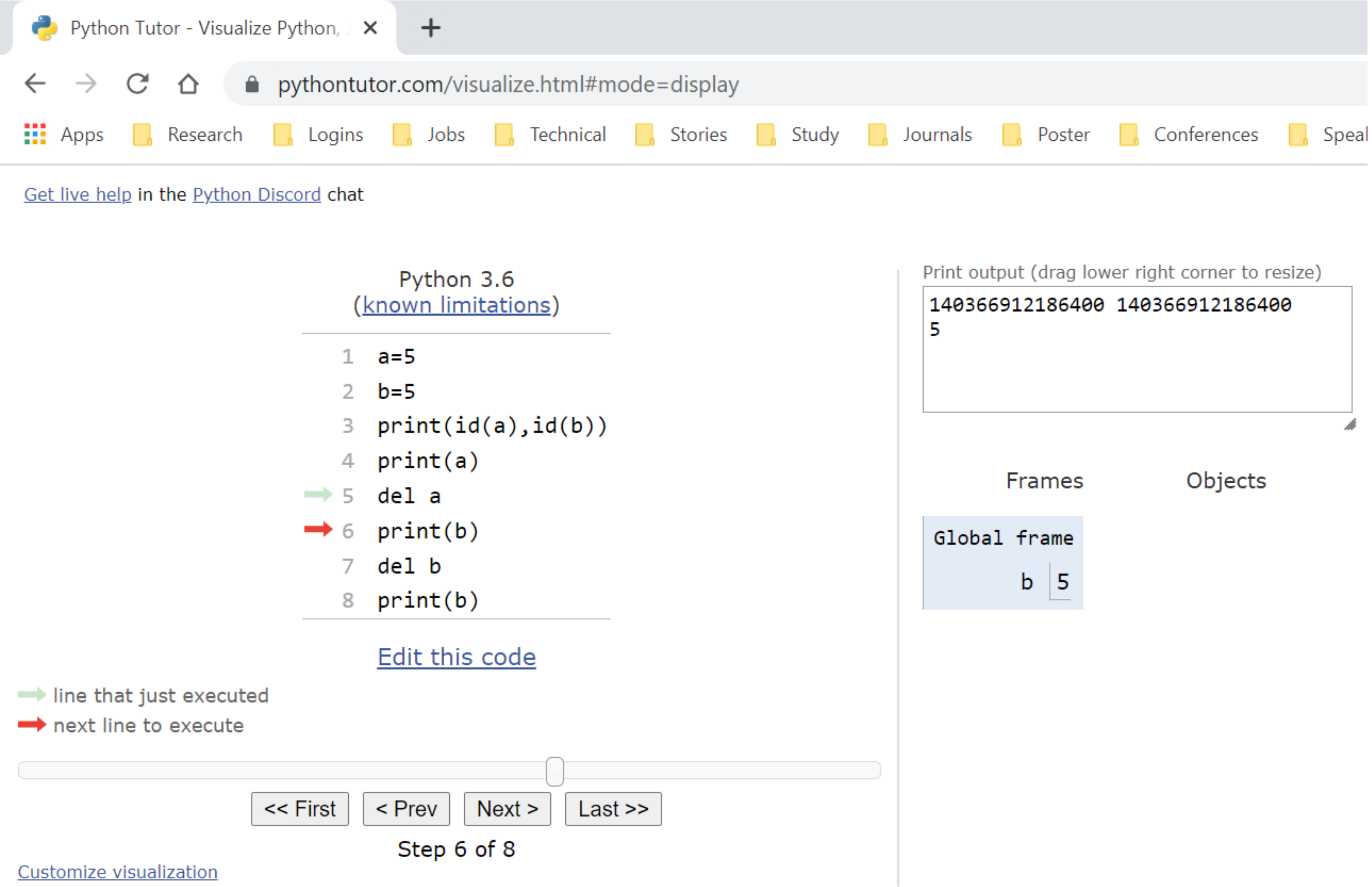
Step 3 of 8

Global frame

b	5
a	5

Visualization of `del` operator (continued)

- Python keeps a count of the number of references to an object
  - When the statement `del a` is executed, it reduces the reference count of `int` object `5` from 2 to 1 and removes the binding of name `a` to `int` object `5`
- Thus, an attempt to access `a` now yields an error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Python 3.6
(known limitations)

```
a=5
b=5
print(id(a),id(b))
print(a)
del a
print(b)
del b
print(b)
```

Edit this code

line that just executed
next line to execute

Step 6 of 8

Customize visualization

Print output (drag lower right corner to resize)

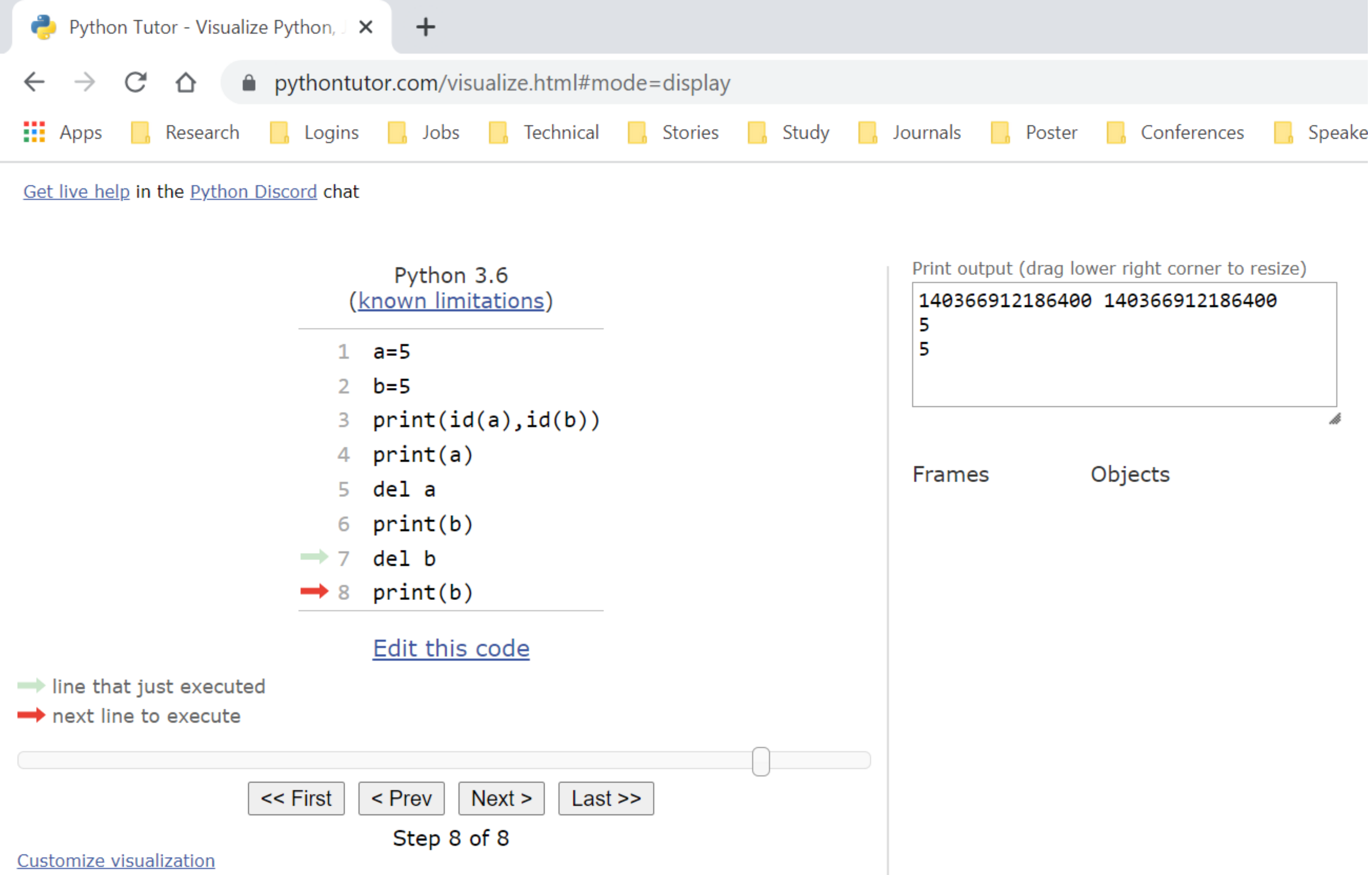
```
140366912186400 140366912186400
5
```

Frames Objects

Global frame
b 5

Visualization of del operator (continued)

- When the statement del b is executed, it reduces the reference count of int object 5 from 1 to 0, and removes the binding of name b to int object 5
- Thus, an attempt to access b now yields an error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Python 3.6
(known limitations)

```
a=5
b=5
print(id(a),id(b))
print(a)
del a
print(b)
del b
print(b)
```

Edit this code

line that just executed
next line to execute

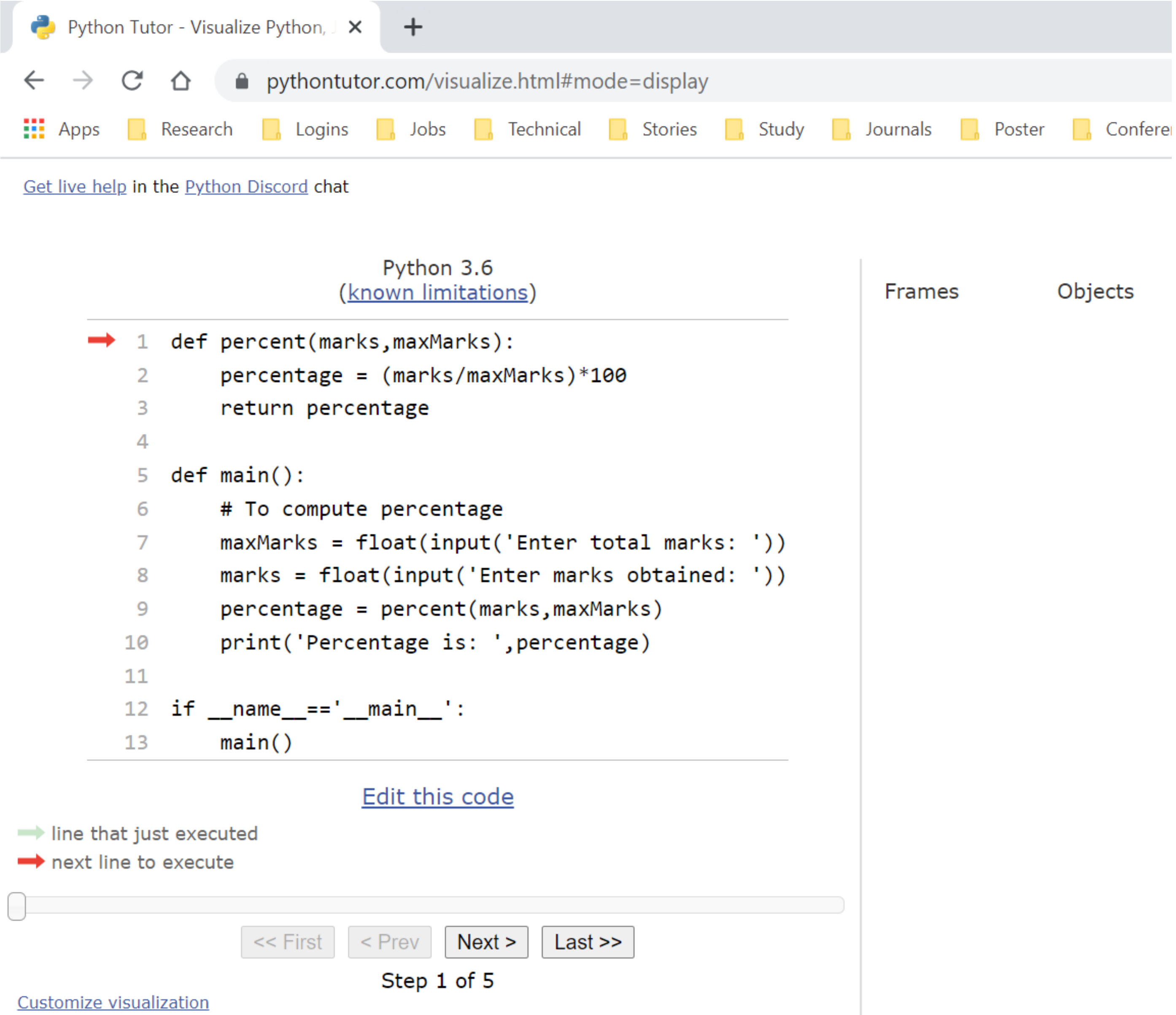
Print output (drag lower right corner to resize)

```
140366912186400 140366912186400
5
5
```

Step 8 of 8

Visualization of Example-II in Python tutor

- Write a program for calculating the percentage of a student in a subject



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Python 3.6
(known limitations)

```python
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

line that just executed
next line to execute

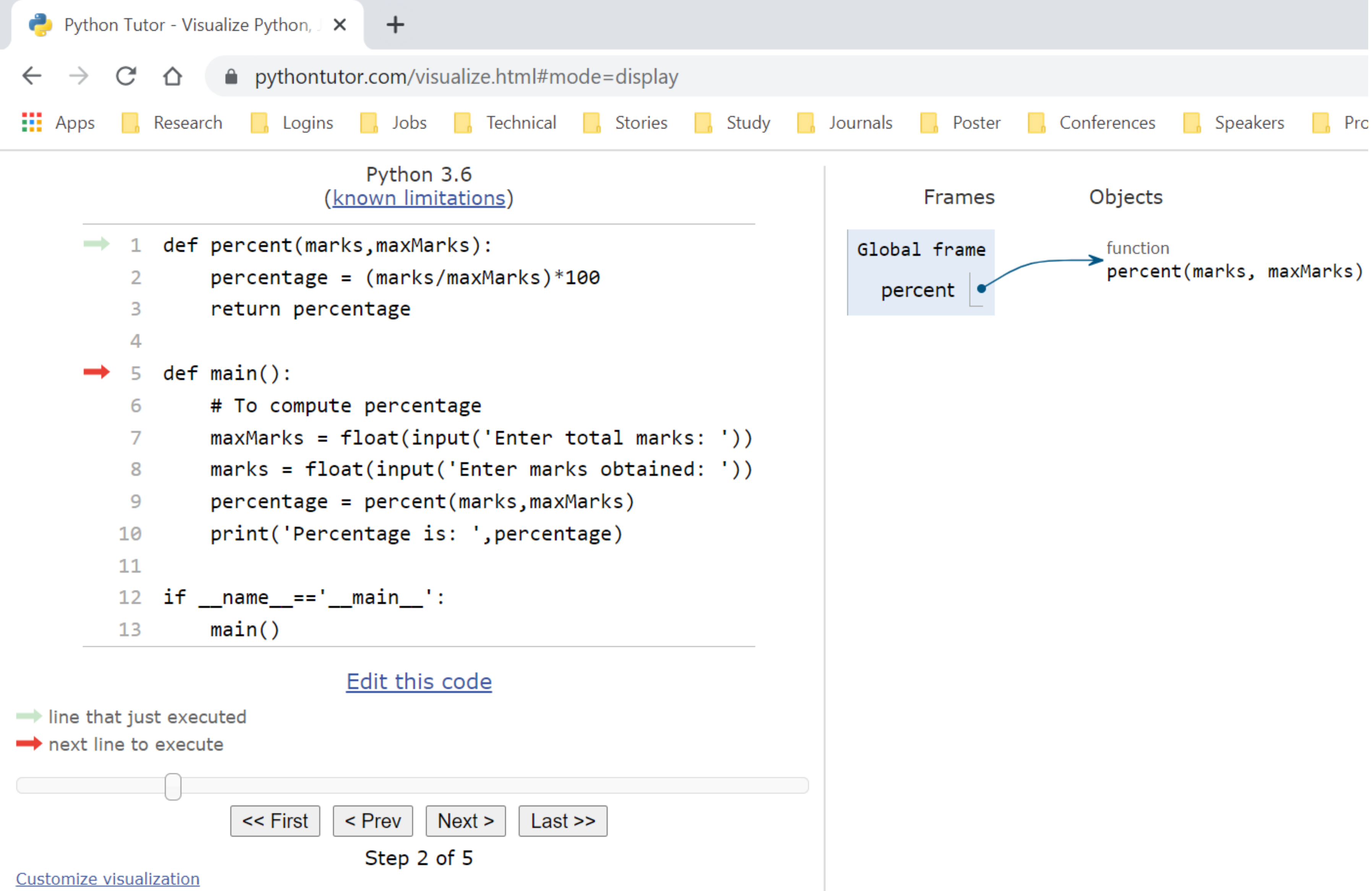
Step 1 of 5

Visualization of Example-II (continued)

- We are about to execute the first of the five steps in the script
- These five steps are as follows:
  - Definition of function `percent(marks, maxMarks)`
  - Definition of function `main()`
  - `if` statement
  - Invoking the function `main()`
  - Execution of function `main()`

Visualization of Example-II (continued)

- On clicking **<Next>**, step 1 is executed and we see the function `percent` in the global frame



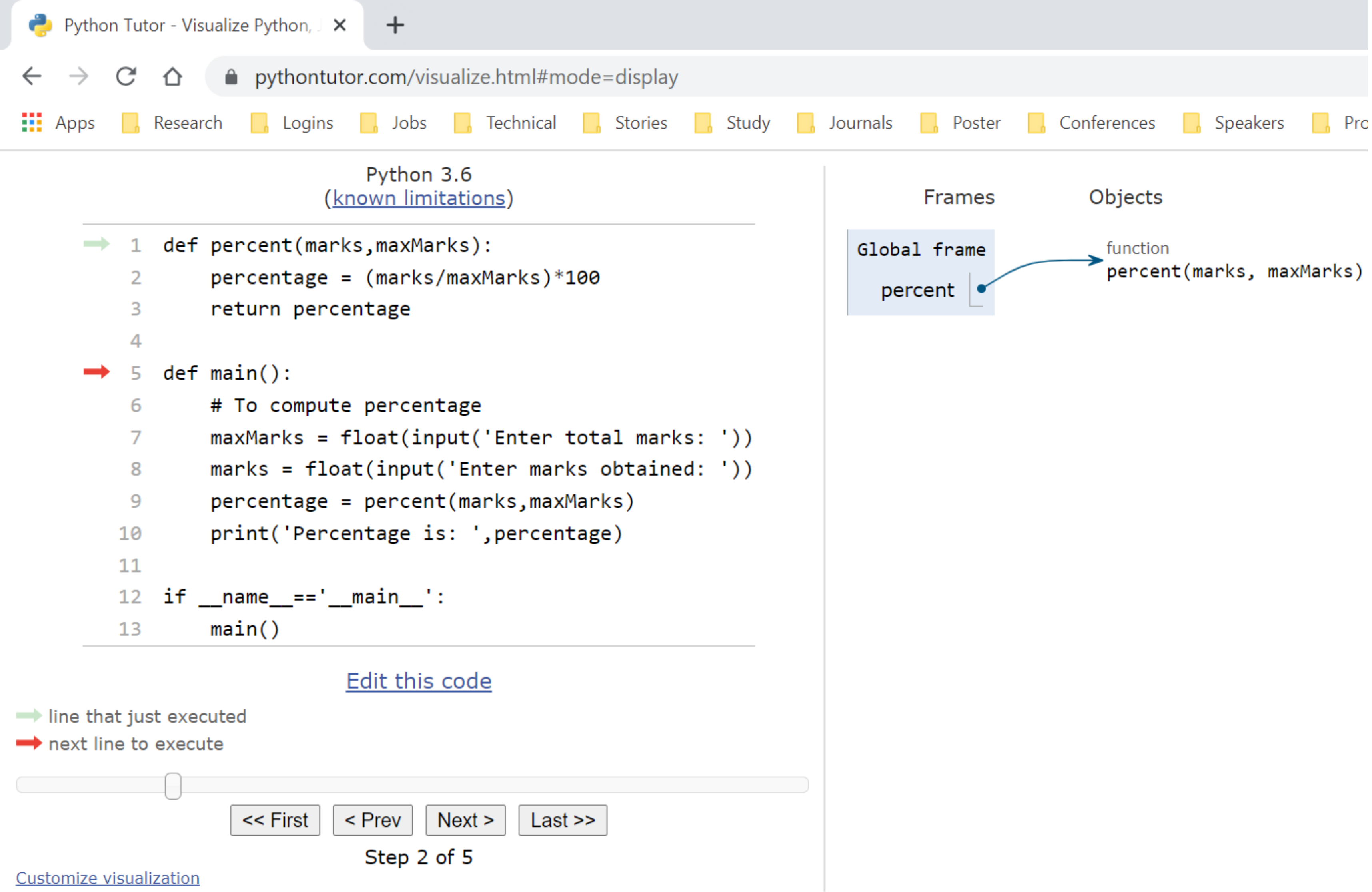
```python
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

Visualization of Example-II (continued)

- On clicking **<Next>**, step 1 is executed and we see the function `percent` in the global frame
- On execution of next step, the function `main` is also shown in the global frame



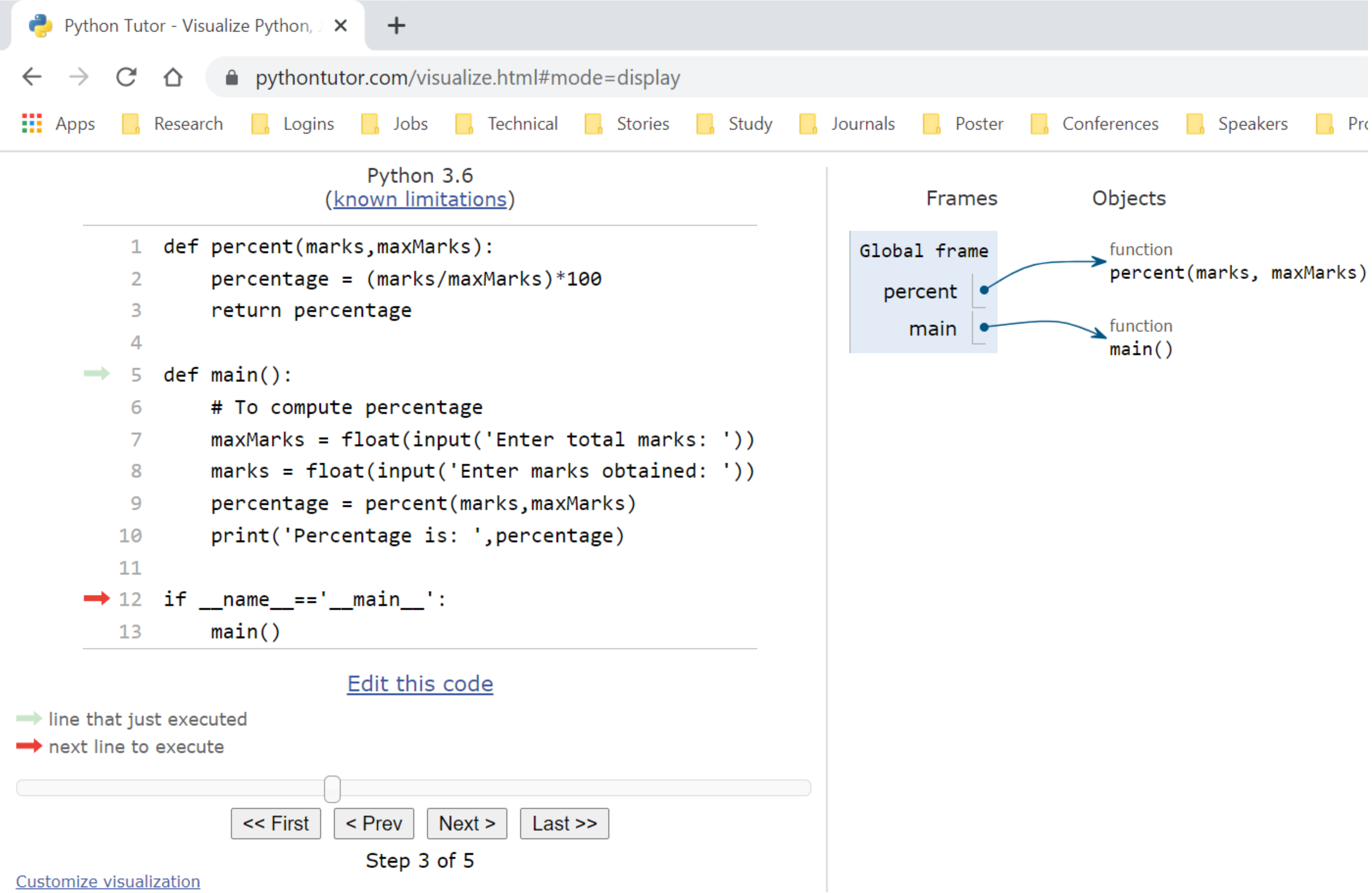
```python
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

Visualization of Example-II (continued)

- When step 3 is executed, the condition `if __name__=='__main__'` evaluates as `True`
- Thus, in step 4 the function `main` is invoked



Python 3.6
(known limitations)

```
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

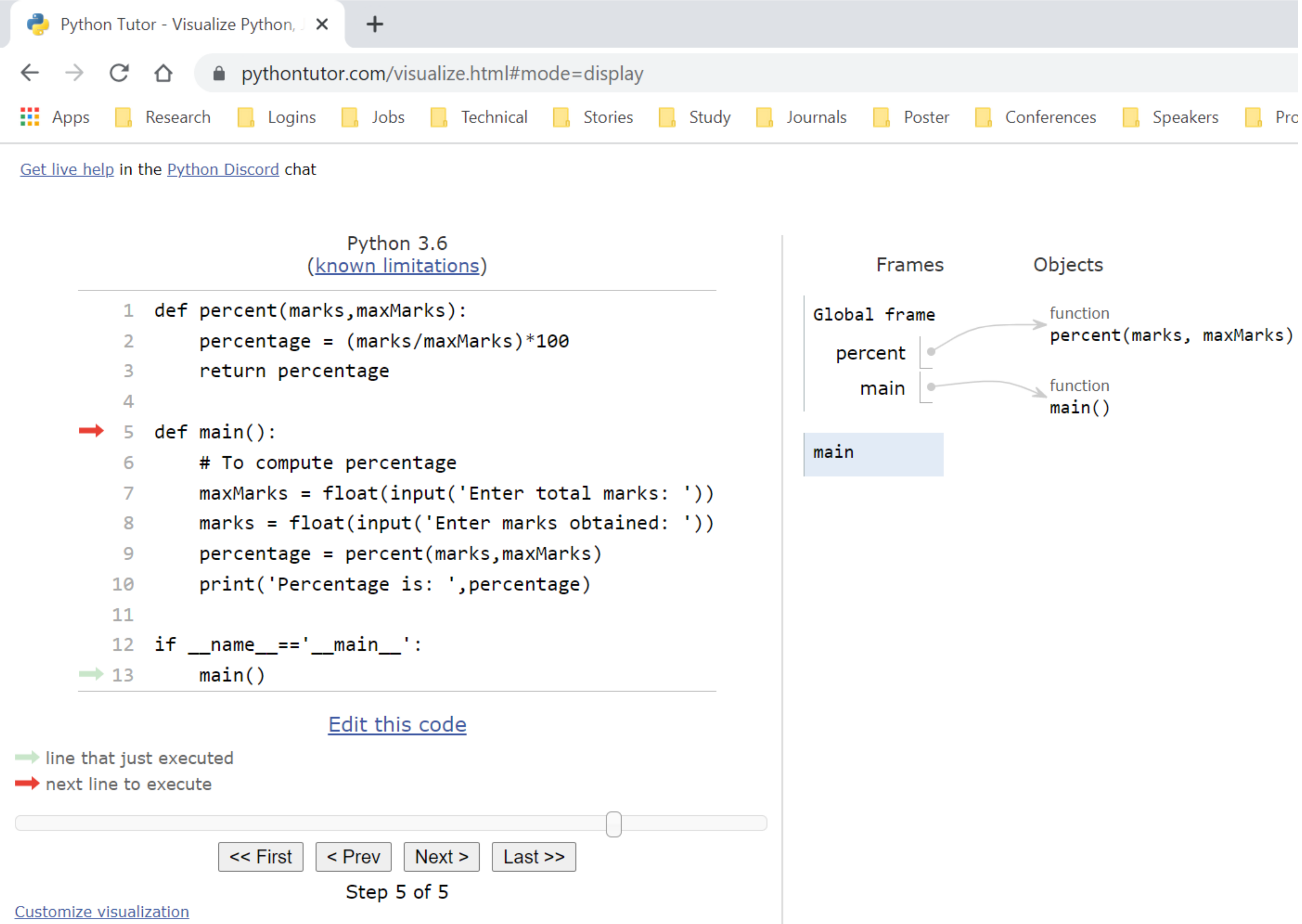
Step 3 of 5

Global frame

percent	function percent(marks, maxMarks)
main	function main()

Visualization of Example-II (continued)

- Next click executes the call to function **main** and the visualizer shows the function **main** among frames



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Python 3.6
(known limitations)

```
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

Edit this code

line that just executed
next line to execute

Step 5 of 5

Customize visualization

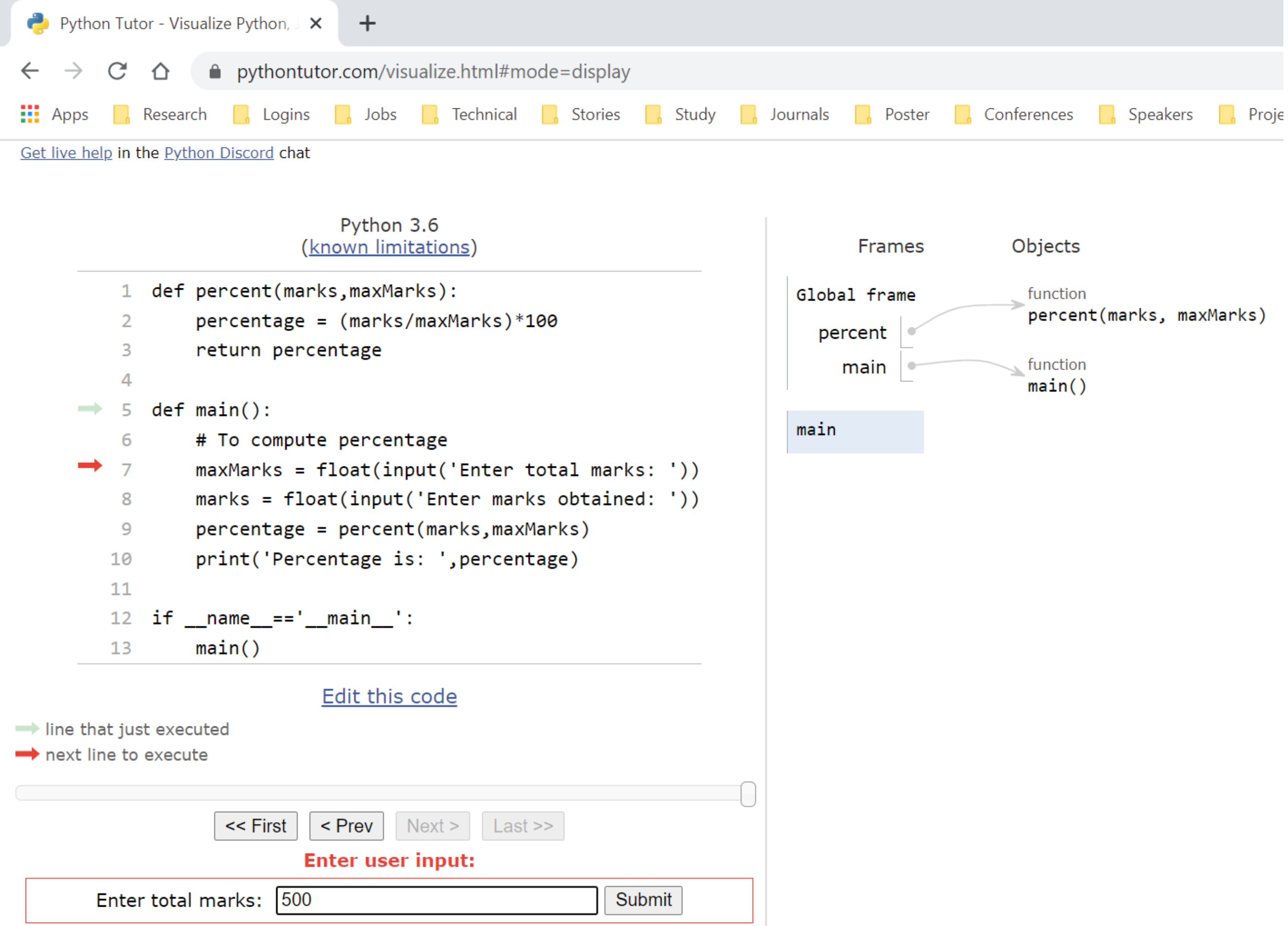
Frames Objects

```
Global frame
  percent  →  function percent(marks, maxMarks)
  main     →  function main()

main
```

Visualization of Example-II (continued)

- Next click yields a message that prompts the user to enter total marks in **<Input Box>** and hit the **Submit** button
- This input message along with the values entered as input are also shown in **<Print output>**
- At this stage, we enter `500` as total marks, and click **Submit**



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Python 3.6
(known limitations)

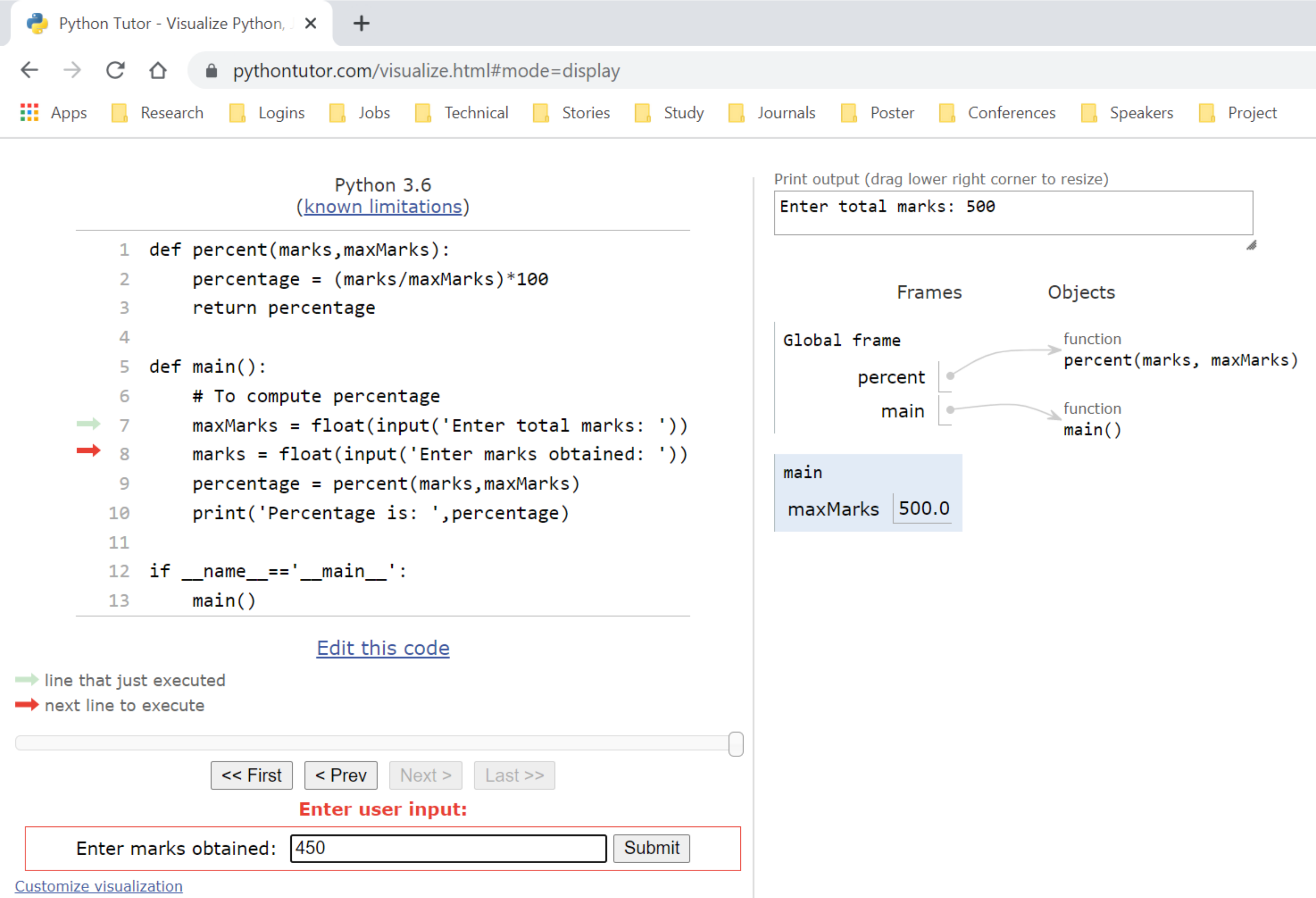
```
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

Enter user input:

Enter total marks: 500

Visualization of Example-II (continued)

- Now the execution is resulting in creation of an instance of **`float`** object **`500.0`**
- This object is named as **`maxMarks`**
- The next click executes again prompting for marks obtained (say, **`450`**)



```python
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

line that just executed

next line to execute

Print output (drag lower right corner to resize)

```
Enter total marks: 500
```

Global frame

percent	function percent(marks, maxMarks)
main	function main()

main

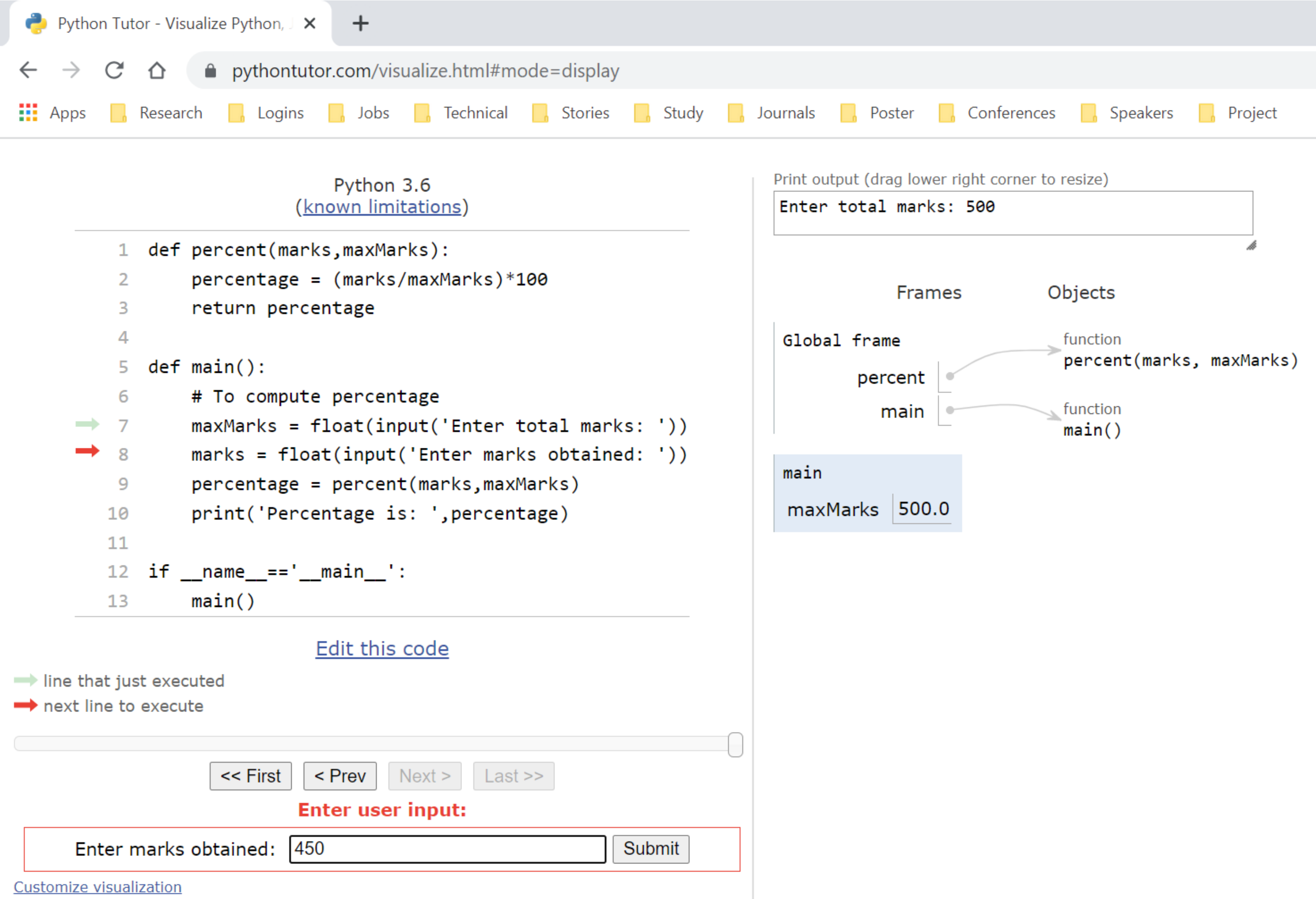
maxMarks	500.0

Enter user input:

Enter marks obtained: 450 Submit

Visualization of Example-II (continued)

- As before, an instance of **float** object **450.0** is created, and named as `marks`
- The control moves the next line



```
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

line that just executed

next line to execute

Enter user input:

Enter marks obtained: 450 Submit

Print output (drag lower right corner to resize)

```
Enter total marks: 500
```

Frames Objects

Global frame

percent → function percent(marks, maxMarks)

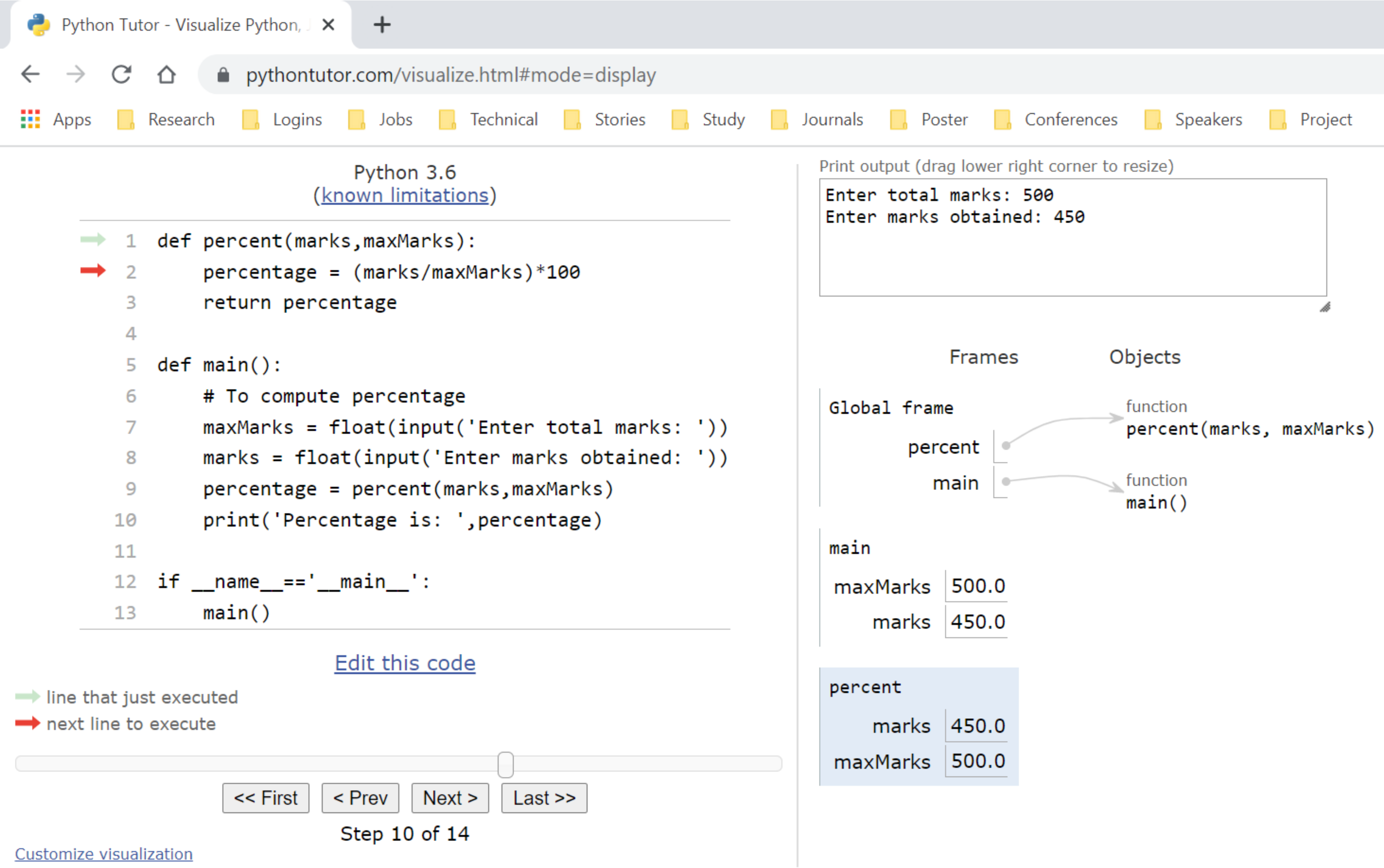
main → function main()

main

maxMarks 500.0

Visualization of Example-II (continued)

- Clicking **<Next>** executes the call to the function **percent** and the visualizer shows the function **percent** among frames
- Note that the parameters **marks** and **maxMarks** are mapped to **float** objects created earlier



Python 3.6
(known limitations)

```
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

Edit this code

➡ line that just executed
➡ next line to execute

Step 10 of 14

Customize visualization

Print output (drag lower right corner to resize)

```
Enter total marks: 500
Enter marks obtained: 450
```

main

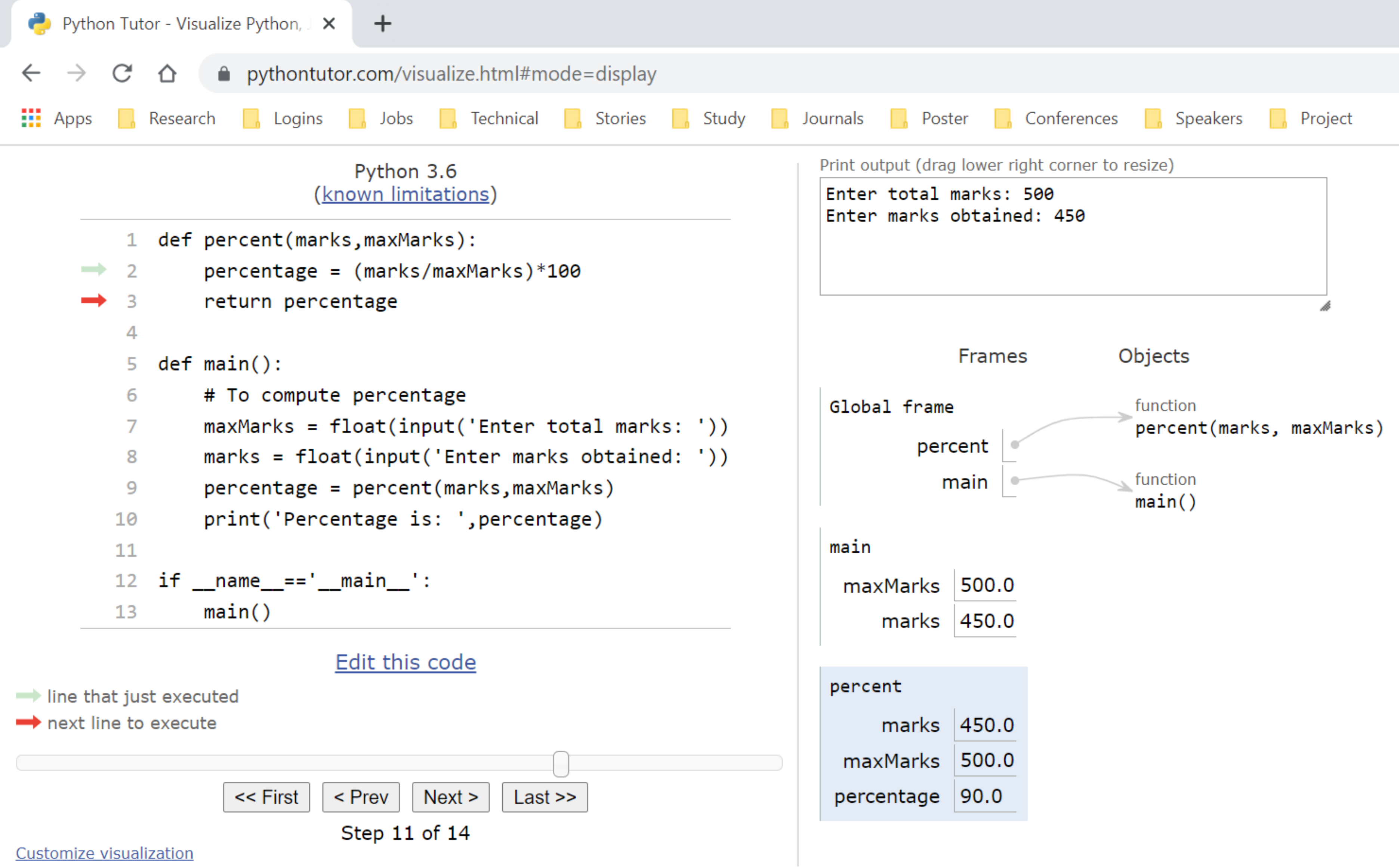
maxMarks	500.0
marks	450.0

percent

marks	450.0
maxMarks	500.0

Visualization of Example-II (continued)

- On the next click, Python creates a return value i.e. the float object (to be returned to the `main` function) `90.0` which was created earlier



Python 3.6
(known limitations)

```
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

Edit this code

➡ line that just executed
➡ next line to execute

Step 11 of 14

Customize visualization

Print output (drag lower right corner to resize)

```
Enter total marks: 500
Enter marks obtained: 450
```

Frames　Objects

Global frame
- percent → function percent(marks, maxMarks)
- main → function main()

main

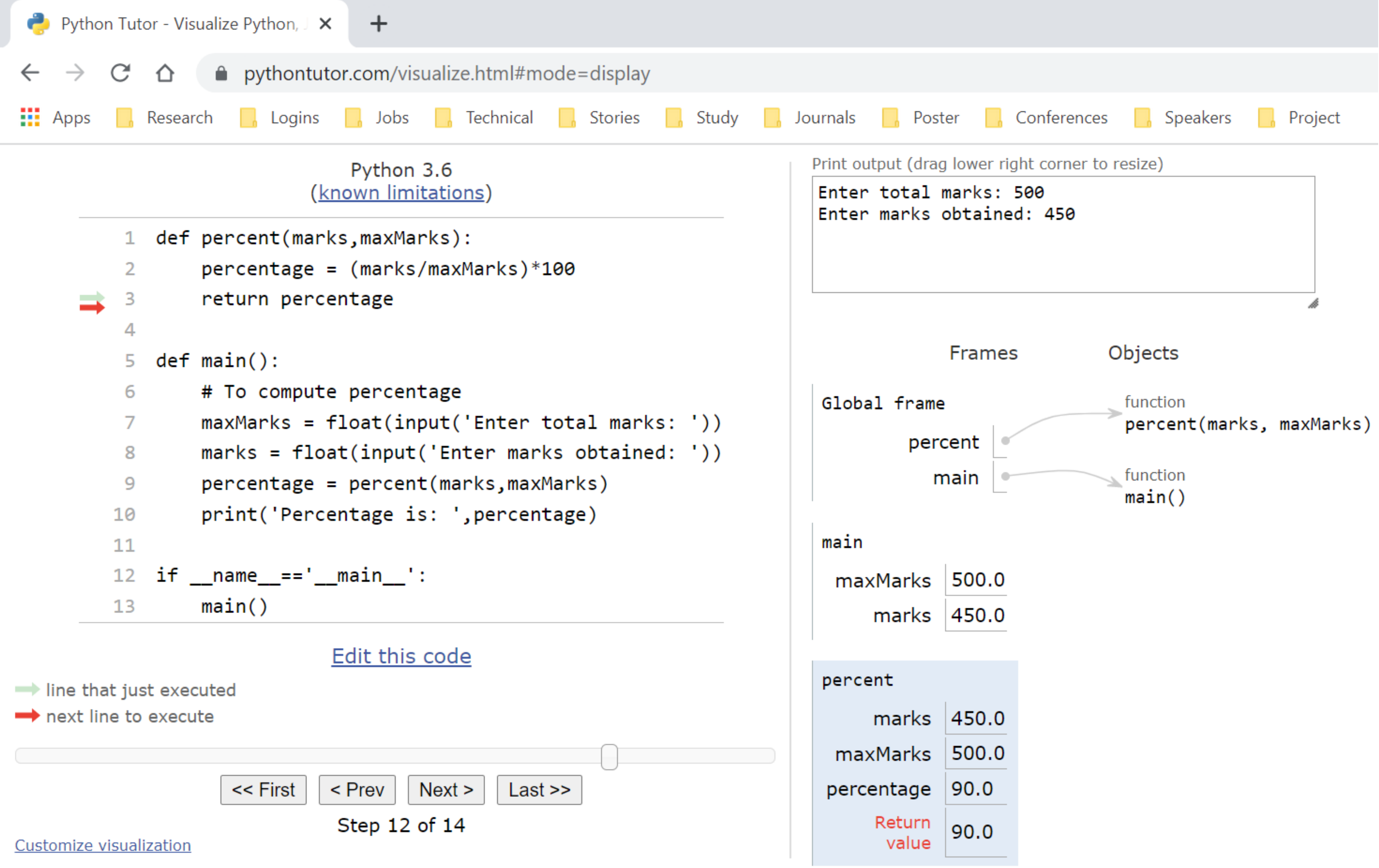
maxMarks	500.0
marks	450.0

percent

marks	450.0
maxMarks	500.0
percentage	90.0

Visualization of Example-II (continued)

- The next click returns the value **`90.0`** from the function **`percent`** by associating it with the variable **`percentage`** of function **`main`**
- Note that the variable **`percentage`** of the function **`main`** now maps to the **`float`** object **`90.0`**



Python 3.6
(known limitations)

```
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

Edit this code

line that just executed
next line to execute

Step 12 of 14

Customize visualization

Print output (drag lower right corner to resize)

```
Enter total marks: 500
Enter marks obtained: 450
```

main

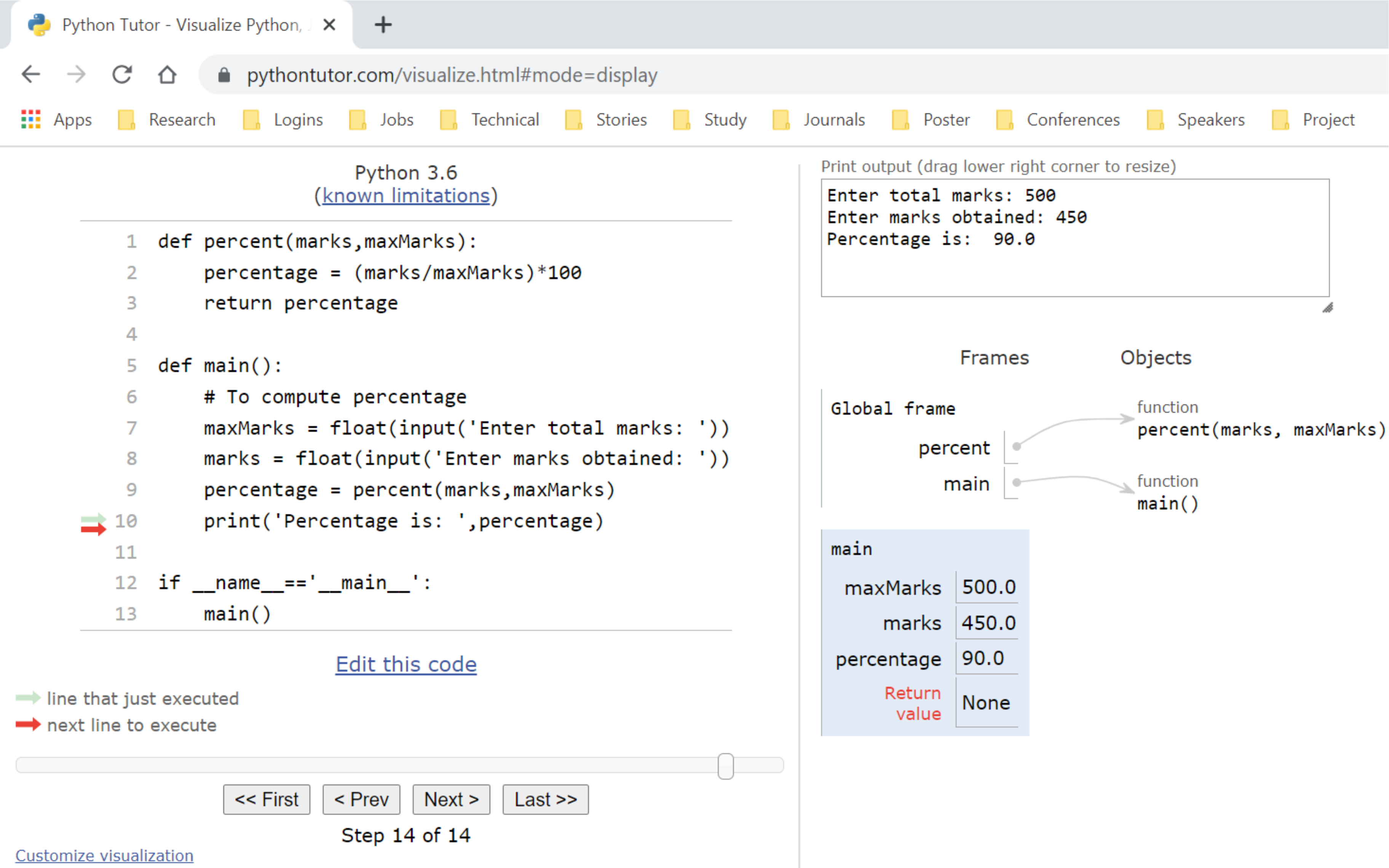
maxMarks	500.0
marks	450.0

percent

marks	450.0
maxMarks	500.0
percentage	90.0
Return value	90.0

Visualization of Example-II

- The next two clicks shows return value **None** associated with the function **main()** as it does not return any value



Python 3.6
(known limitations)

```
def percent(marks,maxMarks):
    percentage = (marks/maxMarks)*100
    return percentage

def main():
    # To compute percentage
    maxMarks = float(input('Enter total marks: '))
    marks = float(input('Enter marks obtained: '))
    percentage = percent(marks,maxMarks)
    print('Percentage is: ',percentage)

if __name__=='__main__':
    main()
```

Edit this code

➡ line that just executed
➡ next line to execute

Step 14 of 14

Customize visualization

Print output (drag lower right corner to resize)

```
Enter total marks: 500
Enter marks obtained: 450
Percentage is:  90.0
```

main

maxMarks	500.0
marks	450.0
percentage	90.0
Return value	None

Namespaces

- As the term suggests, a namespace is a space that holds some names
- A namespace defines a mapping of names to the associated objects
- In Python, a module, class, or function defines a namespace
- Names that appear in global frame (usually outside of the definition of classes, functions, and objects) are called global names and collectively they define the namespace called global namespace
- The names introduced in a class or function are said to be local to it.
- The region in a script in which a name is accessible is called its scope
- Thus, the scope of a name is resolved in the context of the namespace in which it is defined

*Python Programming: A Modular Approach by Sheetal Taneja and Kumar Naveen, Pearson Education India, Inc., 2017

An example

- For example, each of the functions **`f1`** and **`f2`** defined in a script may have the name **`x`**
- The variable **`x`** defined in function **`f1`** may refer to an object of type different from that of the object associated with variable **`x`** in the function **`f2`**
- A namespace maps names to objects
- Being an object-oriented language, definitions of functions and classes are also examples of objects

*Python Programming: A Modular Approach by Sheetal Taneja and Kumar Naveen, Pearson Education India, Inc., 2017

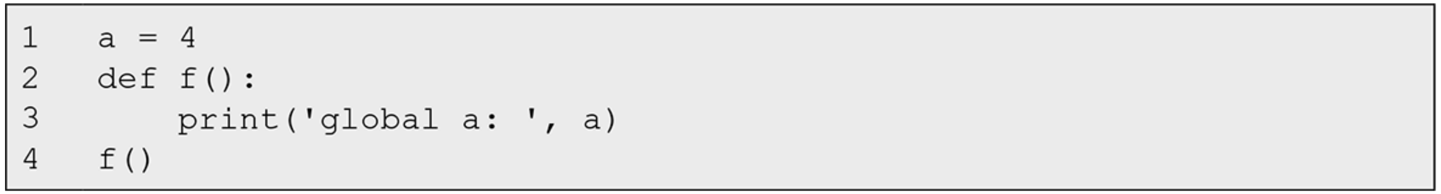
Scope

- The scope rules for names in Python are often summarized as LEGB rule
- LEGB stands for local, enclosing, global, and built in
- All names defined within the body of a function are local to it
- Function parameters are also considered local
- If a name is not locally found, Python recursively searches for its definition in an enclosing scope
- Names defined in the Python script but usually outside of any function or class definition are called global
- Python defines some built-in names such as `len` and `abs`, which can be accessed from anywhere in a program

*Python Programming: A Modular Approach by Sheetal Taneja and Kumar Naveen, Pearson Education India, Inc., 2017

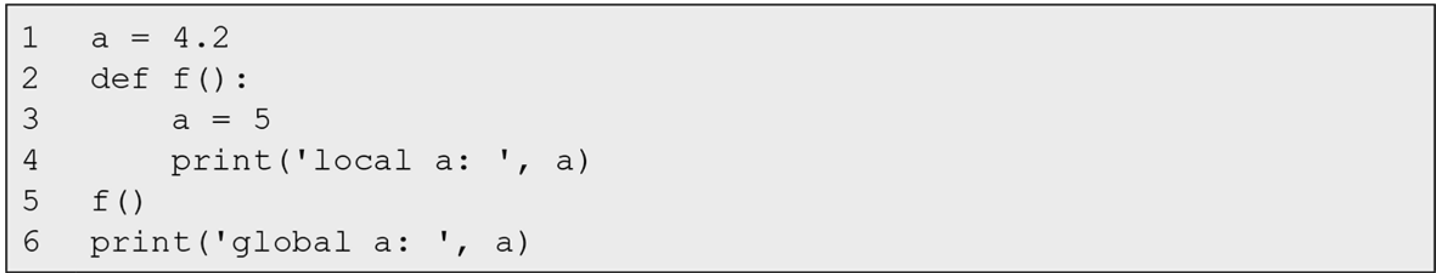
Examples

- Example1: Note that as the variable **a** has global scope, it is accessible in function **f**



```
a = 4
def f():
    print('global a: ', a)
f()
```

- Example 2: Note that the name **a** introduced in line 3 in the function **f** is local to it and has associated value **5**. Thus defining the value of name **a** in the function **f**, does not affect the value of the global name **a**.



```
1   a = 4.2
2   def f():
3       a = 5
4       print('local a: ', a)
5   f()
6   print('global a: ', a)
```

Examples (continued)

- Example 3: In this example, during execution of function **g**, when the variable **a** is to be accessed, Python looks for it in the local scope of function **g**, as it is not defined in the body of function **g**, it is searched in the next enclosing scope, i.e., the scope of function **f**, where the variable **a** is indeed defined, and therefore the value **5** of the variable **a** in function **f** gets bound to the occurrence of variable **a** in the function **g**.

```
a = 6
def f():
    a = 5
    def g():
        b = a
        print('inside function  g,  b: ', b)
    g()
f()
```

- Example 4: In this example, the variable **a** is defined in the body of inner function **g**. When we attempt to access the name **a** in line 5 of the outer function **f**, Python looks for its definition first inside the body of function **f**, as there is no definition of **a** in the function **f**, it looks for definition of **a** in the next available enclosing scope, which is the global scope. Again, there is no definition of the name **a** in global name space, and hence the error message is printed.

```
1   def f():
2       def g():
3           a = 5
4       g()
5       print('in outer function g, a =', a)
6   f()
```

Conclusions

- Python visualizer is an online tool for visualizing the execution of Python code.
- A namespace defines a mapping of names to the associated objects.
- Names that appear in global frame outside of the definition of classes, functions, and objects are called global names, and collectively they define the namespace called global namespace.
- The names introduced in a class, or function are said to be local to it.
- The region in a script in which a name is accessible is called its scope.
- The scope rules for names in Python are often summarized as LEGB rule
- If a name is not locally defined, Python recursively searches for its definition in an enclosing scope.
- Python defines some built-in names such as `len` and `abs` which can be accessed from anywhere in a program.