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Ability-related differences in performance of an inquiry task: The added value of prompts

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ABSTRACT

This study investigated how children of different ability levels approached inquiry tasks, whether prompting improved their inquiry process, and whether their inquiry process led to domain knowledge gain. Fifth and sixth graders ($n = 478$) of three different ability levels worked individually with a simulation, either with or without included prompts. Prompts appeared to affect children's inquiry process at all three ability levels. This inquiry process, in turn, was related to their learning outcomes. High ability children, who engaged in more active and effective inquiry than children of lower ability, used the prompts when available. Average and low ability children rarely used the prompts. High and average ability children gained knowledge from pretest to posttest but not from posttest to retention test; low ability children only gained knowledge from posttest to retention test. The results of this study point to a need to find effective ways to support low and average children in inquiry.

1. Introduction

In modern-day elementary education emphasis is increasingly placed on teaching 21st century skills. In the context of the upcoming knowledge society, children should no longer be educated to become passive knowledge-consumers but should actively discover and integrate new knowledge. A well-known instructional approach that enables children to actively gather and process new knowledge is the inquiry method (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011). Even though research has been done to sketch an optimal inquiry process, little is known about differences in inquiry approaches and the effects of inquiry-specific support for children of different ability levels. Optimizing the inquiry learning method for children of different ability levels requires more insight into these differences. The aim of this study was to explore the inquiry approaches of children of different ability levels, whether and how children integrated support that was offered to them into their learning process, and whether children's inquiry approaches affected their learning outcomes and motivation.

1.1. Inquiry learning

Recent studies have shown that inquiry learning, if well-designed, can lead to better results than learning by more direct forms of instruction (see, for example, Eysink & de Jong, 2012; Furtak, Seidel, Iverson, & Briggs, 2012; Smetana & Bell, 2012). This applies to a variety of domains, but inquiry is especially effective for learning in science domains (Arnold, Kremer, & Mayer, 2014). These benefits can mainly be attributed to the fact that in inquiry learning students are expected to actively collect information, process information, and construct knowledge (Alfieri et al., 2011; Mayer, 2003, 2004; Minner, Levy, & Century, 2010). This active engagement in the learning process enhances students' development of knowledge and skills (Manlove, Lazonder, & de Jong, 2006).

When engaging in inquiry, students are expected to learn actively by completing a set of different activities (de Jong, 2006; de Jong & van Joolingen, 1998). The inquiry process often starts with orientation to the domain, which leads to generation of hypotheses concerning the domain. To test the hypotheses, experiments are designed and conducted, after which conclusions are drawn from the experimental outcomes. As a wrap-up activity, the inquiry outcomes and procedure are evaluated (Pedaste et al., 2015). Students are often given considerable freedom in working through these different activities (Mayer, 2004), allowing them to determine their own learning process and learning pace (Minner et al., 2010). The downside of this freedom is that students then experience difficulties with inquiry learning (Mayer, 2004). This is why it has repeatedly been stated that inquiry learning is only effective when it is adequately guided (Alfieri et al., 2011; d'Angelo et al., 2014; Mayer, 2004).

Difficulties students experience with carrying out the different inquiry activities and how to support them in these activities have been addressed in a considerable body of research (e.g., Alfieri et al., 2011; de Jong, 2006; de Jong & van Joolingen, 1998; Rutten, van Joolingen, & van der Veen, 2012). Students are often unsuccessful in generating hypotheses (Gijlers & de Jong, 2009; Njoo & de Jong, 1993), experience difficulties with conducting experiments that go beyond their initial understanding of the variables within a domain (Klahr & Dunbar, 1993),

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and find it difficult to draw the right conclusions from the collected data (Klahr & Dunbar, 1988). For younger children, problems with inquiry learning activities are often attributable to difficulties they experience with identifying relevant variables within an inquiry task (Zimmerman, 2007). Identification of these variables is a prerequisite for conducting the right set of experiments to answer a research question, or even for formulating an appropriate research question in the first place.

1.2. Differences between ability levels

Students of different ability levels are expected to differ in how they approach an inquiry task, because they vary in how skillful they are at relating new information to their existing knowledge and determining its relevance and meaning (Wang, Kinzie, McGuire, & Pan, 2010). More specifically, within the context of inquiry learning students are expected to vary in skillfulness at drawing accurate conclusions from experimentation and integrating this knowledge into their existing knowledge schemas (Zimmerman, 2007).

In general, it is assumed that high ability students are skilled at independently figuring out how to solve a problem or complete a task (Diezmann & Watters, 1997; vanTassel-Baska, 2003). They prefer a challenging learning process (Phillips & Lindsay, 2006; Reis & Renzulli, 2010), and favor learning tasks that involve complexity and the possibility of engaging in open-ended discovery (Diezmann & Watters, 1997; vanTassel-Baska, 2003). Challenging and complex tasks align with high ability students' advanced knowledge schemas (Kalyuga, Ayres, Chandler, & Sweller, 2003). In fact, providing high ability students with tasks and support that are too explicit could even be counterproductive. In contrast, low ability students tend to experience more difficulties with navigating through learning tasks than high ability students (Alexander & Schwanenflugel, 1996; Margolis & McCabe, 2003), and most studies conclude that low ability students need more structured tasks to engage in successful learning (e.g., Lou et al., 1996; Wang et al., 2010). Therefore, positive effects of instruction and support seen for children with lower levels of ability might disappear for children with higher levels of ability, as the level of redundancy of the instructional materials might be too high (cf., expertise reversal effect; Kalyuga, 2007; Kalyuga et al., 2003).

Advocates of differentiated instruction maintain that instruction and support should match children's ability level and their specific learning needs (e.g., Tomlinson, 2000; Vygotsky, 1986; Weinert & Helmke, 1998). This should then lead to an efficient learning process with effective learning outcomes (i.e., aptitude-treatment interaction; Cronbach & Snow, 1977), and lead to high motivational levels when working on learning tasks (Lens & Rand, 2000; Margolis & McCabe, 2003). Within the context of inquiry learning, this means that average and low ability students, in particular, need support to engage in effective inquiry learning (Lou et al., 1996; Wang et al., 2010). When they are challenged too much and have to face the learning task and its difficulties on their own, they can become discouraged, demotivated, and even become frustrated (Margolis & McCabe, 2003). High ability students, however, might be able to carry out successful inquiry without much or any additional support, as they prefer challenging, complex, and open-ended learning tasks (Diezmann & Watters, 1997; vanTassel-Baska, 2003). Challenging and complex tasks are an important motivator for high ability students (Lens & Rand, 2000). Providing these students with too much support might decrease their levels of motivation when working on these tasks. Recent research has shown that these children could also benefit from support (Eysink, Gersen, & Gijlers, 2015), but that additional studies should be done to look into the type of support that fits the needs of these children best.

1.3. Differentiated support

A suitable type of support that capitalizes on differences between children could be prompts. First, prompting is a form of support that incorporates autonomous learning (Davis & Linn, 2000). When available upon request, prompts function merely as stepping stones and do not necessarily intrude upon children's inquiry process. Consequently, high ability children should profit from prompts, which still leave them enough freedom to determine their own learning process (Diezmann & Watters, 1997; vanTassel-Baska, 2003). For the same reason, high ability children's motivation should not be negatively affected by offering prompts during their inquiry process (Lens & Rand, 2000). Lower ability children would also benefit from prompts, as the prompts provide them with direct assistance when needed (Margolis & McCabe, 2003) and guide them through difficulties they often experience with their inquiry process. Consequently, the guidance offered by prompts should positively influence lower ability children's level of motivation (Margolis & McCabe, 2003).

Second, prompts have proven to be effective in explaining scientific domains and underlying principles (Davis & Linn, 2000), and can provide students with proper guidance during formulation and conducting of experiments (Zacharia et al., 2015). As stated above, most difficulties that younger children experience with inquiry learning are related to their inability to identify relevant variables within a domain (Zimmerman, 2007).

1.4. Research issues

The literature indicated that children's learning processes and their need for support in general are ability dependent. However, specific differences between children of different ability levels in their learning approach have not yet been investigated in the context of inquiry learning. Studies on inquiry learning show that support is needed for inquiry learning processes to be effective, without making a distinction between children of different ability levels (Alfieri et al., 2011; d'Angelo et al., 2014; Mayer, 2004). This discrepancy gives us reason to further explore differences in children's inquiry processes and the role of support for different ability levels. Consequently, we explored high, average, and low ability children's inquiry approaches in conditions with and without support to structure their inquiry process.

With regard to children's *inquiry learning process*, two main issues were central to this study. First, the abovementioned literature provides clear indications that children of different ability levels differ on how they address problem-solving tasks. This gave us reason to believe that these differences would also manifest themselves in children's inquiry approaches. The current study was designed to give more insight into how these differences express themselves in the experimental activities children of different ability levels undertake, such as performance of unique experiments, and the correctness of their conclusions (Research Question 1).

Second, literature related to children's use of support during their learning process is more ambiguous. Even less information is available on children's tendency to use support in the context of inquiry learning. On the assumption that problems young children experience with inquiry are mainly attributable to identification of relevant variables (Zimmerman, 2007), prompts were offered to help children identify the relevant variables within the domain. A major issue we wanted to explore was high ability children's inclination to use the prompts during their inquiry approach. High ability children might, on the one hand, consider the prompts redundant and disruptive to their learning process (cf., expertise reversal effect; Kalyuga, 2007); they might therefore be inclined not to use the prompts during the inquiry tasks. On the other hand, as all children need to be supported for their inquiry process to be effective (Mayer, 2004), and prompts are considered a way of support that allows children to act autonomously (Davis & Linn, 2000), high ability children might feel they could benefit from the prompts and therefore use them to structure their inquiry process. High ability children's level of *motivation* is likely to coincide with this. In the event they consider the prompts as beneficial, this might enhance their level of motivation. When the prompts are considered disruptive to their learning process,