Modeling the ability to reason about oneself and others in educational contexts

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Introduction

There is a huge gap between educational science on the one hand and cognitive science on the other. Cognitive scientists investigate learning and cognitive skill acquisition in a fundamental way. The result of their research almost never reaches real-world educational practice. Educational scientists, on the other hand examine realistic learning situations and improve instructions and educational settings to fit the learner's needs. They cannot do so without resorting to results from cognitive science. On certain topics, there is little fundamental work they can rely on. However, the educational field is rapidly changing and many new forms of learning and approaches to learning have emerged in the last few years. Educational science is in the forefront of investigating and evaluating new forms of learning like discovery learning, self-regulated learning and cooperative learning (see e.g., Hoek, van der Eeden & Terwel, 1999). Especially the self-regulation and social interaction aspects of learning receive much attention these days. To be able to provide fundamental cognitive results that can be of service for educational science and instruction design, the inclusion of social processes into cognitive modeling seems timely.

Cognitive load theory

Educational research gratefully embraces cognitive load theory (CLT; see Paas, Renkl & Sweller for an overview) as a framework for investigating the interaction between information structures and human cognition. CLT is based on several assumptions regarding cognition: a virtually unlimited capacity of long-term memory, schema theory of mental representations of knowledge, and limited processing capacity for working memory. Based on CLT, educational researchers have been able to generate a variety of new and sometimes counterintuitive instructional designs and procedures. However, cognitive load cannot be measured directly. In this respect cognitive modeling had a lot to offer, because cognitive models can predict in a very precise way the form, interaction and size of the different kinds of cognitive load involved in a certain learning task.

Reflection on oneself and others

Most of the time, cognitive load is investigated in the context of self-regulated learning. However, in our opinion, cooperative learning might just as well profit from cognitive load theory. Seen from a cognitive point of view the two forms of learning call on quite similar cognitive mechanisms. We propose that in both learning situations reflection is an important process. Figure 1 depicts how we perceive the cognitive connection between self-regulated learning and cooperative learning. Central to our approach is the hypothesis that performing a task and simultaneously reflecting upon this task can be seen as a form of dual tasking. In some learning situations this reflection upon the task concerns mainly reflecting upon the learner's own knowledge and reflecting upon the process. In cooperative learning situations reflection upon what *others* know or believe is crucial. Regardless of what the nature of the reflection might be, we assume that a reflection process cannot start until cognitive resources are freed, due to automation of the task at hand (see Figure 2). For novices, reflection is not yet possible, because they place a heavy burden upon declarative memory for performing the task at hand. As declarative memory is also involved in reflection, performing a task and reflecting on it can be thought of as a dual-task. We think of reflection as the complement of automation. Whereas automation can be described as a process from declarative to procedural knowledge,

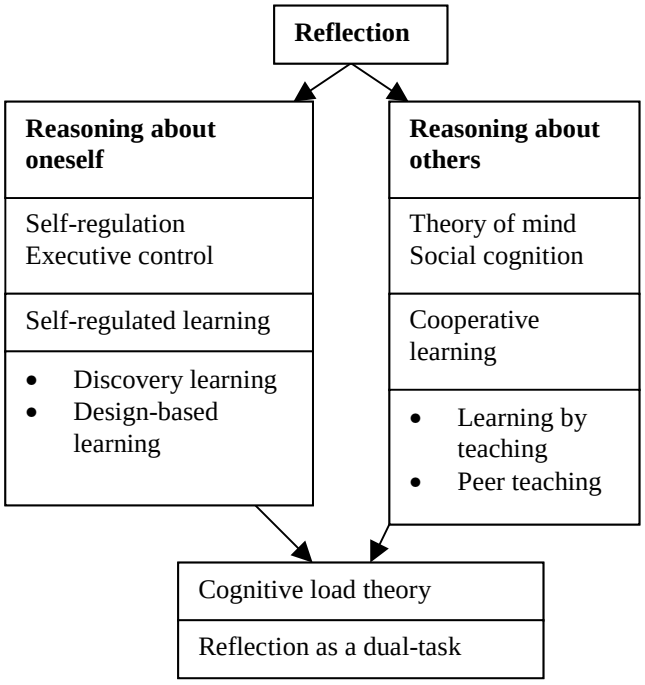

Figure 1: Associating cognition and education

reflection can be thought of as a process from procedural knowledge to new, more abstract declarative knowledge.

Developing new declarative knowledge

Karmiloff-Smith (1992) describes a developmental process in which children acquire explicit knowledge through a process of *representational redescription*. She conducted experiments with children who already had mastered a

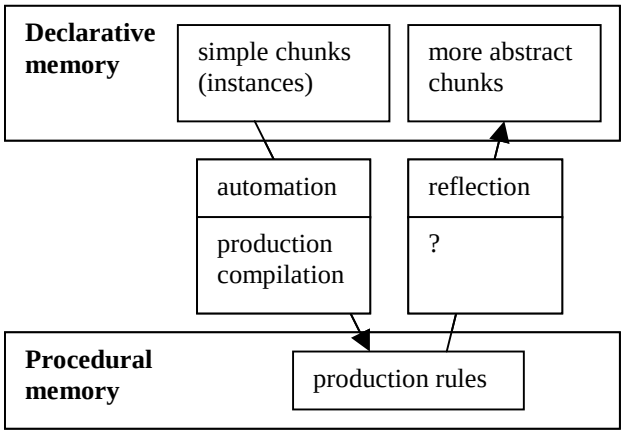

Figure 2: Reflection in ACT-R

certain task. On a micro time-scale of a few hours as well as on a macro time-scale as long as several years she demonstrated a development in which the internal representations of the children changed. Due to the development of more abstract and explicit representations, the children became able to give verbal justifications and descriptions of their behavior in the learning task. A simulation model in ACT-R of this representational redescription process (Zondervan & Taatgen, 2003) explicates some of the representations and redescriptions involved. However, it is unclear how verbalization is reached. In order to answer this important question, a reflection mechanism is needed in ACT-R. Since production rules are not directly accessible, we assume the existence of a reflective process that generates new declarative knowledge in order to reach possible verbalization of what has been learned. Computationally modeling how learners reach verbalization of the learned content can be seen as a first step in investigating social cognition and interactive learning.

Theory of mind and productive helping

Cooperative learning settings can be seen as situations in which two or more agents collaborate, changing roles of "teacher" and "student". Sometimes also other forms of cooperative learning, e.g. collaborative discovery take place. We are investigating forms of collaborative learning in which *peer teaching* and *learning by teaching* are central themes. Our focus is on productive helping in cooperative groups, as experimentally assessed by Webb, Farivar and Mastergeorge (2002). Intuitively, people must rely on their so-called "theory of mind" in order to effectively provide help. A huge amount of developmental experimental research concluded children aged six already have a sophisticated adult-like theory of mind, enabling them to understand the actions of others in terms of underlying mental states and to distinguish between their mental states and those of others. However, Keysar, Lin and Barr (2003) argue that even adults sometimes forget to account for deviations in others' mental states while performing actions, for instance in speech interactions. It is unclear what causes these egocentric mistakes. We assume they are related to cognitive load and the dual-task of executing a task and reflecting on oneself and others. The more the task at hand is automated, the more cognitive resources are available for reflection on what others might or might not know. Whether people can learn to prevent this type of failures in general remains an open question.

Social interaction with models

To investigate how helping can be productive for learning we are going to develop cognitive models of help-givers (teachers or peer teachers) and help-seekers (students) in learning situations. We aim at direct interaction between humans and cognitive models. Playing against a cognitive model in a game setting has proved to be feasible already. In a similar vein we hope to develop cognitive models with which humans can actually interact in cooperative learning settings, dynamically changing the roles of teachers and learners. These models will be a valuable extension of current research in the field of intelligent tutoring systems, in which cognitive models are used as learner models but not as teacher models. Besides that, this type of research will have implications for social cognition research and research on embodied communication. Above all that, it can enrich research endeavors to display and explain what our cognitive models are actually doing, by letting the models explain it themselves!

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