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Inductive reasoning, domain specific and complex problem solving: Relations and development

Gyöngyvér Molnár[a,*], Samuel Greiff[b], Benő Csapó[a]

[a] Institute of Education, University of Szeged, 30-34. Petofi S sgt., Szeged, H-6723, Hungary
[b] Department of Psychology, Heidelberg University, Hauptstraße 47-51, Heidelberg, D-69117, Germany

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ABSTRACT

This paper focuses on three different types of reasoning: domain-specific problem solving, complex (general) problem solving, and inductive reasoning. The objective of the study is to examine the differences in the developmental levels of inductive reasoning, domain-specific problem solving, and complex problem solving between three age groups and to describe the relations between the three constructs. The sample was drawn from 3rd to 11th grade students (aged 9–17) in Hungarian primary and secondary schools. There were 300–400 students in each cohort. The internal consistencies of the tests were good: Chronbach α varied between .72 and .95. Each of the skills showed a developmental tendency that could be identified with a logistic curve. In every area the pace of development proved to be relatively slow and the steepest change took place in Grade 7. The bivariate correlations between the three constructs were moderate ranging from .35 to .44 signalling that they do not constitute the same construct. The strength of the relationships between inductive reasoning and complex problem solving proved to be the most stable over time. The correlations between domain-specific and complex problem solving showed an increasing trend over time indicating that the strategies used in different problem solving situations become more similar with age. This study provides evidence that inductive reasoning, domain-specific problem solving and complex problem solving are related but distinct constructs and these skills can be fostered most efficiently between Grades 6 and 8.

1. Development of thinking skills

Fostering the development of thinking skills has long been considered one of the most important educational goals (Resnick, 1987). In theory, two main groups of thinking skills are distinguished: Skills closely related to specific domains (e.g. domain specific problem solving; Schoenfeld & Herrmann, 1982) and general thinking skills applicable in a variety of different contexts (e.g. complex problem solving, see Frensch & Funke, 1995; inductive reasoning, see Klauer & Phye, 2008). In practice, there is no sharp distinction between the two sets of skills, because measurement of a specific thinking skill is always embedded in some kind of content, and requires the application of general mental processes as well (Ericsson & Hastie, 1994), even though the twofold conceptual distinction is important when understanding the cognitive processes and the development underlying these thinking skills. Beyond doubt, thinking skills are tools to success in today's society characterized by rapid change, where the nature of applicable knowledge changes frequently and specific contents quickly become outdated (de Konig, 2000).

* Corresponding author. Tel.: +36 20 77 56 478; fax: +36 62 420 034.
E-mail address: gymolnar@edpsy.u-szeged.hu (G. Molnár).

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Measures of thinking skills are rooted in intelligence research, which has dedicated a lot of attention to the role of inheritance: Early views considered thinking skills fixed and immutable (Jensen, 1973). Recent studies, on the contrary, indicate that thinking skills develop over time and that their development spans several decades; moreover, they are modifiable offering opportunities for enhancement by specifically designed and targeted educational interventions (Adey, Csapó, Demetriou, Hautamaki, & Shayer, 2007). Thus, the description of their development is relevant not only for theoretical reasons, but from a practical perspective as well, first of all, because the stimulation of thinking skills is most efficient when their development is still in progress, especially in the fast-growing phases (Csapó, 1997).

Problem solving skills (PS) have been extensively studied over the last decade as they are seen as the most broadly applicable cognitive tools. Developing problem solving skills is a major objective of educational programmes in several countries (OECD, 2010). To this end, a consistent research finding is that problem solving depends on domain-specific knowledge and strategies (e.g. Mayer, 1992; Funke & Frensch, 2007); however, problem solving skills also involve the ability to acquire and to use new knowledge, or to use pre-existing knowledge to solve novel problems (i.e., problems that are non-routine; Sternberg, 1994). In the present study, our focus is twofold: First, we will relate three different types of reasoning to each other: domain-specific problem solving, complex (general) problem solving, and inductive reasoning. Second, we will describe their development over time by using cross-sectional data.

2. Inductive reasoning, domain-specific problem solving and complex problem solving

2.1. Inductive reasoning and its development

Inductive reasoning (IR) is a general thinking skill (Pellegrino & Glaser, 1982; Ropo, 1987), which is related to almost all higher-order cognitive skills and processes (Csapó, 1997), such as general intelligence (Klauer & Phye, 2008), problem solving (Gentner, 1989; Klauer, 1996; Tomic, 1995), knowledge acquisition and application (Bisanz, Bisanz, & Korpan, 1994; Hamers, De Koning, & Sijtsma, 2000), and analogical reasoning (Goswami, 1991). Nevertheless, there is no universally accepted definition of IR even though several definitions have been proposed (e.g., Klauer, 1990; Osherson, Smith, Wilkie, Lopez, & Shafir, 1990; Sloman, 1993; Gick & Holyoak, 1983). The exact psychological mechanisms underlying IR, however, are yet to be discovered. A classical interpretation of IR views it as the process of moving from the specific to the general (Sandberg & McCullough, 2010). That is, IR is described as the generalization of single observations and experiences in order to reach general conclusions or derive broad rules (rule induction). We view IR as a general cognitive ability and adopt Klauer's theory (1993) interpreting IR as the discovery of regularities through the detection of similarities, dissimilarities, or a combination of both, with respect to attributes or relations to or between objects (Klauer, 1993).

Empirical studies examining IR from a developmental perspective are scarce at best (Sandberg & McCullough, 2010; Goswami and Brown, 1989). In particular, research on samples of a broad age-range (e.g., Lunzer, 1965; Levinson & Carpenter, 1974) is difficult to find. According to the few available studies, IR develops mainly during elementary and secondary education with the average pace of development being relatively slow at about one quarter of a standard deviation per year (Csapó, 1997; Molnár & Csapó, 2011). This suggests that fostering IR is not an integral part of school curricula (de Konig, 2000), however it can be developed effectively and to a significant extent (Klauer & Phye, 2008; Molnár, 2011). In the absence of direct and explicit stimulation of IR in schools, development occurs spontaneously as a 'by-product' of teaching ordinary school material rather than being guided by explicit instruction (de Konig, 2000).

2.2. Domain-specific problem solving and its development

Different definitions and theoretical models of problem solving have been proposed in the literature (for an overview see Sternberg, 1994), most of them sharing a common aspect, namely, that a problem is characterized by a gap between the current and the goal state with no immediate solution available (Mayer & Wittrock, 1996).

As this gap can be found in any content domain, the research field of domain specific problem solving (DSPS) studies these processes in a variety of settings (Sugrue, 1995): either in connection with specific national school curricula (e.g. Mullis et al., 2009), or explicitly in a specific domain such as mathematical (Daniel & Embretson, 2010), technical (Baumert, Evans, & Geiser, 1999), or scientific (Dunbar & Fugelsang, 2005) problem solving or problem solving in game playing (Frensch & Sternberg, 1991). One of the most comprehensive international large-scale assessments, the Programme for International Student Assessment (PISA), places special emphasis on PS processes and measured it in 2003 as an innovative domain complementing the traditional school subjects of reading, science and mathematics (OECD, 2004). In line with other research findings (e.g. Nickerson, 1994), the level of problem solving skills in PISA is shown to be closely related to domain-specific knowledge and strategies (e.g. Mayer, 1992). Thus, problem solvers need to combine knowledge acquired in and out of the classroom to reach the desired solution by retrieving and applying previously acquired knowledge in a specific domain. In the present study, we treat DSPS is as a process of applying domain specific – especially mathematical – knowledge in three different types of new situations: (1) complete problems (all necessary information to solve the problem is given at the outset), (2) incomplete problems relying on missing information that is expected to have been learned at school, (3) incomplete problems relying on missing information that was not learned at school.

Development of PS was a central area of research for the information-processing approach to cognition. This approach focuses on how students progress from being novices to becoming experts within specific domains (see Mayer, 2008) and