The role of strategic theories in learning using computer-based representations

Conference or Workshop Item

The role of strategic theories in learning using computer-based representations

Abstract

This paper examines how learners interact with variations in representations presented in a computer environment. In particular, it explores how analysis of learning in terms of the notion of *strategic theories* can provide insight into learners' cognitive processes when using such representations. The study reported here looked at problem-solving using concurrent mathematical representations (numbers, graphs, algebra). For each task, the set of representations was presented in one of three *instantiations*. These were: *Static* (non-moving, non-changing, non-interactive); *Dynamic* (animated, following keyboard inputs); and *Interactive* (directly manipulable using a mouse). A variety of data was collected from 18 participants: learners' shifts in attention were recorded using an unobtrusive eye-tracking device and screen capture software; keyboard and mouse actions were logged automatically; utterances and gestures were video recorded; and notes and sketches were recorded in real-time. This rich data was analysed in an integrated way, with the aim of characterising learners' strategies. The results show that participants tend to use multiple strategies over the course of task completion, and that the number and type of representation influence the strategies used. It is argued that this form of strategic analysis offers a systematic way of understanding learning journeys.

Domain: Learning and Cognitive Science

SIG:
SIG7 Learning and Instruction with Computers
SIG3 Cognitive change

Scheduling category:
Learning and Instructional Technology: Multimedia and Hypermedia Learning

Keywords: Representation; Cognition; Problem-solving; HCI; eye-tracking

Extended Summary

Aims

Computers are offering learners new ways to interact with visual representations, and to make links between these representations; yet learners' traditional difficulties with representations often remain (Dunham & Osborne, 1991); and indeed dynamic, linked and interactive representations may carry their own additional difficulties (Ainsworth, 2006). At the same time, developments in technology for real-time capture of gestures and utterances (Blake & Scanlon, 2002), eye-tracking (Hansen et al., 2001), and notes and sketches (Mann et al., 2008) mean that it is now possible to capture rich data on learners' interactions with representations.

However, the very richness of this data presents problems. Firstly, software to coordinate and integrate the analysis of these different multiple streams of data is only recently beginning to appear. Secondly, the processes of rendering, collating, synchronising, transcribing, coding, and comparing such data are time-consuming. Finally – and this is the focus of this paper – it is not at all clear how best to bring theory to bear on the analysis of this data to provide genuine insight into learners' cognitive processes.

This paper explores how analysis of learning in terms of the notion of *strategic theories* (Aczel, 2006) can provide insight into learners' cognitive processes when using variations in computer-based representations.

The representation study

In order to explore the sense that learners make of multiple mathematical representations when problem-solving, a study was conducted in which a set of representations was presented in one of three instantiations. These were: *Static* (non-moving, non-changing, non-interactive); *Dynamic* (animated, following keyboard inputs); and *Interactive* (directly manipulable using a mouse).

A variety of data was collected from 18 participants: shifts in attention were recorded using an unobtrusive eye-tracking device and screen capture software; keyboard and mouse actions were logged automatically; utterances and gestures were video recorded; and notes and sketches were recorded in real-time.

A strategic theory approach

A number of theoretical explanations for the difficulties with representations identified in the research literature can be discerned, and some of these could be examined using the data collected in the study. We chose to explore a "strategic theory approach" to analysis (Aczel, 2006), in which learners are seen as having "concerns" (problems of special interest in a given context); they conjecture "strategic theories" (attempts to address the concerns); and then they subject these strategic theories to some kind of "error-elimination", typically a sifting or testing process.

Learning then is portrayed in terms of processes of discontinuous trial-and-improvement of strategic theories under the selection pressures provided by concerns.

Application of the strategic theory approach

The data was analysed in an integrated way, with the aim of characterising participants' strategies. The results show that participants tend to use multiple strategies over the duration of task completion, and that the number and type of representation given influence the strategies used.

For example, it was seen that participants may often choose a strategy dependent on the particular form of mathematical representation with which they have started (e.g. a line graph). Should this attempt fail, participants may attempt to improve this strategy by combining it with another form of representation (e.g. numbers). Participants were also seen constructing their own representations ("re-representing strategies"). In addition, the eye-tracking data showed that participants sometimes constructed representations with their eyes ("imagining strategies").

By identifying the different kinds of strategies being used at particular times, the points at which strategies were abandoned or refined, and the frequency of chosen strategies, a pattern of activity can be constructed for an individual participant over the duration of a task (e.g. Figure 1).

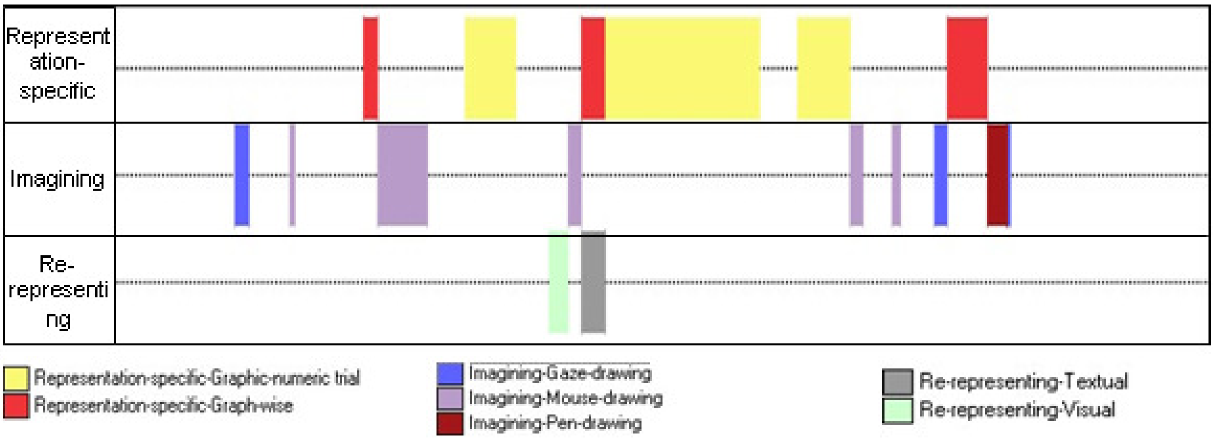

Figure 1

By comparing such patterns between tasks and between participants, it might be possible to identify significant commonalities and differences.

It was found that the relationships between performance, strategy and time spent on task are complex. It was also found that strategy choice can be influenced not just by the representations given but also by the participant's prior knowledge and concerns.

The data hints that participants change strategies when they experience difficulty in using a strategy; when their attention shifts to a different mathematical form; when they experience difficulty in visualising mental images; when a strategy imposes excessive cognitive load; and when they fail to link multiple representations.

Participants appear to apply strategies differently depending on the number of external representations being manipulated. For example, participants tended to use their eyes or mouse when manipulating one external representation at a time; their hands when manipulating or comparing manipulations of two representations at the same time; and notes and sketches when comparing more than two manipulated representations.

Instantiation also appears to influence participants' use of strategies. For example, participants given Static instantiations tended to spend more time using imagining strategies than participants given Dynamic or Interactive instantiations. Static and interactive instantiations tended to encourage graphical strategies; dynamic instantiations tended to encourage algebraic strategies. Dynamic and interactive instantiations tended to encourage re-representation.

More research is clearly needed to test the findings over a larger sample of participants and tasks. However we would suggest that this form of analysis offers a systematic way of understanding learning journeys.

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