Model Software Tools for Inquiry-based Learning

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Abstract

It is widely agreed upon that mathematics is not a spectator sport: one does not learn mathematical reasoning by simply watching somebody else perform it, but rather one needs to do it oneself. We believe that all students at all levels should experience doing mathematics (and science and engineering) the way professional mathematicians (scientists and engineers) do it - as has been called for most prominently in the US National Science Foundation report Shaping the Future (of Education in Math, Sciences and Engineering and Technology).

Doing mathematics means solving problems, it means to start with experiments and making observations, making conjectures, formulating possible theorems, and establishing these through proof (with an appropriate level of rigor) while making suitable definitions that facilitate precise statements and arguments. Axiomatization is the very last step. Contrast this with the all-too-common daily practice in college classrooms which completely reverses this order, starting with (e.g. real number axioms, alas, the intermediate value axiom), stating polished theorems, rules and algorithms, and asking the students to repeatedly apply these to toy-exercises.

One of the main obstacles to doing more mathematics in our classrooms is the perception that this would simply take too much time. Many argue that this is already false, provided one uses measurement tools that assess the long-time retention and deep mastery of the learnt topics (as opposed to throw-away quizzes that may be aced with short-term memory alone). Nonetheless, the amount of time and other resources to consistently engage in an inquiry-based approach to learning mathematics remains a major concern.

We argue that modern technology provides the means to finally make such approach a reality! Specifically, we present model interactive software that employs a highly visual language, and which makes it trivial to perform, within a few minutes, hundreds of experiments that form the starting point for developing intermediate level college math material. We present the new third panel of the JAVA vector field analyzer II which provides the means to develop notions of line integrals, to discover their key properties (leading to conjectures that ask for formal proof), all the way to the integral theorems of vector calculus (Green's theorem, Gauss' divergence theorem and Stokes' theorem). In contrast, recall the traditional fare which is very much top-down, and which, due to the inefficient algebraic language employed in most paper-and-pencil explorations, allows only for a minuscule number of explorations. On the other end, modern technology, as we demonstrate in our model-software, is moving towards a vastly more efficient visual language, for both input and output: On one side we see ever more iconification (cf. J. Mason) of directly manipulable mathematical objects, while on the other side the sophistication of providing visual feedback is growing rapidly.