Can Object (Instance) Diagrams Help First Year Students Understand Program Behaviour?

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Abstract. This paper investigates whether first year programming students can be helped to understand program behaviour through the use of Object (Instance) diagrams. Students were introduced to this diagramming technique as a way of visualising program behaviour and then given questions that tested their understanding of object referencing. It appears that drawing their own diagrams *is* a strategy applied by more successful students. Attempts to encourage all students to use this technique through scaffolding with partially completed diagrams failed however. Weaker students did not appear to find that the partially completed diagrams helped their understanding or go on to use the technique themselves.

1 Introduction

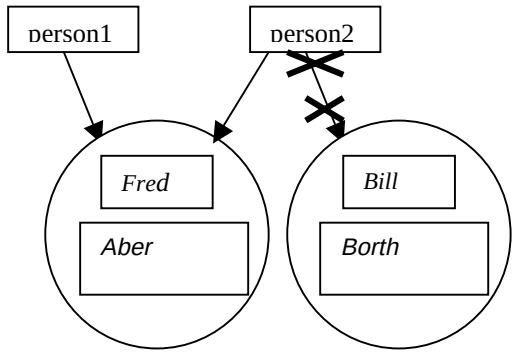
There seems to be a general agreement amongst CS educators that many of our students have problems in mastering programming. One of the manifestations of lack of understanding of program behaviour, is that many students do not seem to be able to trace code. In particular, some students do not seem to be able to produce for themselves a diagram that demonstrates an understanding of object references, which as Holland points out is one of the most fundamental concepts in learning Object-oriented programming [1].

In order to understand program behaviour it is necessary for the programmer to have a model of the computer that will execute it. This 'notional machine' provides a "foundation for understanding the behaviour of running programs" [2].

In the introductory programming sequence in Aberystwyth, we demonstrate program behaviour in lectures and tutorials mainly by drawing pictures of variables and what they reference, as in Figure 1. These diagrams represent a rough UML Object (Instance) diagram [3]. Essentially they provide a snapshot of the objects in a system at some point in program execution. They are a diagrammatic representation of the 'notional machine' that can then be mentally animated to observe the changes in values as the code executes.

One problem we have observed is that when students might appropriately use this technique themselves (debugging their programs for instance), weaker students fail to do so. They are often impatient when the instructor resorts to drawing a diagram, then amazed that the approach works. Even in the more restricted situation of a test that

asks the students to trace out what happens when just a few lines of code are executed, as in Figure 1, scratch sheets are often returned blank. In a previous investigation we discovered that only 36% of the sheets were returned with any kind of 'working out'.




```
Person person1 =
new Person("Fred", "Aber");

Person person2 =
new Person("Bill", "Borth");

person2 = person1;
person1.setAddress ("Llan");
-----------------------------------
```
What is person2's address?

Figure 1: A partially completed Object diagram and related question

2 Background, Questions and Results

In a previous Diagrams conference, Hegarty and Narayanan [4] outlined a cognitive model of understanding dynamic systems that supposes that the viewer: decomposes the system into simpler components; constructs a static model by making representational connections to prior knowledge and other components; integrates information between different representations (e.g. text and diagrams); hypothesizes lines of action, and finally constructs a dynamic mental model by mental animation.

In addition, they have empirically validated the design guideline that people learn more from being induced to mentally animate a system before viewing an animation than by passively viewing the animation. If we examine Object diagrams we can see that the first two steps outlined in the Hegarty/Narayanan model are essentially the creation of the basic diagram, and the last three steps involve the actual tracing of the program code with reference to that diagram. This provides some justification that our approach of encouraging students to produce Object diagrams for their notional machine is a reasonable one. We were, however, frustrated that many students did not produce such diagrams themselves and we wanted to encourage them to do so.

We performed an experiment that sought to answer three research questions about the use of Object diagrams (see below) The students were divided into a control group and a group who were given partially completed object diagrams (the Experimental group). A follow-up test was also given. See [5] for a complete report on the experiment.

Is drawing some kind of Object-like diagram correlated with success in solving multiple-choice tracing questions? There is an indication that the technique *is* used by higher achieving students. The higher scores achieved by beginners who use dia-

grams, as opposed to those who do not, comes close to statistical significance (p=.07 with one tailed t-test).

Table 1: Correlation between Diagram Use and Performance

Group	Follow-up Test Average - on tracing questions
Beginners who do not use diagrams (23)	47%
Beginners who do use diagrams (45)	68%

Does providing students with scaffolding in the form of partially completed Object diagrams help them correctly answer multiple-choice tracing questions? It seemed very unlikely that students would NOT do better if they were given partial diagrams than if we simply give them the code with no help whatsoever. We wanted to confirm this conjecture but were very surprised by the results. When we initially tested the experimental group against the control group we discovered that Object diagrams hardly helped students trace code at all (not significant). When we looked at the results in a follow-up test, we saw that students who had been given the diagrams on the first test did slightly (but not significantly) *worse* than the control students.

Table 2: Intervention Test Results

Group	Test Average
Beginners Control (28)	28%
Beginners Experimental (40)	36%

In light of this result it was not surprising that the answer to our third research question: **Do students who have been provided with this scaffolding continue to use it in such multiple-choice questions?** was 'no'. Since the technique was not 'useful' why would students continue to use it?

We are still pondering the results of this experiment. We have provided the students with what seems like a reasonable notional machine, but we have considered that by producing the diagrams ourselves we have removed the first two steps of the Hegarty/Narayan cognitive model and thus short-circuited the students' creation of their *own* mental model. Research is still on going.

References

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