How to Make your System Teach Well

Learning about teaching from teachers and learners

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Abstract. In 1987 Ohlsson [11] described the great variety of teaching actions available in a versatile teacher's repertoire, and berated AIED for implementing only a tiny proportion of this versatility. At that time we agreed with Ohlsson in his criticism. This paper represents our initial step in determining whether the criticism still stands. It offers a broad set of headings within which a taxonomy of recent work on modelling teaching may be constructed. Once complete this taxonomy should allow us to address such questions as: should we design computer systems to adopt a human approach?

In the design of Intelligent Tutoring Systems various approaches have been adopted which are informed by our knowledge of how humans teach and learn. In order to learn more about designing such systems we reflect upon past successes and failures. We start to map out the territory of systems which try to embody teaching strategies with the aim of constructing a taxonomy of the methodologies used by system designers. Once complete this taxonomy should allow us to address the following questions:

- Should we design computer systems to adopt a human approach?
- Can we do it effectively, and if we can, when do these approaches work well: are there some factors which are critical to the success off using human teaching tactics with machines?

We intend to pay particular attention to systems which address the learner's need for assistance at the domain and at the metacognitive level and point towards issues which are pertinent to the design of systems which are intended for use over the world wide web. In our earlier work [6] we presented a tentative initial categorisation which suggested the following three principled methodologies for developing the teaching expertise in AIED systems.

First is the empirical observation of human learners and human teachers followed by an encoding of effective examples of the teacher's expertise, typically in the form of rules. An influential early example of this methodology was "Socratic Tutoring" [5]. Socratic Tutoring provides a number of detailed teaching tactics for eliciting from and then confronting a learner with her misconceptions in some domain. A more recent example of the methodology is provided by Lepper et al. [9] who analysed the methods that human tutors use to maintain students in a positive motivational state with respect to their learning. Ohlsson [11] provides an analysis of the great variety of teaching actions in a versatile teacher's repertoire, and berates AIED for implementing only a tiny proportion of this versatility. Bloom [2] compared the effectiveness of a number of general teaching strategies in terms of learning outcomes and provided adaptive systems with the goal of increasing mean learning gains by two standard deviations compared to conventional classroom teaching.

The second methodology starts from a learning theory and derives appropriate teaching tactics and strategies from that theory. Conversation Theory [12] and its reification in various teaching systems is an example of this approach. As with Socratic Tutoring, Conversation Theory is concerned essentially with epistemology rather than with affective aspects of teaching and learning. It is concerned to ensure that the learner constructs a multifaceted understanding of a domain that allows her to describe (to herself or to others) the inter-relationships between concepts. In some ways it is echoed by the "self-explanation" view of effective learning [4]. An example of the second methodology that partially addresses some of the affective issues is Contingent Teaching [15]. Here the idea is to maintain the learner's agency in a learning interaction by providing only sufficient assistance at any point to enable her to make progress on the task. The evaluation of this strategy in the hands of non-teachers who had been deliberately taught it shows that it is effective but sometimes goes against the grain for experienced teachers who often wish to provide more help at various points than the theory permits [16].

The third methodology is an amalgam of the above two. This builds a computational model of the learner or of the learning process and derives a teaching strategy or constraints on teaching behaviour by observing the model's response to different teaching actions. For example, VanLehn et al. [14] compared two strategies for teaching subtraction to a production rule model of a subtraction learner and concluded, on the basis of the amount of processing engaged in by the mode, that the "equal additions" strategy was more effective than the more widely taught "decomposition" strategy. With a similar general methodology VanLehn [13] derived "felicity conditions" on the structure of tutorial examples, for instance that they should only contain one new subprocedure.

This provides a useful start, but how well does this sort of categorisation encompass more recent advances in ITS design? There are clear instances of recent work which supports this scheme. For example, Grandbastien [7] stresses the need for effective methods to access, organise and use the expertise of the teacher or trainer. Empirical observations of professionals teaching still has its part to play here. Learning theories are still being used to inform system design: Constructivism [1], The Zone of Proximal Development [10] and Reciprocal Teaching [3], for example. Our scheme does however need a more effective means of dealing with systems which are informed by empirical studies of teachers using strategies derived from a learning theory. It is perhaps harder to find examples of teaching strategies being derived from the construction of a computational model of the learner or of the learning process — is this task simply too tough?

In addition to the lack of recent work in our third category a closer inspection of our scheme suggests the need for further revision and refinement in order to encompass systems which are clearly informed by the way that humans interact within a learning environment, but which do not fit neatly into our 3 initial categories. For example, systems which attempt to simulate human face-to-face interactions through the use of animated pedagogical agents [8]. Does the fact that some of the power of such systems derives from their physical appearance require the introduction of a new category? The introduction of networked technologies which allow learners to interact across widely distributed geographical locations enables interactions between human learners and teachers which were previously unavailable. Are the issues which were pertinent to traditional face-to-face human teaching and learning still pertinent or should we be exploring the changes in human teaching within this paradigm in order to inform our designs for intelligent systems to support this learning?

In the workshop we will discuss these issues further and consider the next refinement to the categorisations scheme and some tentative answers to our initial questions.

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