AN INTERACTIVE ANIMATION TOOL FOR JAVA OBJECT ORIENTED PROGRAMMING UNDERSTANDING

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ABSTRACT

Java Language becomes the most common Object-Oriented Programming Language over the entire world. Students from Computer Sciences and Information Technology are struggling to lean Java concepts and programs on Java. That is because of the various difficulties in understanding Object Orientedconcepts especially by novice programmers. This research adopts the design of interactive animationtool named LearnOOP which includesan animatedvisual model that shows the role of an object within a Java program. The visual object reflects the attributes and behaviour of that object to enhance students' understanding. The interaction between the developed tool and students is conducted and the usability is measured using a questionnaire. The results show that the developed tool is more effective than using traditional teaching and positively impact learning. The results also have confirmed that LearnOOP tool is promising with respect to quality assurance, effectiveness and usability.

KEYWORDS

Visual role of variable, Java object oriented programming, animation,understanding

1. INTRODUCTION

Object Oriented Programming (OOP) concepts are currently the most widely used approach in programming fields, particularly in comprehensive programs including the graphical user interface [1]. It has many special features and advantages, including inheritance, data hiding, multiple versions of an object, and the ease of division of work for any project [2]. OOP is an influential model nowadays, with many of its structures being part of the language and ready to use. Moreover, it helps to write large programs by multiple teams, each of which is programmed to part of the whole system. Accordingly, Computer sciences colleges and institutes consider the teaching of OOP languages as one of their most important educational curricula.

Based on previous studies, object programming has proved to be more complex than procedural programming for beginners, the difficulty lies in the ambiguities of variables [3, 4, 5]. The abstract nature of programming is another source of difficulties due to lack of mental perception and difficulty of visualizing how programming structures and its datavariables work [6, 7, 8].

Researchers look forward for providing tools to facilitate understanding of programming.They should understand the difficulties experienced by the novice programmers which resulting from a lack of good understanding of how to write the program correctly, and thus can develop methodologies and tools that can address these difficulties [9, 10, 11].

Some studies have focused on how to overcome these difficulties by providing useful systems and effective interactive tools, or prepare a work environment for beginners to improve learning programming [12, 13, 14, 15, 16].

There are new concepts that strongly support learning programs. One of the most important of these concepts is the role of variable [17, 18, 19, 20], where these roles of the variables are highlighted in the executed program to show and explain their behaviour and consequences values during execution time.Using this approach, a few tools were developed with support of visualization and animation techniques to interactively help students gain knowledge and acquire skills about programming structures. However, none of these tools are used for object oriented programming understanding. For this reason, this research proposes and develops an interactive tool named LearnOOP which includes an animated visual model that shows the role of an object within a Java program. The visual object reflects the attributes and behaviour of that object to enhance students' understanding and perception.

The evaluation of the developed tool is carried out using an empirical evaluation and the usability is measured using a questionnaire. The following section describes the most related works to our paper. The developed tool description is explained in section 3. Experimental procedure and results are described in section 4. The usability questionnaire and results are given in section 5 while the discussion of this paper is explained in section 6. Finally, the conclusion is provided in section 7.

2. RELATED WORK

The visualization and animation techniques are widely being used and adopted in Computer Science education with the promise of enhancing student understanding of complex concepts [21]. Using these techniques, tools were developed to interactively help students easily understand difficult subjects and tough topics.

In the area of learning and teaching programming languages, the program structure is explained as a visual and animated form especially for describing program variables. The main variable of object oriented programmingis an object which contains of data (object attributes) and methods (object behaviour). In fact, the OOP program outputs are the results of the processes and operations that an object's functions perform on its data. This is also could be denoted as the role of that variable which described in a visual animated form. Visualizing the role of the variable makes the student aware of the reality of this variable. It alsodescribes for them the need of this variable within the program.

From the literature, a few tools have been developed for teaching/learning programming languages. Some of them adopt role of variable concept such as PlanAni [22] and ViLLE [23,24], others are not, such as OOP-ANIM [8] and Jeliot [25,26,27]. PlanAni and ViLLE tools are used for procedural programming understanding while OOP-ANIM and Jeliot are used for object oriented programming comprehension. Moreover, the animation and visualization techniques have been adopted in all of these tools but in different ways. Only PlanAni tool visualizes the role of variable from a real world component, for example; counter variable is visualized as a step foot. Figure 1 describes the PlanAni tool interface.
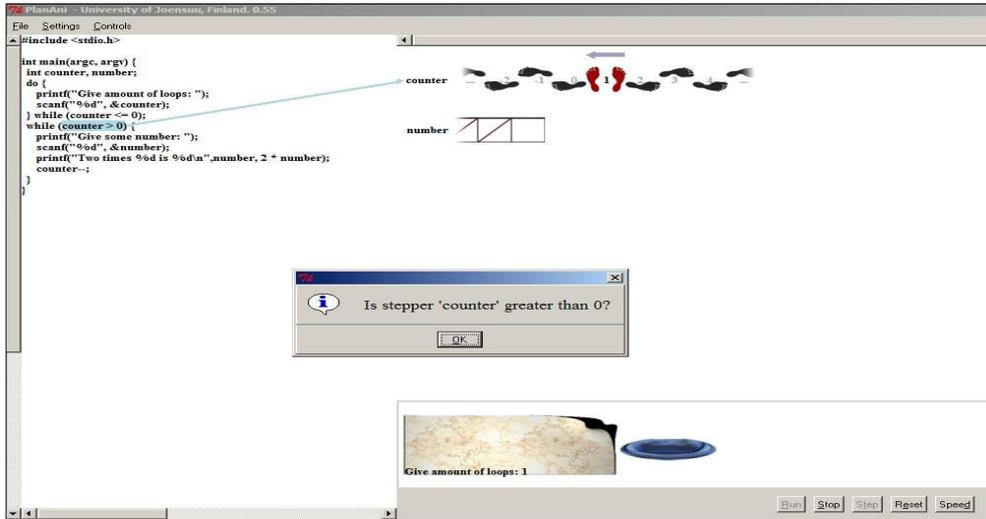
Figure 1.PlanAni tool main interface

ViLLE tool gives a description of role of variable in text-based form. It explains the changing values of variable at each stage of program executing. Figure 2describes the ViLLE tool main interface.
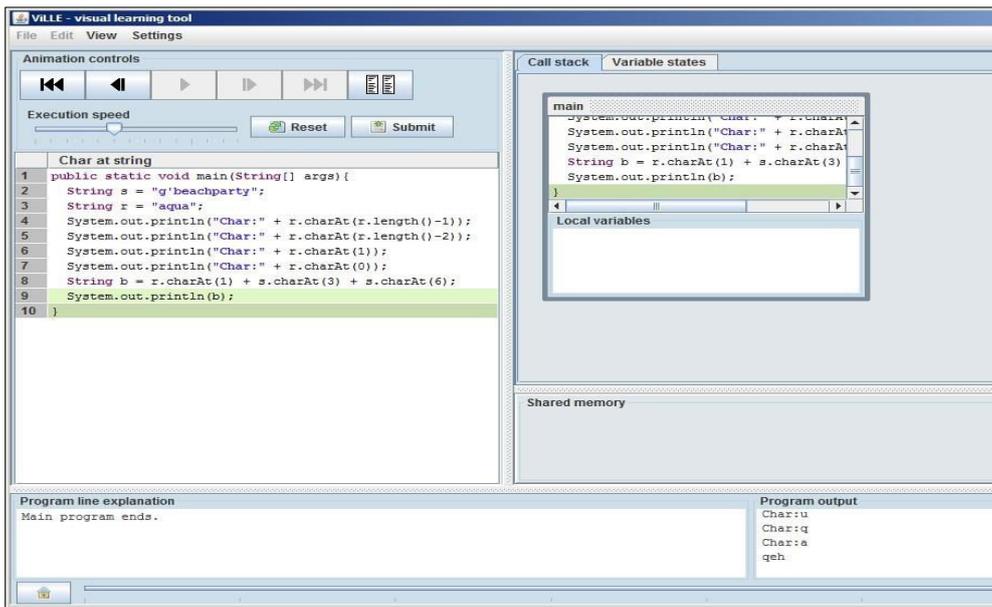

Figure 2.ViLLE tool main interface

Although the OOP-ANIM and Jeliot tools explain the object oriented programming concepts, none of them include the concept of role of variables. OOP-ANIM uses UML diagrams as a visual form of program parts, in the other side; Jeliot tool uses boxes and text form for program executing visualization. Figure 3 and 4 describe the interfaces of OOP-ANIM tool and figure 5 describes the interface of Jeliot tool.
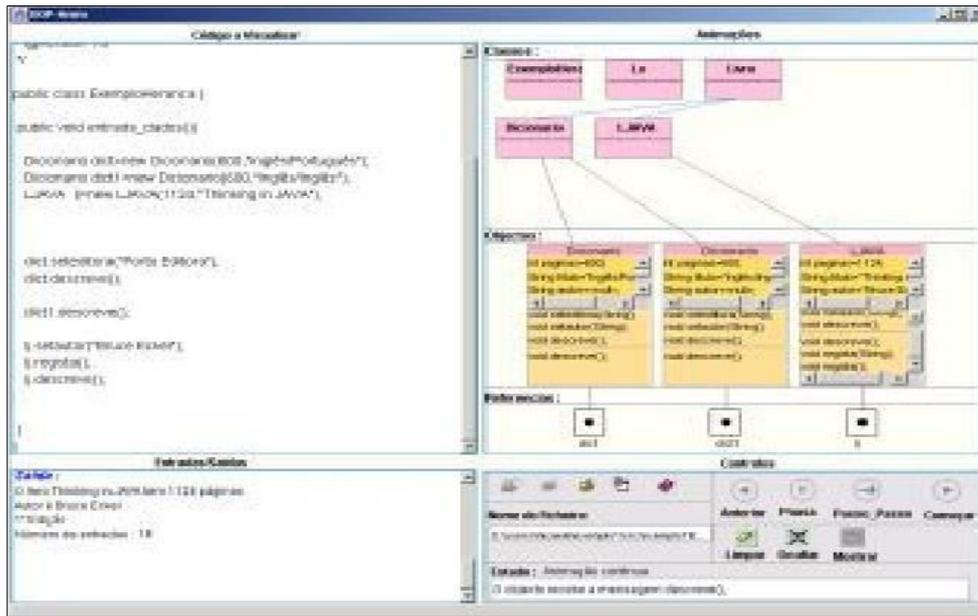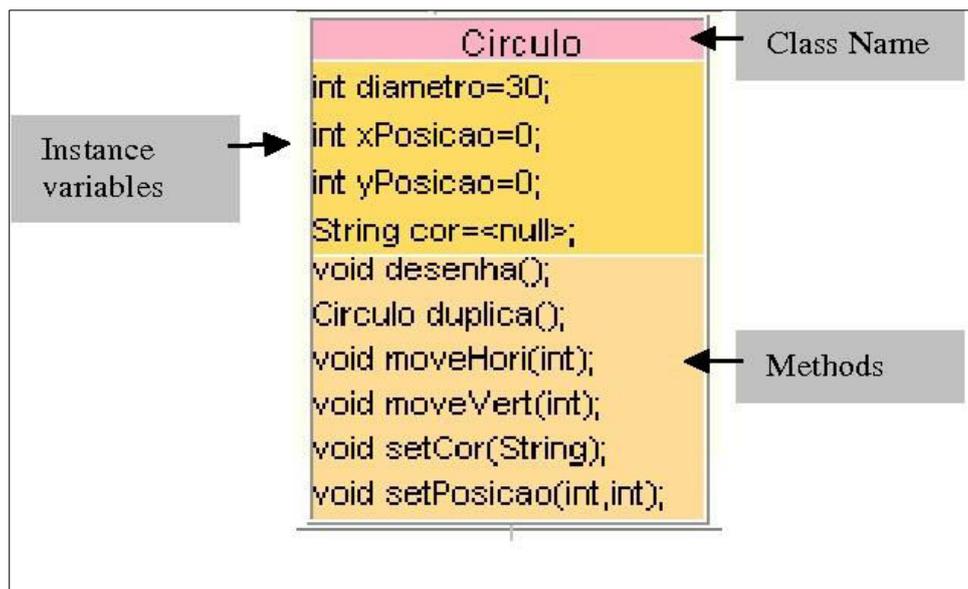
Figure 3.OOP-ANIM tool main interface
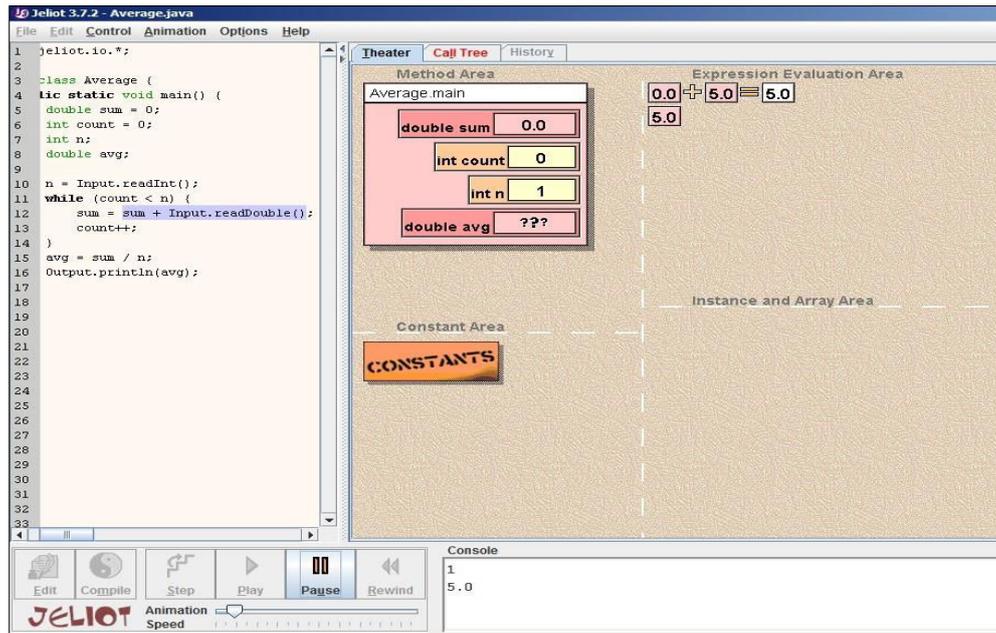

Figure 4.OOP-ANIM tool visual form

Figure 5.Jeliot tool main interface

Different studies have been carried out for evaluating these tools to know how much does role of variable concept effect in learning and understanding. From the literature, Sajaniemi et al. have conducted various studies [5, 18, 22, 28, 29]. Their results showed a positive effect of roles of variables in understanding of programming languages. They also agree thatthe concept of role must be enhanced by visual description that reflects the reality of its behavior.

Another research has been carried out by Shi et al. [30]. They considered the visualization and animation effects of role of variable in building a novice program. They carried out an experiment on 55 students of computer sciences. They divided the students into two groups; the first learning group learned programming in the traditional way based on the role. The second group learned with the support of PlanAni tool based on the visualizing roles of variables. Their data analysis showed a general improvement of the level of SOLO and high approval for the second group.

Al-Barakati et al. have conducted an experimental study[31]. They used a PlanAni tool to teach students an introductory programming course. Their results showed in scores on a post-test used to evaluate the effect of visual role of variable in understanding with 91 students divided into three groups. The results showed that the visual role of variable groupssignificantly outperformed the non visual group.

A case study have been carried out by Rajala et al. [23] on ViLLE toolfocusing on the effectiveness of visualization of role of variable on learning basic programming concepts. They were randomly divided students into two groups. The control group used traditional textual material during the course, while the treatment group used the same material extensively with interactive examples using the ViLLE tool. The study found that the ViLLE tool improves student learning without prior programming experience. They also found that ViLLE tool benefit novice learners more than learners who have some previous experiences.

Various studies have been carried out using Jeliot tool during the development of the tool versions[27, 32]. Regarding of learning with visualization and animation within the program execution, the results show positive effect. They also concluded that the educational tool must be incorporated into classes and assignments rather than once used as an aid in teaching.

Although there are tools in object programming for increasing students' understanding, they lack of the concept of variables roles and if variable roles are included, they still need to be visualize for enhancing students' understanding. All of these motivate us to propose and developa new tool which adopts the visualization of variables roles using real world objects for more students' perception and understanding of OOP java language.

The main goal of this paper is to justify the positive effect of visualizing the role of variable in OOP Java programming understanding through our developed tool called LearnOOP and evaluate quantitatively the effectiveness and usability of it. For the purpose of this paper, effectiveness refers to the ability of this tool in enhancing student's perception and understanding and usability refers to the extent to which the tools are useful, easy to use, easy of learning, satisfy and clear. Our goal is evaluated using an empirical evaluation approach (traditional teaching without a tool vs. usingLearnOOP tool). The question is, "*Is teaching using LearnOOP tool which includes the visualization and animation of role of variables more effective than traditional teaching medium?''.*

3. LEARNOOP TOOL DESCRIPTION

LearnOOP is an interactive tool used for teaching/learning Java OOP programming language. It contains the description of object and how being created from a special class. It adopts the role of variable concept through an object description and different opeartions on it. The decriptoin of object is given by visualization and animation of his attribues and behaviour. The tool includes various examples of objects from the real world to increase the ability of undersanding OOP. For an example; an object car1 is created from a class Car. Figure 6 shows the interface of the tool and the object car1 example.
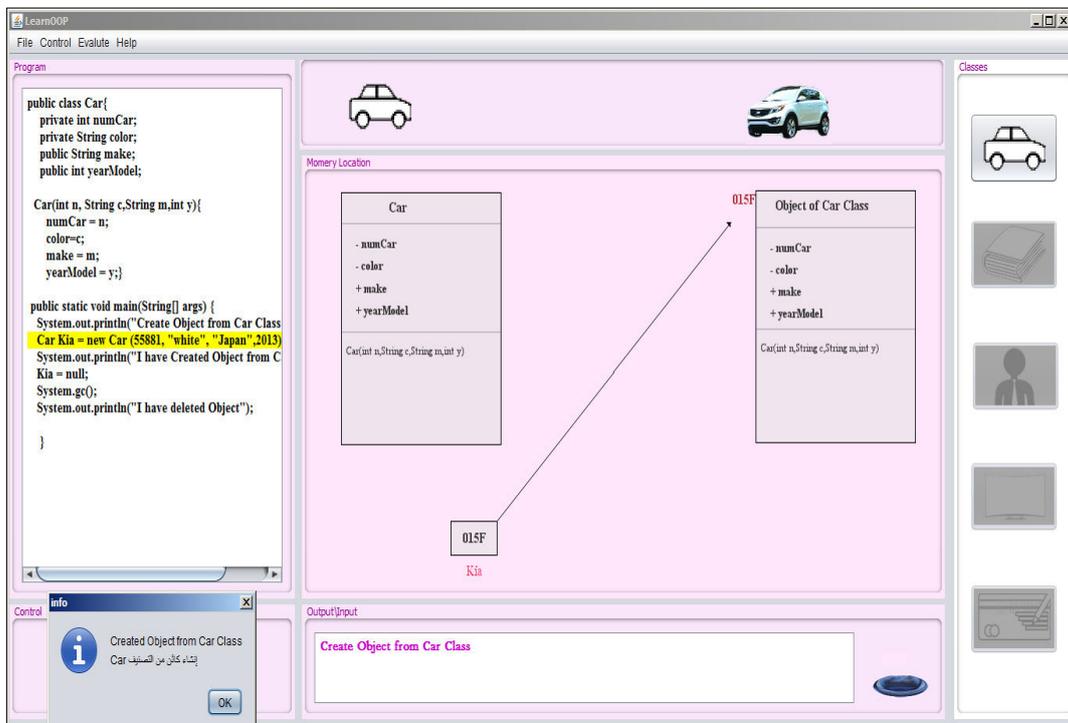

Figure 6.LearOOPTooluser interface

4. LEARNOOP TOOL EVALUATION

We carried out an experiment consists of 40students of the same lesson taught to the undergraduate Computer Science inJava Programming I (OOP) course at Sebha University of Libya during the semester I of 2017-2018 year. The students never studied OOP before. The experiment was conducted in two stages where each stage uses a different learning medium approach; the first stage uses only text-based materials (no visualization and animation of roles of variables), in the second stage, we divide the students into two groups randomly. Each group consists of 20 students. The first group called the control group which continuous in traditional teaching way while the other uses LeanOOP tool (visualizing role of variable concept).The students will be given a same test throughout the two stages. They are allowed to improve their answer after each stage. The results of the tests after each stage of the medium approach are compared.

The same topics of the lessons are given during all of the two stages. These topics are: class and object concepts, operations on object such as create, delete, copy, display, and modify object attributes. It also covers the inheritance lesson.

In this experiment, the tool SPSS [33] is used to statistically evaluate the effectiveness of LearnOOP tool using t-test and p-value.

4.1. Experimental Procedure

A total of 40 students participated in the experiment. The students are second year of Computer Science students (undergraduate students) at Sebha University of Libya. We follow the pre-test to post-test accuracy [34,35] in order to evaluate the effectiveness of LearnOOP tool. At the first stage, all of the students were given the same lesson using traditional teaching medium followed by a pre-test. At the second stage, the students were divided into two equal groups randomly; the first group continuous with traditional teaching medium and the second group were introduced to LearnOOP tool followed by a post-test for both groups.

The experiment was controlled by delivering the same lessons to all of the students by the same teacher during one semester long. The semester was divided into two equal stages of time. In the first stage, only text-based materials were used during the lesson time with the help of electronic slides. At the end of the stage, the students were given a pre-test of three OOP questions with a time limit of one hour to answer them.

In the second stage, after the pre-test, students were divided into two equal groups; group A and group B. group A continued with traditional teaching medium. group Bintroduced to LearnOOP tool and to its visual interface. They were asked to experiment with some examples of real world objects such as Car, Employ, Television, Book and Account. They were also asked to experiment with the concepts of class and object, operations on objects and inheritance. At the end of the session, both groups were given a post-test of different OOP questions regarding of the same objects with a time limit of one hour to answer them.

To control the tasks performance, the students were not allowed to consult books or use any materials. Then the results of pre-test and post-tests were compared.

4.2. Experimental Results

To determine the effectiveness of LearnOOP tool, a pre-test and post-test accuracy is used. Table 1 describes the students' scores of group B for the pre-test before using LearnOOP tool and post-test after using LearnOOP tool. Notice that the maximum score for each student is 15.

Table 1. The students' scores (group B) of pre-test and post-test

No.	Pre-test scores Without a tool	Post-test scores Using LearnOOP tool
1	2	10
2	2	11
3	5	12
4	5	12
5	2	11
6	2	10
7	11	14
8	2	9
9	1	4
10	3	7
11	2	10
12	2	9
13	4	12
14	1	7
15	2	10
16	2	10
17	1	4
18	1	4
19	3	7
20	1	4
total	54	177

The means (averages) of students' scores of pre-test and post-test are calculated.Table 2 describes the meansvalues of the group tested.

Table 2. The students' scores means of pre-test and post-test (group B)

Time	Treatment	No.	Mean
Sebha University	Without a tool	20	2.7
	Using LearnOOP tool	20	8.85

According to the chart analysis of the means values, it's clear that the mean value using LearnOOP tool is higher than the mean value without using the tool.Figure 7 explains the idea.
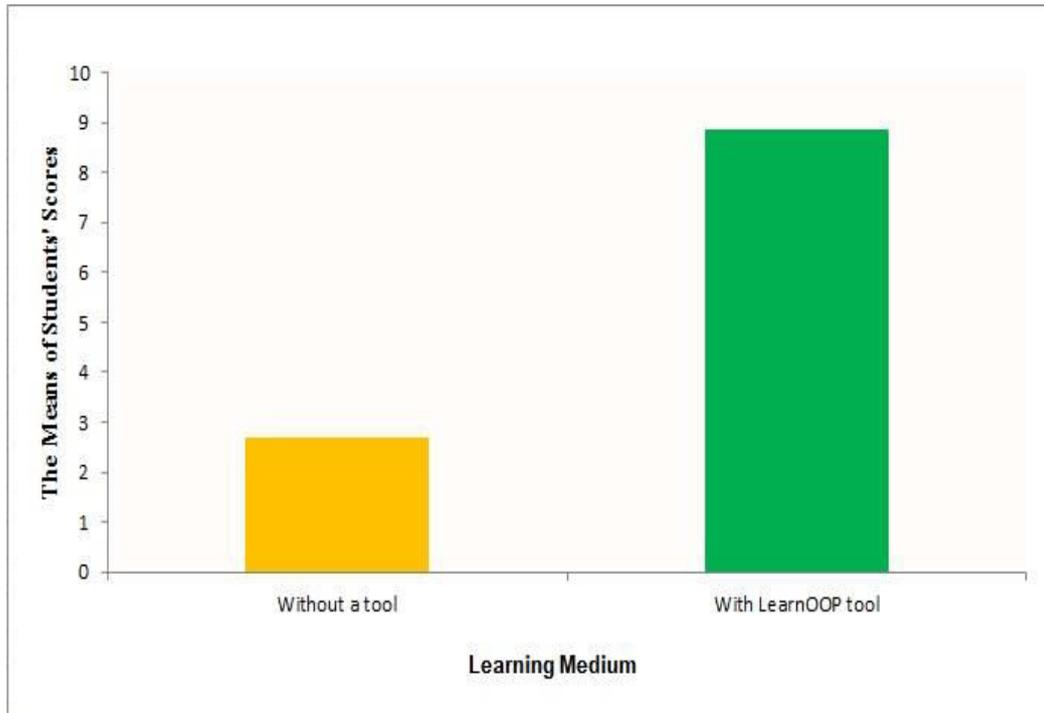
Figure 7. The means of the students' scores (group B)

The adopted statistical analysis of this experiment is that:

- Null Hypothesis (H_0): the conducted hypothesis is that there is no difference in the mean of pre-test and post-tests scores. In other words, the pre-test and post-tests scores will have equal means.
- Alternative hypothesis (H_1): the alternative hypothesis is that there is at least one difference in the mean of the pre-test and post-test scores in the group tested.
- p-value: the return value of the statistical test which indicates the probability of getting a mean difference between the per-test and post-test as high as what is observed by chance. The lower the P-value, the more significant difference between the groups. The typical significance level that has been chosen in this experiment is 0.001.
- t-test: this test was run on the pre-test and post-test scores. In this experiment, the result t-test shows that there is a difference between the pre-test and post-test according to the p-value which is 0.000 and less than the significance level 0.001. Table 3 shows the result of t-test.

Table 3. The results of t-test

Treatment	No. of student	Mean	p-value	t- test
Without a tool Using LearnOOPTool	20 20	2.7 8.85	0.000	LearnOOP tool >No tool

The test shows that there is a difference between using the LearnOOP tool and without using it based on the p-value which equal to 0.000. The p-value is less thanthe significance level (0.001) and that means the improvement from pre-test to post-test is statistically high significant.

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Table 4 describes the students' scores of group A (without a tool) for the post. Notice that the maximum score for each student is 15.

Table 4. The students' scores (group A) of post-test

No.	Post-test scores without a tool
1	5
2	2
3	10
4	3
5	3
6	2
7	7
8	2
9	6
10	7
11	4
12	4
13	4
14	4
15	2
16	3
17	2
18	1
19	10
20	13
total	94

Again, The students' scores means of post-test for group A is calculated.Table 5 describes the means ofboth groups tested.

Table 5. The students' scores means of post-test for group A and B

Time	Treatment	No.	Mean
Sebha University	Without a tool (group A)	20	4.7
	Using LearnOOP tool (group B)	20	8.85

According to the chart analysis of the means values, it's clear that the mean value of group B, which usesLearnOOP tool, is more higher than the mean value of the group A, which does not use it. Figure 8 explains the idea.
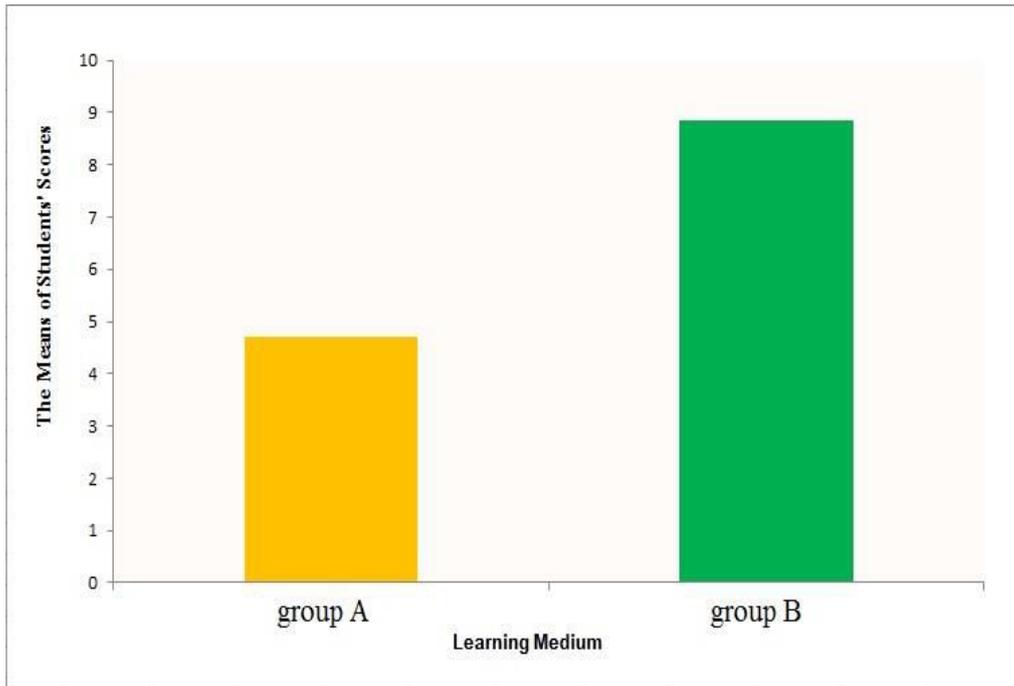
Figure 8. The means of the students' scores between group A and B

The same pervious statistical analysis is adopted for calculating the t-test; in this time, the test was run on the post-test of the two groups; A and B scores. The result t-test shows that there is a difference between the post-test of group A and post-test of group B according to the p-value which is 0.000 and less than the significance level 0.001. Table 6 shows the result of t-test.

Table 6. The results of t-test

Treatment	No. of student	Mean	p-value	t- test
Without a tool (group A) Using LearnOOPTool(group B)	20 20	4.7 8.85	0.000	LearnOOP tool >No tool

5. THE USABILITY QUESTIONNAIRE

The objective of this questionnaire is to measure the most important dimensions of usability for users in order to evaluate the LearnOOP developed tool. In order to develop the questions of our questionnaire, we considered five factors for evaluating the users' perceptions of usability and interface issue[36, 37]. We considered these factors as independent variables; that is, the factors they cause usability. On the other side, the usability was considered as a dependent variable of our research; hence, we want to measure the usability according to the answers of the provided questions of the questionnaire. We provided 19 questions to mostly cover the related points to the five factors. The questions are: 1 to 4 for usefulness, 5 to 9 for ease of use, 10 and 11 for ease of learning, 12 to 16 for satisfaction and 17 to 19 for clarity. We also included some questions for comments on usability. The format and the questions of the questionnaire are provided in figure 9; a, b, c and d.

Questionnaire for evaluating interface and usability issues of interactive visualization tools

Please be assured that all the informationg your name, telephone number and email will be kept absolutely confidential and will have no impact on any of your other work or studies.

Please answer all questions below by filling (ticking or writing) in the required sections.

Name: _____

Personal Telephone Number: _____

Your Email address: _____

Registration no.: _____

Tool name: _____

Figure 9a. The Usability Questionnaire personal information

	Strongly agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
1. The tool is useful in learning	○	○	○	○	○
2. The tool meets its learning objective	○	○	○	○	○
3. The tool gives me more understanding of the ideas and concepts	○	○	○	○	○
4. the tool helps me to understand it better than I knew before	○	○	○	○	○
5. The tool is easy to use	○	○	○	○	○
6. The tool is simple to use	○	○	○	○	○
7. The tool is user friendly	○	○	○	○	○
8. The tool does not take much time to learn and understand	○	○	○	○	○
9. Whenever I make a mistake using the tool, I recover easily and quickly	○	○	○	○	○
10. I leaned to use the tool quickly	○	○	○	○	○
11. The tool is easy to learn to use it	○	○	○	○	○
12. I would recommend the tool to my friends	○	○	○	○	○

Figure 9b. The Usability Questionnaire questions from 1 to 12

13. The tool is attractive	○	○	○	○	○
14. The tool is enjoyable	○	○	○	○	○
15. I think I need to have this tool	○	○	○	○	○
16. I am satisfied with the tool	○	○	○	○	○
17. The interface of the tool is clear	○	○	○	○	○
18. The images of the tool are compatible with their roles and meaning	○	○	○	○	○
19. The tool images are clearly understandable	○	○	○	○	○

Figure 9c. The Usability Questionnaire questions from 13 to 19

PLEASE GIVE US YOUR COMMENTS BY ANSWERING THESE QUESTIONS:

What would you suggest to make the tool a better application?

_____
_____
_____
_____

What were the things you liked best about the tool?

_____
_____
_____
_____

What were the things you liked least about the tool?

_____
_____
_____
_____

Please give any other relevant comments to make the _questionnaire_ or the _tool_ more clear and better:

_____
_____

Figure 9d. The Usability Questionnaire comments questions

5.1. The Usability Evaluation

Five choices of answers to these 19 questions are provided. The answers are: strongly agree, agree, neither agree or disagree, disagree and strongly disagree. These answers encourage the students to honestly choose the correct answers according to their perceptions. The five given choices of answers enable us to measure the usability using statistical tests such as percentage.

To determine the usability and user interface of LearnOOP tool, a questionnaire was given to the students of group B after the tool is used. The result of the questionnaire is summarized in Figure 10.
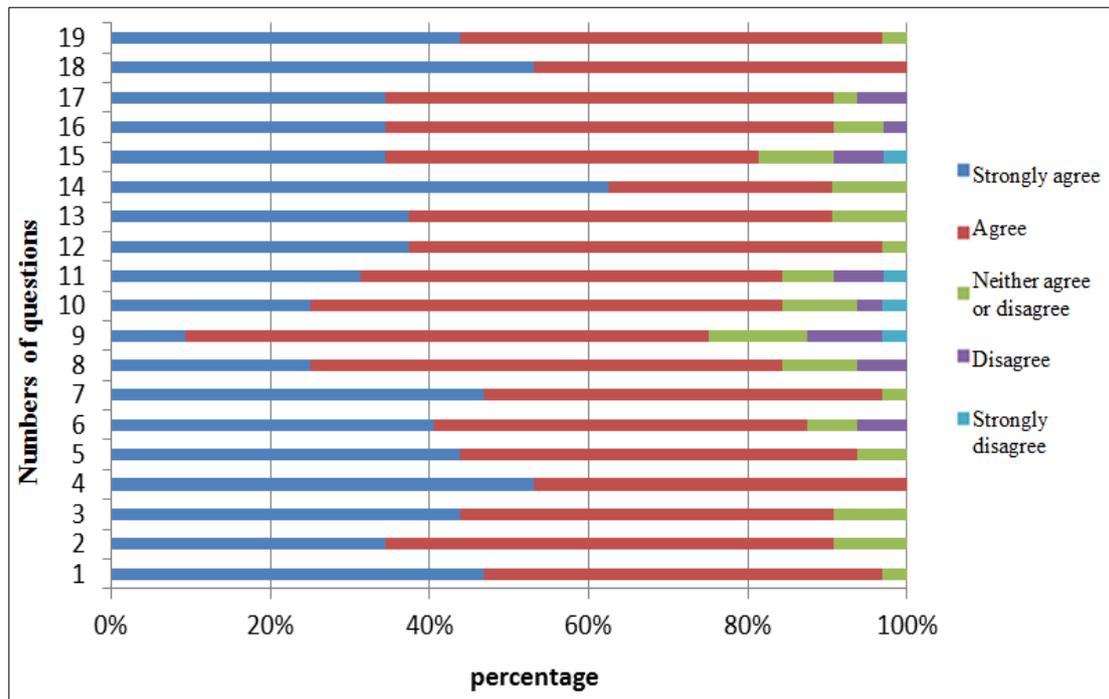
Figure 10. The Usability Questionnaire results

The questions of the questionnaire are concerned with five factors which strongly related to usability and user interface. The first factor is usefulness which includes the first question until the fourth question. All of the students strongly agree that the LearnOOP tool is useful. The second factor is ease of use which includes the fifth question until the ninth question. It seems that not all of the students strongly agree that the LearnOOP tool is easy to use but 74% agree that they can recover the tool mistake easily and quickly. For the third factor, ease of learning, most of the students strongly agree that the LearnOOP tool is easy to learn. For the fourth factor, satisfaction, 85% of the students strongly agree that they are satisfied with LearnOOP tool while 15% of them agree with satisfaction of LearnOOP tool. The last factor is clarity. Most of the students strongly agree that interface and images of LearnOOPtool are clear and understandable. The only point is that 26% of students disagree with the recovering of mistakes during the tool using. This may refer to the lack of experience and use of the specific tool.

We also collected some comments from the students in the same questionnaire about LearnOOP tool. About the question "what would you suggest to make the tool better?" some of the students suggested to add voice and instructional guideline. Regarding of what the students liked best and least about the tool, most of them liked very much the way of LearnOOP tool animation but nothing that the students liked least about the tool.

6. DISCUSSION

The results in this experiment indicate that LearnOOPTool is more effective and efficient than traditional learning medium. According to our hypothesis testing, there is a significant difference between using LearnOOPTool as a teaching/learning medium and text-only material. It shows that learning with visualizing role of variable significantly outperformed text-only material. The students realize many facts about object programming, the most important of which is that the object name indicates a variable that contains the object data address in the memory. They also

learn from the tool how to extract the object's attributes through visual form. Meanwhile, the overall improvement of enhancing the students' ability for understanding the OOP Java using LearnOOPTool is demonstrated and achieved. Compared with the previous studies, we almost agree with them on the need for the use of supporting education tools. We also agree on the need of adopting the role of variable concept for clarifying the programming and coding of different programming languages.

Looking at the usability questionnaire and test, we recognize that the students enjoy using educational tools. They emphasize that thesekind of tools really support their understanding during lecture lessons. They also agree that the educational learning and teaching tools provide a great deal of fun during lessons time and urge students to receive and absorb information enthusiastically.

7. CONCLUSION AND FUTURE WORK

The emerging of modern teaching approaches with educational techniques absolutely enhances the students' understanding.Experimental assessment and empirical evaluation have been shown that using computer educational tools during lectures and classrooms time could improve the ability of understanding and retention. Unfortunately, many teachers avoid using this type of teaching tools and a few researches dealt with the problem of the lack of using these kinds of tools.

Furthermore, studies have shown that the role of variable concept educationally enhanced students' understanding if they were supported by visualizing forms from the real world. This paper was motivated by these observations. In particular, this paper suggested more experiments of other tools through empirical evaluation in order to improve their effectiveness and teaching/learning support in the field of programming understanding. Our future work will consider adding more OOP features to LearnOOP tool such as polymorphism. Showing the relationship between entity and objects is also an interested area of OOP programming languages. Another future work is running more experiments and empirical evaluation for LearnOOP tool and other related tools.

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