# Moving from Visualization for Teaching to Visualization for Learning

*(Position Paper)*

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***Abstract*—Good teachers choose from a rich set of visualizations to clearly communicate ideas and concepts to students. Good educational visualizations are designed in a way that supports the teaching process: they help to tell a story that leads to understanding.**

**In this paper, we argue that teachers should *not* produce such visualizations. Instead, they should ask their *students* to do that. We argue that *creating* a concise visualization is an excellent opportunity to gain a profound understanding of a concept or skill. Visualizing implies learning! Thus, we advocate the development of pedagogical methods and tools that enable students to learn by producing visualizations.**

***Keywords*-Information transfer vs. knowledge acquisition, Active learning, Technology-enhanced learning, Classroom clickers, Informa**

## I. Visualization for Teaching

Visualization is about the visual *representation* of information, in the form of graphs, diagrams, tables, text, or any other visually perceptible way. Visualization is a cornerstone of education, because it helps in the transfer of information from teachers to students. However, education is not just about the *transfer of information*, it is much more about the *acquisition of knowledge*. When the goal is knowledge acquisition, the one-way communication of information – in visual or other forms – from teacher to students is often not the most effective means of education.

When producing an educational visualization that helps to teach a concept, a teacher goes through an intense process of reflection and design. First, she needs to acquire a complete understanding of the concept, including all the relevant aspects, as well as the context surrounding the concept. Then she needs to distill the essence of the concept, eliminating all irrelevant or distracting aspects. She needs to consider the background knowledge of her students. Based on that, she needs to identify common misconceptions and misunderstandings, as well as the key insights the students need to have to be able to grasp the idea. Then she needs to determine the most intuitive representation, or multiple representations, that allow her to tell a story that provides the right learning opportunities for her students.

This process of developing an educational visualization is truly rewarding. Throughout this process, a teacher often learns new aspects about the concepts, or comes to a more complete, more profound understanding. In short: the teacher *learns*. So, why reserve this learning opportunity for *teachers*?

## II. Visualization for Learning

How should "visualization for learning" look like? Should we just replace the visualizations thoughtfully crafted by experienced teachers with visualizations that students, who are novices with respect to a concept, have produced?

Despite our controversial statement in the abstract of this paper, we do *not* believe that teachers should completely stop producing and using great visualizations for teaching: the use of visualizations created by teachers can be an effective pedagogical approach. However, we strongly believe that the act of visualizing a concept should not *exclusively* be reserved for teachers: a pedagogical approach should provide students with the opportunity to "learn by visualizing".

This active involvement of students is consistent with "active learning" [1] approaches. "Active learning" is an umbrella term for a host of pedagogical approaches that all focus on the student as an active participant instead of a passive consumer of information. Many approaches to active learning would benefit from student-developed visualizations, for example:

- Learning by teaching [2]. The most extreme approach is to have students teach, under the supervision and guidance of an experienced teacher. As a result, it is also the students who have to prepare the material they use for communicating. This includes the creation of visualizations that are effective in explaining a concept.
- Collaborative learning [3]. Students can learn collaboratively, for example by cooperating on specific tasks in small groups. One kind of task can be the development of visual explanations of the concepts under study.
- Classroom clickers [4]. Classroom clickers (also known as classroom response systems) are an effective means to make lectures more interactive, and to solicit feedback from students. Modern clicker systems go far beyond multiple-choice questions. They can ask students to answer much richer questions, for example by creating visual diagrams.

Any of the above teaching methods could be used to allow students to visualize the concepts they are studying. In our own past work, we have focused on visualization-enabled classroom response systems.

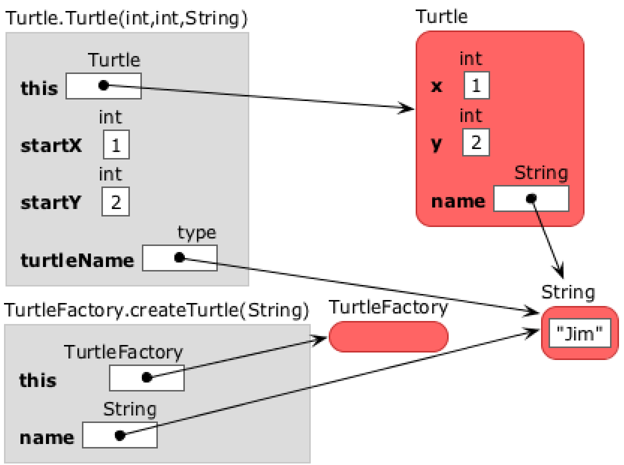


Figure 1. Student-created visualization of the state of a running program

## III. Visualization in Informa

Informa [5] is a software-based classroom clicker system. The instructor runs the Informa server on her computer, and each student runs an Informa client on their own computer. The instructor posts a problem, which the students solve on their computers and submit back to the instructor's computer. The instructor then projects an analysis of the submitted solutions on the classroom projector. While traditional clickers only support multiple-choice problems, where "solving" a problem consists of picking from a set of pre-defined solutions, Informa provides a set of much richer problem types, including problems where students need to *visualize* a concept, or transform one visual representation into another. This enables an approach where students develop visual models [6] to demonstrate their understanding. We improved the pedagogy surrounding Informa, involving students also in evaluating the solutions produced by their peers [7], [8].

Figure 1 shows an example of an Informa problem that requires a student to visualize the current state of a program. Students receive a code listing, and are given a point in the execution of the program, and they need to create the visualization including stack frames, heap objects, and variables.

Informa problem types like this include syntax-directed solution editors. Thus, students are limited in their freedom when creating a visualization: the "visual language" only offers those "visual patterns" deemed necessary for a solution to the given type of problem. For example, the editor the student used to create Figure 1 allows the creation of stack frames (gray boxes on the left), heap objects (rounded boxes on the right), and variables inside stack frames or heap objects. It also enforces that every variable is represented by a white rectangle, and that it has a name (left, bold) and a type (above). Moreover, it distinguishes between primitive variables, where the value appears in their box, and reference variables, where the value is represented by an arrow to a heap object. Thus, students are only able to create well-formed visualizations, in a prescribed problem-type-specific visual language.

This limitation of the students' freedom has several advantages: (1) It prevents students from creating "freak solutions", visualizations that are not well-formed or not meaningful. (2) It significantly speeds up the creation of a visualization[1]. (3) It allows the automatic checking of submitted solutions. However, constraining students by forcing them to use a specific visual language eliminates the intellectual effort – and thus the learning opportunity – of coming up with the proper visual language to use for visualizing a given concept.

Overall, we have found Informa to be a very valuable tool in our teaching toolbox. Students appreciate the early feedback about their understanding, and they even enjoy assessing the visual solutions of their peers. And for us as instructors, the visual solutions students have produced with Informa have allowed us to gain deeper insight into their misconceptions and their understanding.

## IV. Conclusions

We hope that our position provides a stimulus for constructive discussions on pedagogical approaches and tools that use visualizations not only for teaching, but also in active learning.

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[1]Students using Informa in the classroom asked for permission to use it also for their homework assignments, specifically because of its efficiency in creating problem-specific visualizations.