Learning and Instruction 16 (2006) 374–387

Learning and Instruction

www.elsevier.com/locate/learninstruc

The impact of intellectual ability and metacognition on learning: New support for the threshold of problematicity theory

Frans J. Prins [a,b,*], Marcel V.J. Veenman [c,d], Jan J. Elshout [e]

[a] Educational Technology Expertise Centre, Open University of the Netherlands, 6401 DL Heerlen, The Netherlands
[b] Faculty of Social and Behavioural Sciences, Department of Pedagogical and Educational Sciences, Utrecht University, PO Box 80140, 3508 TC Utrecht, The Netherlands
[c] Department of Developmental and Educational Psychology, Leiden University, Leiden, The Netherlands
[d] Graduate School of Teaching and Learning, University of Amsterdam, Amsterdam, The Netherlands
[e] Department of Psychonomics, University of Amsterdam, Amsterdam, The Netherlands

Abstract

Three models representing different relations between intellectual ability, metacognitive skills, and learning were compared. The conditions under which each of these models holds were investigated, on the basis of the threshold of problematicity theory [Elshout, J. J. (1987). Problem solving and education. In E. De Corte, H. Lodewijks, R. Parmentier, & P. Span (Eds.), *Learning and instruction* (pp. 259–273). Oxford/Leuven: Pergamon Books/University Press]. Novice and advanced learners ($N = 44$) passed through a computer-simulated inductive-learning environment of different complexity levels. Results show that correlational patterns between intellectual ability, metacognitive skilfulness, and learning outcomes of novice learners at the easy level were similar to the patterns of advanced learners at the intermediate level. Metacognitive skilfulness rather than intellectual ability appears essential for learning when learners operate at the boundary of their knowledge.

Keywords: Metacognition; Intellectual ability; Inductive learning

1. Introduction

Intellectual ability and metacognition are two important determinants for learning (Veenman, 1993). *Intellectual ability* is regarded here as the acquired repertoire of general cognitive skills that is available to a person at a particular point of time (Humphreys, 1968; Snow & Lohman, 1984). As Anderson (1996, p. 356) phrased it, ‘‘intelligence is the simple accrual and tuning of many small units of knowledge that in total produce complex cognition. The whole is no more than the sum of its parts, but it has a lot of parts.’’ According to this view, performance on mental ability tests can be understood in terms of basic information-processing components (Carroll, 1993; Simon, 1976; Sternberg, 1988). This is a cognitive approach of understanding intelligence rather than the dominant psychometric approach. Whereas

* Corresponding author. Faculty of Social and Behavioural Sciences, Department of Pedagogical and Educational Sciences, Utrecht University, PO Box 80140, 3508 TC Utrecht, The Netherlands. Tel.: +31 030 253 3707; fax: +31 030 253 2352.
E-mail address: f.j.prins@fss.uu.nl (F.J. Prins).

0959-4752/$ - see front matter
doi:10.1016/j.learninstruc.2006.07.008

psychometric theories deal primarily with the structural aspects of intelligence, cognitive theories deal primarily with its processing parts (Sternberg, 1988).

The concept of *metacognition*, first introduced by Flavell (1976), refers to both the knowledge about one's own cognitive processes (i.e., metacognitive knowledge) and the regulation of these processes (i.e., metacognitive skills). Metacognitive knowledge concerns knowledge about the interplay between person characteristics, task characteristics, and the available strategies in a learning situation (Flavell, 1979), whereas metacognitive skills (i.e. executive skills; see Kluwe, 1987) concern the self-regulatory activities actually being performed by a learner in order to structure the problem-solving process. The assessment of metacognitive skills through self-reports is problematic because it appears that learners have poor insight into their own behaviour (Nisbett & Wilson, 1977; Prins, Busato, Elshout, & Hamaker, 1998; Veenman, Prins, & Verheij, 2003). A valid but time-consuming method to assess metacognitive skills is the use of think-aloud protocols (Brown, 1987; Garner & Alexander, 1989; Veenman, 1993, 2005; Veenman, Elshout, & Groen, 1993). The think-aloud method taps processes in working memory (Ericsson & Simon, 1993), which means that automatic problem-solving processes cannot be measured by this method. Thus, the think-aloud method is suitable to assess metacognitive skills of novice as well as advanced learners as long as the learning task is complex enough for learners to prevent their problem-solving activities from being executed automatically. Scores for metacognitive skills measured with the think-aloud method are strongly related to metacognitive skills measured through observational data (Veenman, Kerseboom, & Imthorn, 2000) or log-file data (Veenman, Wilhelm, & Beishuizen, 2004).

For years now educational researchers have been discussing the relations between intellectual ability, metacognitive skills, and learning (e.g., Davidson, Deuser, & Sternberg, 1994; Maqsud, 1997; Sternberg, 1985, 1988, 1994; Swanson, 1990; Veenman, 1993), not in the least because knowledge concerning these relations is essential for the design of adequate instructional support. There are reasons to consider metacognitive skills and intellectual ability as distinct concepts. First, metacognitive skills appear to be applicable over a wide range of tasks (cf. Veenman & Verheij, 2003), while mental abilities, such as verbal ability and inductive reasoning, apply to a smaller range of tasks (Schraw, 1998; Sternberg, 1988). Second, evidence implies that the frontal lobes of the brain are of critical importance for human metacognition (Metcalfe, 1996; Shimamura, 1996, 2000), whereas cognitive operations are also located in other areas of the brain (Kalat, 1992; Posner, Petersen, Fox, & Raichle, 1988). Consequently, a person who has lost the most central metacognitive abilities because of brain damage "… appear to drift about like a rudderless ship", even given a high level of cognitive abilities as measured by a variety of tests (Metcalfe, 1996, p. 404). Third, metacognitive skills are teachable and supportable (Brown & Palincsar, 1989; Schraw, 1998; Veenman, Elshout, & Busato, 1994), whereas a durable improvement of more specific cognitive abilities through training and support is rather difficult to achieve (Elshout, 1987).

Considering metacognition and intellectual ability as distinct theoretical concepts does not imply that the two are unrelated. There are three models that may represent the relations between intellectual ability, metacognitive skills, and novice learning (Veenman, 1993; Veenman et al., 2004), namely the *intelligence model*, the *independency model*, and the *mixed model*, each of which are described below. Some researchers (e.g. De Corte & Van Pelt, 2003) tend to focus on which of these models is the right one. In contrast, we seek to determine the conditions under which each of these models holds. Based on Elshout's (1987) *threshold of problematicity theory*, which describes the varying impact of intellectual ability on learning due to task complexity, we suggest that task complexity is a key variable here. However, the theory still has two drawbacks. First, the theory does not explicitly include the role of metacognition. Second, the empirical evidence for the threshold of problematicity theory is limited as far as realistic learning tasks are concerned. Thus, the aims of the present study are to extend the threshold of problematicity theory to the role of metacognition, and to provide empirical evidence for the theory for learners in a realistic, ill-structured, self-directed learning task.

1.1. The relation between intellectual ability and metacognitive skills

The first model that represents the relations between intellectual ability, metacognitive skills, and novice learning is called the *intelligence model*. This model regards metacognition as a manifestation of intellectual ability. For instance, Sternberg (1985, 1988, 1994) conceived *metacomponents* as an essential part of human intelligence. Metacomponents are used to decide what to do, to monitor ongoing activities, and to evaluate the outcome of those activities after they have been completed and, thus, they are similar to metacognitive skills. In the same vein, the Planning, Attention, Simultaneous, and Successive (PASS) theory of intelligence (e.g., Das, Naglieri, & Kirby, 1994) conceives